REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

MINISTRY OF HIGHER EDUCATION

UNIVERSITE DE NGAOUNDERE
INSTITUT UNIVERSITAIRE DE TECHNOLOGIE

THE UNIVERSITY OF NGAOUNDERE
UNIVERSITY INSTITUTE OF TECHNOLOGY

DEPARTEMENT DE GENIE ALIMENTAIRE ET CONTROLE QUALITE

DEPARTMENT OF FOOD PROCESSING AND QUALITY CONTROL

DOSSIER PRESENTE AU COMITE CONSULTATIF DES INSTITUTIONS UNIVERSITAIRES (CCIU) EN VUE DE LA PROMOTION AU GRADE DE MAITRE DE CONFERENCES

COMMISSION VI : SCIENCES DE L'INGENIEUR

Section 2/Sous-section 2 : Biologie et Biochimie Appliquées

Soumis par :

Desobgo Zangué Steve Carly

Chargé de Cours

Session: Novembre 2019

Table des matières

I	**IDENTIFICATION**	**1**
I.1)	Demande timbrée adressée au MINESUP s/c Madame le Recteur	3
I.2)	Fiche de synthèse de candidature	5
I.3)	Curriculum Vitae détaillé	7
I.4)	Photocopie de l'acte de naissance	22
II)	**DIPLOMES**	**23**
II.1)	Baccalauréat D	25
II.2)	Diplôme Universitaire de Technologie (DUT) en Génie Agro-Industriel	27
II.3)	Diplôme d'Ingénieur des Industries Agricoles et Alimentaires	29
II.4)	Certificat de Réussite au Diplôme d'Etudes Approfondies (DEA) en Génie des Procédés	31
II.5)	Rapport de Soutenance de Thèse de Doctorat / Ph.D en Génie des Procédés	33
II.6)	Attestation de Soutenance de Thèse de Doctorat / Ph.D en Génie des Procédés	35
III)	**ACTES ADMINISTRATIFS**	**36**
III.1)	Décision de recrutement	38
III.2)	Contrat de travail	40
III.3)	Certificat de prise de service	46
III.4)	Actes d'avancements	48
III.5)	Acte de promotion au grade de Chargé de Cours	58
III.6)	Attestation de présence effective	61
IV)	**ACTIVITES ACADEMIQUES**	**62**
IV.1)	Contribution à l'enseignement, à la recherche, au développement de la science et de la culture ainsi qu'à la gouvernance de l'Université, de l'enseignement supérieur et de la nation	63
IV.1.a)	Contribution à l'enseignement	64
IV.1.b)	Contribution à la recherche, au développement de la science et de la culture	70
IV.1.c)	Contribution à la gouvernance de l'université et de l'enseignement supérieur	89
IV.1.d)	Contribution au développement de la nation	93
IV.2)	Liste des enseignements dispensés dûment approuvée par le Chef de Département	102
IV.2.a)	Liste des enseignements dispensés à l'IUT de l'Université de Ngaoundéré	104
IV.2.b)	Liste des enseignements dispensés à l'ENSAI de l'Université de Ngaoundéré	106
IV.3)	Liste des mémoires et thèses dirigées ou codirigées + procès-verbaux de soutenance certifiés	107
IV.3.a)	Attestations de co-encadrement des Thèses de Doctorat/Ph.D	109
IV.3.b)	Décisions portant sélection des candidats en vue de l'inscription en thèse de Doctorat/Ph.D	114
IV.3.c)	Attestation d'encadrement des mémoires de Master	123
IV.3.d)	Attestation d'encadrement des mémoires d'Ingénieur	126
IV.3.e)	Procès-verbaux de soutenance et Photocopies certifiées des pages de garde de 05 Masters et 24 diplômes d'ingénieur	129
IV.4)	Publications au niveau national et international dans le grade	185
IV.4.1)	Optimization of the Impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the Turbidity of *Madjeru* sorghum cultivar wort	186
IV.4.2)	Comparison of the mashing and brewing potentials of crude extracts of *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*	227
IV.4.3)	Dimethyl Sulfide Stripping Behavior During Wort Boiling Using Response Surface Methodology	248
IV.4.4)	Partial purification of α-amylase from *Burnatia enneandra* Micheli. Part 1: Extraction using statistical model	270

IV.4.5)	Chapter 25: Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview	289
IV.4.6)	Derivation and Application of a Simultaneous Volatile Formation and Stripping Kinetics Equation for Wort Boiling	323
IV.4.7)	Comparative Study of Limit Dextrinase Potential of Three Sorghum Cultivars (*Safrari*, *Madjeru*, and *S.35*)	349
IV.4.8)	Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains	373
IV.4.9)	Modeling of Dimethyl Sulfide Stripping Behavior When Applying Delayed Onset of Boiling During Wort Boiling	408
IV.4.10)	Impact of Gaseous Carbon Dioxide and Boiling Power on Dimethyl Sulfide Stripping Behavior During Wort Boiling	432
IV.4.11)	Optimization of fermentation conditions for ting production using response surface methodology	457
IV.4.12)	Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice	501
IV.4.13)	Chapter 11: Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry	524
IV.4.14)	Chapter 19: Winemaking: Control, Bioreactor and Modelling of Process	568
IV.4.15)	Sorghum Coffee-Lactose Stout Production and its Physico-Chemical Characterization	609
IV.5)	Rapport pédagogique confidentiel établi par le Chef de Département Génie Alimentaire et Contrôle Qualité (GACQ)	647
IV.6)	Rapport administratif confidentiel établi par le Chef d'Etablissement (Directeur IUT de Ngaoundéré)	649
V)	**AUTRES**	**650**
V.1)	Participation aux séminaires, colloques nationaux et internationaux	651
V.1.1)	University of Johannesburg Winter Beverage Symposium. 20 June 2013, Sedibeng Brewery, South Africa	652
V.1.2)	Cameroon Bioscience Society, 24th Annual Conference. University of Buea	663
V.1.3)	Cameroon Bioscience Society, 25th Annual Conference. University of Ngaoundere	666
V.2)	Sociétés savantes dont le candidat est membre	668
V.3)	Reviewer pour les journaux internationaux	673

I) IDENTIFICATION

I.1) Demande timbrée adressée au MINESUP s/c Recteur

TRESORERIE-GENERALE
DE-NGAOUNDERE-BIS
321046 12 E2A4
17/09/19 10:37

MINISTERE DES FINANCES
DIRECTION GENERALE DES IMPOTS
FCFA 0001000
TIMBRE FISCAL-FISCAL STAMP
CMR10459

Ngaoundéré le 12 Septembre 2019

Dr. Desobgo Zangué Steve Carly

Département Génie Alimentaire et Contrôle Qualité
Institut Universitaire de Technologie
Université de Ngaoundéré
BP 455 Ngaoundéré, Cameroun
Tel : 697160004/672790222
Email : desobgo.zangue@gmail.com/desobgo@yahoo.fr

A

Monsieur le Ministre d'Etat, Ministre de l'Enseignement Supérieur
S/C Madame Le Recteur de l'Université de Ngaoundéré
S/C Monsieur le Directeur de l'IUT de Ngaoundéré

Objet : Demande de changement de grade de Chargé de Cours à Maître de Conférences

Monsieur le Ministre d'Etat,

J'ai l'honneur de venir auprès de votre haute bienveillance solliciter un changement de grade de Chargé de Cours à Maître de Conférences dans la spécialité Biochimie et Biologie Appliquées.

En effet, je suis enseignant au Département de Génie Alimentaire et Contrôle Qualité (GACQ) à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, depuis le 16 avril 2008, date de ma prise de service. Titulaire d'un Doctorat Ph.D, j'ai été admis au grade de Chargé de Cours au cours du Comité Consultatif des Institutions Universitaires (CCIU) du 27 au 30 Novembre 2012.

Au sein de mon établissement IUT et au sein de l'ENSAI, je dispense plusieurs enseignements. Mes activités de recherche portent sur la technologie alimentaire, avec des thématiques variées couvrant un large éventail des applications de la biochimie et autres aspects de la modélisation dans le domaine des boissons. Je suis aujourd'hui titulaire de 23 publications donc 18 dans le domaine des boissons. J'ai également contribué à la rédaction de 3 livres dont 2 sont déjà publiés. J'ai participé à l'encadrement de 05 Masters GP et une vingtaine mémoires d'ingénieurs en IAA soutenus. Je suis actuellement co-directeur dans l'encadrement de 05 thèses de Doctorat Ph.D dont les soutenances de 2 candidats sont imminentes.

C'est fort de ce qui précède que je sollicite votre approbation et celle de mes pairs enseignant-chercheurs pour accéder au grade de Maître de Conférences.

Dans l'attente d'une suite favorable à ma demande, je vous prie d'agréer, Monsieur le Ministre d'Etat, l'expression de mes sentiments distingués.

Pièces jointes : Sept exemplaires du dossier de candidature

Dr Desobgo Zangué Steve Carly

I.2) Fiche de synthèse de candidature

REPUBLIQUE DU CAMEROUN
Paix - Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

REPUBLIC OF CAMEROON
Peace - Work – Fatherland
MINISTRY OF HIGHER EDUCATION

CONSEIL CONSULTATIF DES INSTITUTIONS UNIVERSITAIRES
SESSION DE NOVEMBRE 2019

FICHE DE SYNTHESE DE CANDIDATURE

UNIVERSITE : Université de Ngaoundéré

1. ETABLISSEMENT: Institut Universitaire de Technologie
2. DEPARTEMENT: Génie Alimentaire et Contrôle Qualité
3. GRADE ACTUEL: Chargé de Cours Depuis : 2012

4- GRADE POSTULE: Maître de Conférences
5- SOUS-SECTION: 2
6- SECTION: 2
7- COMMISSION : Sciences de l'Ingénieur

Identification du candidat	Cursus et Titres Universitaires	Publications	Avis motivé du département	Avis de la Section
Nom : DESOBGO ZANGUE **Prénom : Steve Carly** **Né le : 02 Janvier 1977** **A : Douala** **Matricule : 652117-M** **Pièces fournies** Sept exemplaires de dossier de changement de grade dont 1 original comprenant chacun : **1.** Demande timbrée de changement de grade **2.** Curriculum Vitae **3.** Photocopie de l'acte de naissance **4.** Photocopie des diplômes depuis le BACC **5.** Actes Administratifs **6.** Actes Académiques **7.** Liste des productions scientifiques **8.** Une liste d'encadrement des thèses et mémoires **9.** Rapport pédagogique (1) **10.** Rapport administratif (1)	**1996 : Baccalauréat « D »** (Institut Privé Polyvalent de Bonamoussadi, Douala) **1998 : DUT en Génie Agro- Industriel** (Institut Universitaire de Technologie, Université de Ngaoundéré) **2001 : Ingénieur des Industries Agricoles et Alimentaires** (Ecole Nationale Supérieure des Sciences Agro-Industrielles, Université de Ngaoundéré) **2003 : DEA en Génie des Procédés** (Ecole Nationale Supérieure des Sciences Agro-Industrielles, Université de Ngaoundéré) **2012 : Doctorat/Ph.D en Génie des Procédés** (Ecole Nationale Supérieure des Sciences Agro-Industrielles, Université de Ngaoundéré) **Expérience Professionnelle** **Depuis 2012 :** Chargé de Cours à l'IUT de Ngaoundéré **2008-2012 :** Assistant à l'IUT de Ngaoundéré **Depuis 2019 :** Editorial Board member de SCIREA Journal of Food. **Depuis 2019 :** Editorial Board member de Journal of Food Stability **Depuis 2017 :** Expert du CNDT, commission Biotechnologie du MINRESI **Depuis 2017 :** Membre de American Society of Brewing Chemists **Depuis 2014:** Reviewer à: Journal of Food and Bioprocess Technologies; Journal of Food Science and Technology; Journal of Biologically Active Products from Nature; African Journal of Science, Technology, Innovation and Development **Depuis 2014 :** Editorial Board Member de African Journal of Biotechnology **2013/2014 et 2015/2016:** Postdoc à l'Université de Johannesburg, Afrique du Sud	**1)** **Desobgo, Z.S.C.*, Nso, E.J., 2013.** Optimization of the impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the turbidity of *Madjeru* sorghum cultivar wort. International Journal of Applied Research and Studies. 2 (1), 1-10. **2)** **Nso, E.J., Aseaku, J.N., Desobgo, Z.S.C., Ngulewu, C., Aleambong, D.K., Taira, A., 2013.** Comparison of the mashing and brewing potentials of crude extracts of Abrus precatorius, Burnatia enneandra and Cadaba farinosa. Journal of Brewing and Distilling. 4 (2), 46-50 **3)** **Desobgo, Z.S.C.*, Stafford, R.A., Metcalfe, D.J.A., 2015.** Dimethyl sulphide stripping behaviour during wort boiling using Response Surface Methodology. Journal of the American Society of Brewing Chemists. 73 (1), 84-89 **4)** **Taira, A., Desobgo, Z.S.C.*, Nso, E.J., 2015.** Partial purification of α- amylase from *Burnatia enneandra* Micheli. Part 1: Extraction using statistical model. International Journal of Research in Biotechnology and Biochemistry. 5 (1), 13-19 **5)** **Desobgo, Z. S. C.*, Mishra, S. S., Behera, S. K., Panda, S. K., 2017.** Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview. In R. C. Ray & C. M. Rosell (Eds.), Microbial Enzyme Technology in Food Applications (pp. 520): CRC Press, Taylor & Francis Group. **6)** **Desobgo, Z. S. C.*, Stafford, R.A. & Metcalfe, D.J.A., 2017.** Derivation and application of a simultaneous volatile formation and stripping kinetics equation for wort boiling. Journal of the American Society of Brewing Chemists. 75(1), 11-21 **7)** **Nguemogne A. C., Desobgo, Z. S. C.*, Nso E. J. 2017.** Comparative study of limit dextrinase potential of three sorghum cultivars (*Safrari, Madjeru* and *S.35*). Journal of the American Society of Brewing Chemists. 75(3), 255-261 **8)** **Makebe, C. W., Desobgo, Z. S. C.*, Nso, E. J. 2017.** Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains. Beverages. 3(2), 1-18. **9)** **Desobgo, Z. S. C.*, Stafford, R.A., Metcalfe, D.J.A., 2017.** Modeling of dimethyl sulfide stripping behavior when applying delayed onset of boiling during wort boiling. Journal of the American Society of Brewing Chemists. 75(3), 269-275 **10)** **Desobgo, Z. S. C.*, Stafford, R.A., Ndinteh D.T., Metcalfe, D.J.A., Meijboom R., 2017.** Impact of gaseous carbon dioxide and boiling power on dimethyl sulphide stripping behavior during wort boiling. Journal of the American Society of Brewing Chemists. 75(4), 324-332. **11)** **Adebo, O. A., Njobeh, P. B., Mulaba-Bafubiandi, A. F., Adebiyi, J. A., Desobgo, Z. S. C., Kayitesi, E., 2018.** Optimization of fermentation conditions for ting production using response surface methodology. Journal of Food Processing and Preservation. e13381. https://doi.org/10.1111/jfpp.13381 **12)** **Ninga, K.A., Sengupta, S., Jain, A., Desobgo, Z. S. C., Nso, E.J., De, S., 2018.** Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice. Journal of Food Engineering. 221, 158-166. **13)** **Desobgo, Z. S. C.*, 2018.** Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry. In Panda, Sandeep Kumar, Halady, Prathap Kumar Shetty (Eds.), Innovations in Technologies for Fermented Food and Beverage Industries. (pp. 343) Springer International Publishing. **14)** **Desobgo, Z. S. C.*, Nso, E.J., 2020.** Winemaking: Control, Bioreactor and Modelling of Process. In Joshi V.K. & Ramesh C. Ray (Eds.), Wine making: Basics and applied aspects. (pp. 700). CRC Press, Taylor & Francis Group. (Galley Proof) **15)** **Fali, M. H., Desobgo, Z. S. C.*, Nso, E.J., 2019.** Sorghum coffee–lactose stout production and its physico-chemical characterization. Beverages. 5 (20), 1-21	**Avis motivé de l'Etablissement**	**Avis motivé de la Commission**
			Avis de la Sous-Section	**Avis motivé du Comité**

I.3) Curriculum Vitae détaillé

Curriculum Vitae

Dr. DESOBGO ZANGUE Steve Carly

(Senior Lecturer at the University Institute of Technology of the University of Ngaoundere, Cameroon)

Expert Member of the National Technology Development Committee (MINRESI), Cameroon

Postdoctoral fellow, University of Johannesburg, Doorfontein Campus

Ph.D in Process Engineering, University of Ngaoundere

Master of Science in Process Engineering, University of Ngaoundere

Master of Engineering in Agricultural and Food Industries, University of Ngaoundere

Personal Informations

Name (s)	**DESOBGO ZANGUE Steve Carly**
Adress	PO. Box 455 University Institute of Technology (IUT), Ngaoundéré, Cameroun
Phone	(+237) 697160004
Email	desobgo.zangue@gmail.com / desobgo@yahoo.fr / desobgo.steve@yahoo.com
Nationality	Cameroonian
Date and place of birth	January 02, 1977 in Douala, Cameroon
Sex	Male
Marital status	Widower and Father of 3 children

Field of competence

Food Technology, Biotechnology, Process Engineering, Chemical Engineering, Development of new products, Environment (biochemistry comprehension of waste transformation)

Scientific Activities

Domain

Process Engineering, Chemical Engineering, Development of new products, Environment, Food Technology and Biotechnology, Environment (biochemistry comprehension of waste transformation)

Direction of activities

- Food Technology, Biotechnology**,** Beverages, Enzymology

- Modeling (Response Surface Methodology)
- Environmental science (biochemistry comprehension of waste transformation)

Publications in the activity

- **23 papers** in refereed journals, **2 books chapter**
- 1 communication to the GP3A, UCL Belgium.
- 1 communication to the Johannesburg Winter Beverage Symposium of the University of Johannesburg at Sedibeng brewery, South Africa

Supervision of students

- **5 students at Ph.D level, ENSAI of Ngaoundere**
- **6 Master students level, ENSAI of Ngaoundere**

Professional experience

Dates **2019**
Name of employer **Journal of Food Stability**
Activity sector Scientific papers publication
Position occupied **Associate Editor**

Dates **2019**
Name of employer **SCIREA Journal of Food**
Activity sector Scientific papers publication
Position occupied **Editorial Board Member**

Dates **2012- till now**
Name of employer University of Ngaoundere/University Institute of Technology (UIT)
Activity sector Higher education
Position occupied **Senior Lecturer/Researcher**
Activities and responsibilities

- Lecturing
- Research
- Practicals
- Students supervision

Dates **2017 till now**
Name of employer **American Society of Brewing Chemists**
Activity sector Scientific papers publication
Position occupied **Member**

Dates **Since april 4th 2017**

Name of employer	**Ministry of Scientific Research and Innovation (MINRESI)**
Activity sector	Research/Technology
Position occupied	**Member of the National Technology Development Committee**
Activities and responsibilities	- Biotechnology development policy in Cameroon - Project selection - Project supervision
Dates	**2016-2017**
Name of employer	**GIZ Cameroon (Gesellschaft Für Internationale Zusammenarbe)**
Activity sector	- Environmental, climate and forest policy - Governance and decentralization - Rural development
Position occupied	**Consultant**
Activities and responsibilities	- Work meeting with the representatives GIZ, SNV, and the company SOCTRACAO. Definition of terms of reference and on-site visit of equipment - Evaluation of machine yields according to processing needs. - Analysis of the quality of materials related to hygienic requirements and sanitary and their availability on the market.
Dates	**2015-2016**
Name of employer	**University of Johannesburg, South Africa**
Activity sector	Higher education
Position occupied	**Postdoctoral fellow at Biotechnology and Food technology department**
Activities and responsibilities	- Lecturing - Research on brewing science - Practicals - Students supervision
Dates	**2017 till now**
Name of employer	**African Journal of Science, Technology, Innovation and Development**
Activity sector	Scientific papers publication
Position occupied	**Reviewer**
Dates	**2017 till now**
Name of employer	**Journal of Food Science and Technology**

Activity sector Scientific papers publication

Position occupied **Reviewer**

Dates **2014- till now**

Name of employer **Journal of Food and Bioprocess Technologies**

Activity sector Scientific papers publication

Position occupied **Reviewer**

Dates **2014- till now**

Name of employer **African Journal of Biotechnology**

Activity sector Scientific papers publication

Position occupied **Editorial Board Member**

Dates **2013-2014**

Name of employer **University of Johannesburg, South Africa**

Activity sector Higher education

Position occupied **Postdoctoral fellow at Biotechnology and Food technology department**

Activities and responsibilities

- Lecturing
- Research on brewing science
- Practicals
- Students supervision

Dates **2008-2012**

Name of employer **University of Ngaoundere/University Institute of Technology (UIT)**

Activity sector Higher education

Position occupied **Assistant Lecturer**

Activities and responsibilities

- Lecturing
- Research
- Practicals
- Students supervision

Dates **2002-2008**

Name of employer **University of Ngaoundere/ENSAI of Ngaoundere**

Activity sector Higher education

Position occupied **Research assistant**

Activities and responsibilities

- Practicals in Agro-industrial process technology

- Practicals in biodynamics
- Practicals in Enzymology
- Practicals in Mechanical and transfer unit operations

Dates	**May – September 2001**
Name of employer	**CAM Assistance**
Activity sector	Food technology (Manufacture of machinery, development of new products)
Position occupied	**Trainee (Internship End of Master of Engineering degree)**
Activities and responsibilities	- Development of the manufacturing processes of juice and pineapple wine - Developing a taste panel - Development of the best process for juice and pineapple wine

Dates	**June – August 2000**
Name of employer	**Cameroon Development Corporation (CDC)**
Activity sector	Food Technology (Rubber, Tea, oil, etc…)
Position occupied	**Trainee (Internship Master of Engineering, year 2)**
Activities and responsibilities	- Investigations on the rubber quality issues - Development of a device to drain water from washing the coagulated latex to pretreatment zone

Dates	**July – August 1999**
Name of employer	**SPC du Cameroon**
Activity sector	Food Technology (Feed mills)
Position occupied	**Trainee (Internship Master of Engineering, year 1)**
Activities and responsibilities	- Contribution to the production of provender for poultry, pigs, rabbits, ... - Contribution to management of feed stocks and Maintenance

Dates	**June – September 1998**
Name of employer	**Guinness Cameroon S.A.**
Activity sector	Food Technology (Brewery)
Position occupied	**Trainee (Internship for end of degree, DUT)**
Activities and responsibilities	- Bottle breakages analysis in Packaging service - Investigation on critical areas of thermal shock and breakage of bottles on the bottling line. - Bottle breakages and valuation costs

Dates	**June – July 1997**
Name of employer	**Guinness Cameroon S.A.**
Activity sector	Food Technology (Brewery)
Position occupied	**Trainee (Internship)**
Activities and responsibilities	- Bottle breakages analysis in Packaging service - Investigation on critical areas of thermal shock and breakage of bottles on the bottling line. - Bottle breakages and valuation costs

Education and formation

Dates	**2004 – 2012**
Title of qualification awarded	**Doctorate/Ph.D in Process engineering**
Skills covered	**General domain:** Process engineering, Mathematics, Statistics **Specific Domain:** Modeling, Process Optimization of Agricultural and Food Industries (Beverages)
Établissement Institution	National Advanced School of Agro-Industrial Sciences (ENSAI), Ngaoundere, Cameroon

Dates	**2001 – 2003**
Title of qualification awarded	**Master of Science in Process Engineering (D.E.A - GP)**
Skills covered	**General domain:** Process engineering, Mathematics, Statistics **Specific Domain:** Modeling, Process Optimization of Agricultural and Food Industries (Beverages)
Établissement Institution	National Advanced School of Agro-Industrial Sciences (ENSAI), Ngaoundere, Cameroon

Dates	**1998 – 2001**
Title of qualification awarded	**Master of Engineering**
Skills covered	**General domain:** Process Engineering and Chemical Engineering, beverages
Établissement Institution	National Advanced School of Agro-Industrial Sciences (ENSAI), Ngaoundere, Cameroon

Dates	**1996 – 1998**
Title of qualification awarded	**University Institute of Technology Diploma (DUT)**
Skills covered	**General domain:** Agro-Industrial Engineering
Établissement Institution	University Institute of Technology (UIT), Ngaoundere, Cameroon

Dates	**1995 – 1996**
Title of qualification awarded	**Bachelor of Secondary Education (Series D)**
Skills covered	**General domain:** Mathematics and Natural Sciences
Établissement Institution	Polyvalent Private Institute of Bonamoussadi (IPPB), Douala, Cameroon

Personal skills and competences

Language **French**

Self evaluation

	Understand		**Speak**		**Write**
	Listen	Read	Conversation	Orally	
English	Well	Well	Well enough	Well enough	Well

Social skills

- Good team skills, easy to adapt to multicultural environments
- Good communication skills

Organizational skills

- General Manager of the Ngaoundere Veterans Football Association (**2018**)
- Academic supervisor of the Bioengineering mention level 2 **(2009-2011)**
- Regular Interim position of Head of Department of Food Engineering and Quality Control (GACQ)
- President of the Association of Monitors and PhD students of the University of Ngaoundere **(2005)**
- Laboratory Technician at ENSAI of Ngaoundere **2004/2005 & 2005/2006**
- Member of the Junior Enterprise Club, Ngaoundere **(1998 – 2000)**
- Registrar of the Commission of projects in the Association of Ph.D Students of ENSAI, Ngaoundere **(2001-2004)**
- Auditor of the Agro - Industrial Club, UIT, Ngaoundere **(1996-1997)**

Computer skills

- Word, Excel, PowerPoint, Publisher, SigmaPlot, Statistica, Mathcad, Matlab, Minitab, Mathematica, Scientific Workplace, Statgraphics, SPSS, Systat, S Plus 2000, Derive 5, Adobe Photoshop, fortran, Origin, Sphinx, Design Expert, etc…

Artistic skills

- Practice drawing and poetry

Other skills

- Practice of Football, basketball, tennis, table tennis etc…

Driving Licence - Driving licence B

Complement

- Special Distinction awarded for completion of all the lectures exams in a normal session by Prof. Maurice TCHUENTE Rector (Rector of the University of Ngaoundere) **(1998)**.
- Highest performance in Master of science results **(2003)**

Course list

1) Enzymology
2) Process diagrams and technical drawing
3) Industrial hygiene
4) Fruits and vegetables
5) Malting & Brewing
6) Food process practical (beer, fruit juice, wine and spirit, etc…)
7) Student professional project
8) Advanced Brewing
9) Wine and spirits
10) Initiation to engineering equipment
11) Industrial Enzymes and Applications
12) Biostatistics and Bioinformatics
13) Processes of Food Industries II (Beverages)
14) Mechanical and Transfer Unit Operations
15) Experimental design

Academic direction of Master Student

Masters completed

1) **Kadlezir Fiacre, 2017**. Optimization of some physicochemical parameters during juice extraction of a date cultivar (*Phoenix dactylifera* L.). Master of Science in Process Engineering, National School of Agro-Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
2) **Wiyeh Claudette Bakisu Muala, 2016.** Influence of drying and mixture conditions on some physico-chemical characteristics of lemongrass (*Cymbopogon citratus*) blended with ginger (*Zingiber officinale*) tea. Master of Science in Process Engineering, National School of Agro-Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)

3) **Makebe Calister Wingang, 2016.** Optimisation of the extraction process and investigation on must fermentation of ripe plantains. Master of Science in Process Engineering, National School of Agro-Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
4) **Tiyou Jules Padrik, 2014.** Application of hydrothermolysis and organosolv treatments for the solubilization of hemicellulosic fractions and lignin of sorghum stalks for the production of bioethanol. Master of Science in Process Engineering, National School of Agro-Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
5) **Nkoum Sem Ronald, 2014.** Optimising Sugar Release by the CSLF Technology and Dilute Acid Hydrolysis from Maize (*Zea mays* l.) Stalks as a Potential for Bioethanol Production. Master of Science in Process Engineering, National School of Agro-Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)

Academic direction of Ph.D students

List of Ph.D. students still in progress

1) **Nguemogne Annick Chancelle**. Modeling the extraction and purification of the limit dextrinase of *Safrari* sorghum cultivar. Ph.D in Process Engineering, National School of Agro-Industrial Science (ENSAI) (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
2) **Acha Anna Affeck**. Modeling the production and clarification of a standardized « Nkang » beer. Ph.D in Process Engineering, National School of Agro-Industrial Science (ENSAI) (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
3) **Ninga Kombele Aimé**. Modeling and optimization of the enzymatic depectinization of guava pulp by the use of polygalacturonases extracted from banana. Ph.D in Process Engineering, National School of Agro-Industrial Science (ENSAI). (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
4) **Makebe Calister Wingang**, Probiotic beverage obtained from extract of *Annona muricata* and *Strychnos spinosa* using a combination of microorganisms. Ph.D in Process Engineering, National School of Agro-Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)
5) **Wiyeh Claudette Bakisu Muala.** Probiotic beverage from infusion of *Cymbopogon cibraties* and *Zingiber officinale* using a combination of microbial strains Ph.D in Process Engineering, National School of Agro-

Industrial Science (ENSAI), Cameroon. (Directors: Pr Nso, E. J.; **Dr. Desobgo, Z.S.C.**)

Thesis & Reports

1) **Desobgo, Z.S.C., 2012.** Optimization of the action of hydrolases on some physico-chemical characteristics of the wort of two sorghum cultivars. PhD Thesis in Process Engineering. ENSAI of the University of Ngaoundere.
2) **Desobgo, Z.S.C., 2003.** Study of the effect of some hydrolases on the filterability of unmalted sorghum-based worts (*Madjeru, Safrari, S.35*). Master of Science thesis in Process Engineering. ENSAI of the University of Ngaoundere.
3) **Desobgo, Z.S.C., 2001.** Production of juice and pineapple wine for a semi-automated unit. Master of Engineering thesis. ENSAI of the University of Ngaoundere.
4) **Desobgo, Z.S.C., 2000.** Investigation into rubber problems. Internship Report, Master of engineering year 2. ENSAI of the University of Ngaoundere.
5) **Desobgo, Z.S.C., 1999.** Contribution to the production of the Feed for poultry, pigs, rabbits. Internship report, Master of engineering year 1. ENSAI of the University of Ngaoundere
6) **Desobgo, Z.S.C., 1998.** Analysis bottles breakages of the packaging line No. 2 (1998). DUT end of thesis. UIT of the University of Ngaoundere.
7) **Desobgo, Z.S.C., 1997.** Monitoring of the packaging lines. Training report. UIT of the University of Ngaoundere.

Conferences

1) Nguemogne A. C., **Desobgo Z. S.C.***, Nso E. J., **2018**. A screening method for the expression of total amylase activity during malting of sorghum. 25th Annual Conference of the Cameroon Biosciences Society. November 28 – December 02, University of Ngaoundere, Cameroon. CBS18_FAA_ORA 25.
2) Mbarga, M.J.A., **Desobgo, Z.S.C.,** Tatsadjieu, N.L., **2017.** Optimisation de quelques paramètres de fermentation de la sève de raphia (*Rafia farinifera*) par *Lactobacillus fermentum* et *Bifidobacterium bifidum*. 24th Annual Conference of the Cameroon Biosciences Society. November 28 – December 02, University of Buea, Cameroon. CBS17-ORA-112. p 94.
3) **Desobgo, Z.S.C., 2013**. Introduction to experimental design in brewing science. University of Johannesburg Winter Beverage Symposium. 20 June 2013, Sedibeng Brewery, South Africa.

4) **Desobgo, Z.S.C., 2008**. Modeling and optimization of the effect of industrial enzymes on the filtrate yield of sorghum mash. 1st Scientific Days (JS) of the Process Engineering Network Applied to AgroIndustry (GP3A). September 11 and 12, 2008, Louvain-la-Neuve, Belgium. http://www.gp3a.auf.org
5) The polyphenol paradox in alcoholic beverages: a beer and wine paradox ?. 13th Chair J. DE CLERCK. 7-10 september 2008. Louvain-laNeuve, Belgium. http://www.gp3a.auf.org

Books Chapters

1) **Desobgo, Z. S. C*. &** Nso, E. J. Winemaking: Control, Bioreactor and Modelling of Process. In Joshi, V.K. and Ramesh, C. Ray (Eds), *Wine Making: Basics and Applied Aspects*. 1st edition. (pp. 700). CRC Press, Taylor & Francis Group. **(Galley Proof)**
2) **Desobgo, Z. S. C*. 2018**. Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry. In Panda, Sandeep Kumar, Halady, Prathap Kumar Shetty (Eds.), *Innovations in Technologies for Fermented Food and Beverage Industries*. (pp. 343). Springer International Publishing.
3) **Desobgo, Z. S. C.*,** Mishra, S. S., Behera, S. K., & Panda, S. K. **2017**. Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview. In R. C. Ray & C. M. Rosell (Eds.), *Microbial Enzyme Technology in Food Applications* (pp. 520). CRC Press, Taylor & Francis Group.

Publications

1) Fali, M.H., **Desobgo, Z.S.C.***, Nso, E.J., **2019**. Sorghum coffee-lactose stout production and its physico-chemical characterisation. *Beverages*. 5(20), 1-21.
2) Adebo, O.A.*, Njobeh, P.B., **Desobgo, Z.S.C.***, Pieterse, M., Kayitesi, E., Ndinteh, D.T. 2018. Profiling of volatile flavor compounds in nkui (a Cameroonian food) by solid phase extraction and 2D gas chromatography time of flight mass spectrometry (SPME-GC×GC-TOF-MS). *Food Science & Nutrition*. 6(8), 2028–2035
3) Ninga, K.A., Sengupta, S., Jain, A., **Desobgo, Z.S.C.**, Nso, E.J., De, S., **2018**. Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice. *Journal of Food Engineering*. 221, 158-166.

4) Nguemogne A. C., **Desobgo Z. S.C.***, Nso E. J., **2018**. A Screening approach for the expression of total amylase activity during malting of *Safrari* sorghum cultivar. *Research Journal of Science and Technology*. 10(4), 244-252

5) Tiyou, J.P., **Desobgo, Z.S.C.***, Nso, J.E., **2018**. Statistical models for *S.35* sorghum stems conversion by hydrothermal treatment. *JSM Environmental Science & Ecology*. 6(1), 1-11

6) **Desobgo, Z.S.C.***, Stafford, R.A., Ndinteh D.T., Metcalfe, D.J.A., & Meijboom R., **2017**. The impact of gaseous carbon dioxide and boiling power on dimethyl sulphide stripping behavior during wort boiling. *Journal of the American Society of Brewing Chemists*. 75(4), 324-332.

7) **Desobgo, Z.S.C.***, Stafford, R.A. & Metcalfe, D.J.A., **2017**. Modeling of dimethyl sulfide stripping behavior when applying delayed onset of boiling during wort boiling. *Journal of the American Society of Brewing Chemists*. 75(3), 269-275

8) Nguemogne A. C., **Desobgo Z. S.C.***, Nso E. J. **2017**. Comparative study of limit dextrinase potential of three sorghum cultivars (*Safrari, Madjeru* and *S.35*). *Journal of the American Society of Brewing Chemists*. 75(3), 255-261

9) Adebo, O. A., Njobeh, P. B., Mulaba-Bafubiandi, A. F., Adebiyi, J. A., **Desobgo, Z. S. C.**, Kayitesi, E., **2017**. Optimization of fermentation conditions for ting production using response surface methodology. *Journal Food Processing and Preservation*. e13381. https://doi.org/10.1111/jfpp.13381

10) **Desobgo, Z.S.C.***, Stafford, R.A. & Metcalfe, D.J.A., **2017**. The derivation and application of a simultaneous volatile formation and stripping kinetics equation for wort boiling. *Journal of the American Society of Brewing Chemists.* 75(1), 11-21

11) Makebe, C. W., **Desobgo, Z. S. C.***, Nso, E. J. **2017**. Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains. *Beverages.* 3(2), 1-18.

12) Ekorong, F. J. A. A., Zomegni, G., **Desobgo, Z. S. C.***, & Ndjouenkeu, R., **2015**. Optimization of drying parameters for mango seed kernels using central composite design. *Bioresources and Bioprocessing*. 2(8), 1-9.

13) Taira, A., **Desobgo, Z.S.C.***, Nso, E.J., **2015**. Partial purification of α-amylase from *Burnatia enneandra* Micheli. Part 1: Extraction using

statistical model. *International Journal of Research in Biotechnology and Biochemistry*. 5 (1), 13-19

14) **Desobgo, Z.S.C.***, Stafford, R.A. & Metcalfe, D.J.A., **2015**. Dimethyl sulphide stripping behaviour during wort boiling using Response Surface Methodology. *Journal of the American Society of Brewing Chemists.* 73 (1), 84-89

15) Nso, E.J., Aseaku, J.N., **Desobgo, Z.S.C.,** Ngulewu, C., Aleambong, D.K. & Taira, A., **2013**. Comparison of the mashing and brewing potentials of crude extracts of *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*. *Journal of Brewing and Distilling*. 4 (2), 46-50

16) NGouadjo, T.L., Youmssi, A., **Desobgo, Z.S.C.*,** & Kayem, G.J., **2013**. Optimization of the extraction of roselle (*Hibiscus sabdariffa* L.) dried calyxes' juice. *International Journal of Innovation and Applied Studies.* 2 (4), 499-510.

17) **Desobgo, Z.S.C.*,** & Nso, E.J., **2013**. Optimization of the impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the turbidity of *Madjeru* sorghum cultivar wort. *International Journal of Applied Research and Studies.* 2 (1), 1-10.

18) **Desobgo, Z.S.C.*,** Naponni, Y.F. & Nso, E.J., **2013**. Characterization of *Safrari* sorghum worts and beers hopped with *Vernonia amygdalina* and *Nauclea diderrichii. International Journal of Innovation and Applied Studies.* 2 (1), 83-91.

19) **Desobgo, Z.S.C.*,** Nso, E.J. & Tenin, D., **2011**. The response surface methodology as a reliable tool for evaluating the need of commercial mashing enzymes for alleviating the levels of reducing sugars of worts of malted sorghum: Case of the *Safrari* cultivar. *Journal of Brewing and Distilling*, 2**,** 5-15.

20) **Desobgo, Z.S.C.*,** Nso, E.J. & Tenin, D., **2011**. Use of the response surface methodology for optimizing the action of mashing enzymes on wort reducing sugars of the *Madjeru* sorghum cultivar. *African Journal of Food Science*, 5**,** 91-99.

21) **Desobgo, Z.S.C.*,** Nso, E.J. & Tenin, D., **2011**. Modeling the action of technical mashing enzymes on extracts and free-amino nitrogen yields of the *Madjeru* sorghum cultivar. *Journal of Brewing and Distilling*, 2**,** 29-44.

22) **Desobgo, Z.S.C.*,** Nso, E.J. & Tenin, D., **2011**. Optimisation of the Action of Commercial Mashing Enzymes on Wort Extracts and Free Amino

Nitrogen of the *Safrari* Sorghum Cultivar. *Technical Quarterly Master Brewers Association of the Americas,* 48**,** 77-86.

23) **Desobgo, Z.S.C.*,** Nso, E.J., Tenin, D. & Kayem, G.J., **2010**. Modelling and optimizing of mashing enzymes-effect on yield of filtrate of unmalted sorghum by use of response surface methodology. *Journal of the Institute of Brewing,* 116**,** 62-69.

Publications in Press

1) Taira, A., **Desobgo, Z.S.C.***, Nso, E.J., **2019**. Partial purification of α-amylase from *Burnatia enneandra* Micheli. Part 2: Aqueous two-phase system purification and enzyme characterization. *Journal of Food Stability*. **In press**

2) Calister W. Makebe; **Zangue Steve C. Desobgo**; Wilson A. Agwanande; Abraham Billu; Emmanuel J. Nso, Nisha P., **2019**. Optimization of pectinase-assisted extraction conditions of *Annona muricata* L. juice and investigation of the impact of liquefaction on the structure of its pectin. *Food Chemistry*. **In press**

Dr. DESOBGO ZANGUE Steve Carly

I.4) Photocopie de l’acte de naissance

DEPARTEMENT
DIVISION
du Wouri

ARRONDISSEMENT
SUBDIVISION
de Douala

REPUBLIQUE UNIE DU CAMEROUN
Paix—Travail—Patrie

UNITED REPUBLIC OF CAMEROON
Peace—Work—Fatherland

CENTRE D'ETAT CIVIL
CIVIL STATUS REGISTRATION CENTRE
de - Of Deido et Akwa Nord

Acte de Naissance N° 9/77
BIRTH CERTIFICATE

Nom de l'enfant - Name of the child: Dessobgo Fiangue Steve Cinly
Le - On the: Deux Janvier mil neuf cent soixante dix sept
Est né à - Was born at: Douala Cameroun
Nom de l'enfant - Name of the child: Dessobgo Fiangue Steve Cinly
De sexe - Sex: masculin
De - Of: Sobgo Gabriel
Né à - Born at: Bafoussam
Le - On the: 1er Août 1947
Domicilié à - Resident at: Douala
Profession - Occupation: Tenancier et Automobiliste
Et de - And of: Gueppi Teindjio Emilienne
Née à - Born at:
Le - On the: 13 Mai 1955
Domiciliée à - Resident at: Douala
Profession - Occupation: Ménagère
Dressé le - Drawn up on the: huit Janvier mil neuf cent soixante dix sept
Sur la déclaration de - In accordance with the declaration of: N° 20 de Mme Ac Tiliacos, sage femme

Lesquels ont certifié la sincérité de la présente déclaration.
Who attested to the truth of this declaration.

Par Nous - By Us: Ekoualla Henri, Officier de l'Etat Civil
Chef du Centre Spécial de Deido

Le Déclarant, The declarant.

Signature de l'Officier de l'Etat-Civil
Signature of Registrar.

EKOUALLA HENRI

II) DIPLOMES

II.1) Baccalauréat D

Ministère de l'Education Nationale
Office du Baccalauréat
du Cameroun

République du Cameroun
Paix Travail Patrie

Baccalauréat de l'Enseignement Secondaire

N° 03730

Vu les textes en vigueur portant organisation des Baccalauréats de l'Enseignement Secondaire

Vu le Procès-verbal des délibérations du jury, session de Juin 1996 Jury N° 069

Le diplôme du Baccalauréat de l'Enseignement Secondaire Général

série/spécialité BAD MATHEMATIQUES ET SCIENCES DE LA NATURE

est conféré à M. DESOBGO ZANGUE STEVE CARLY Matricule 509807

né(e) le 02/01/1977 à DOUALA Mention PASSABLE

Pour en jouir avec les droits et prérogatives qui y sont attachés.

Signature du titulaire

Fait à Yaoundé le 23 Novembre 2001

Pour enregistrement conforme
Le Directeur de l'Office du Baccalauréat du Cameroun

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON
LE DIRECTEUR p.i.
CAMEROON BACCALAUREAT BOARD
OFFICE DU BACCALAUREAT DU CAMEROUN

Matsogo Zacharie

Le Ministre de l'Education Nationale

Le Ministre

Joseph OWONA

Le Ministre de l'Enseignement Supérieur
Chancelier des ordres académiques

Mbangana Mebara

II.2) Diplôme Universitaire de Technologie (DUT) en Génie Agro-Industriel

27

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDÉRÉ

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

UNIVERSITY INSTITUTE OF TECHNOLOGY

Diplôme Universitaire de Technologie

"D.U.T" Diploma

N° 98/DUT/008/IU

Vu le décret n°93/028 du 19 janvier 1993 portant organisation administrative et académique de l'Université de Ngaoundéré
Mindful of decree n° 93/028 of 19 january 1993 to organise the University of Ngaoundere

Vu l'arrêté n° 006/MINESUP/F120 du 28 janvier 1993 fixant les domaines de formation et les conditions d'admission à l'Institut Universitaire de Technologie de Ngaoundéré
Mindful of Ministerial Order n° 006/MINESUP/F120 of 28 january 1993 to fixe the domains of training and conditions of admission into the University of Ngaoundere Institute of Technology

Vu les procès verbaux des délibérations du jury, session de ..... Octobre 1998 .....
Mindful of the decisions of the board of examiners, session of

Le Diplôme Universitaire de Technologie

The "D.U.T" Diploma

Spécialité / *Major* ..... Génie Agro-Industriel .....

Est délivré à / *Is conferred on* ..... Monsieur Desobgo Zangué Steve-Carly .....

Né(e) le / *Born on* ..... 02 Janvier 1977 ..... à / *at* ..... Douala ..... N° Matricule / *Registration N°* ..... 96A082IU .....

Pour en jouir avec les droits et prérogatives qui y sont rattachés
With all the rights and privileges appertaining to the said degree.

Fait à Ngaoundéré, le / *Done in Ngaoundere, on* ..... 17 NOV 2000 .....

L'IMPÉTRANT

The Holder

LE RECTEUR

Professeur Zeban Sammy Chumbow

The Rector

LE MINISTRE DE L'ENSEIGNEMENT SUPÉRIEUR, CHANCELIER DES ORDRES ACADÉMIQUES

The Minister of Higher Education, Chancellor of Academic Orders

II.3) Diplôme d'Ingénieur des Industries Agricoles et Alimentaires

29

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDÉRÉ

ÉCOLE NATIONALE SUPÉRIEURE DES SCIENCES AGRO-INDUSTRIELLES

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

NATIONAL ADVANCED SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Diplôme d'Ingénieur
Master of Engineering Degree

Nº 01/ING/028/EN

Vu le décret nº 92/074 du 13 avril 1992 portant transformation des Centres Universitaires de Buea et de Ngaoundéré en Universités
Mindful of decree nº 92/074 of 13 April 1992 to transform Buea and Ngaoundere University Centres into Universities
Vu le décret nº 93/028 du 19 janvier 1993 portant organisation administrative et académique de l'Université de Ngaoundéré
Mindful of decree nº 93/028 of 19 January 1993 to organise the University of Ngaoundere
Vu le décret nº95/061 du 03 avril 1995 portant organisation de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles de l'Université de Ngaoundéré
Mindful of decree nº 95/061 of 3 April 1995 to organise the National Advanced School of Agro-Industrial Sciences of the University of Ngaoundere

Vu les procès - verbaux des délibérations du jury, session de Octobre 2001
Mindful of the decision of the board of examiners, session of

UNIVERSITE DE NGAOUNDERE
SCIENTIA - ARS - CONSCIENTIA

Le Diplôme d'Ingénieur
The Master of Engineering Degree

Spécialité / Speciality: Industries Agricoles et Alimentaires

Spécialisation / Specialization:

Est délivré à / Is conferred on: **Desobgo Zangue Stève-Carly**

Né(e) le / Born on: 02-01-1977 **à** / at: Douala-Cameroun **Nº Matricule** / Registration Nº: 98A005EN

Pour en jouir avec les droits et prérogatives qui y sont rattachés
With all the rights and privileges appertaining to the said degree

Fait à Yaoundé, le / Done in Yaounde, on: 19 MARS 2004

L'IMPÉTRANT
Holder

LE RECTEUR
P. Amwam Zollo Paul Henri
Rector

LE MINISTRE DE L'ENSEIGNEMENT SUPÉRIEUR, CHANCELIER DES ORDRES ACADÉMIQUES
Tchuente
Maurice TCHUENTE
Minister of Higher Education, Chancellor of Academic Orders

II.4) Certificat de Réussite au Diplôme d'Etudes Approfondies (DEA) en Génie des Procédés

UNIVERSITE DE NGAOUNDERE
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
THE NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B.P.: 455 Ngaoundéré – Cameroun
Tél/Fax : (237) 225-27-51
E-mail : ensai_stages@yahoo.fr
Site Internet : http://ensai-iut.minesup.gov.cm

DIPLOME D'ETUDES APPROFONDIES EN GENIE DES PROCEDES

CERTIFICAT DE REUSSITE / SUCCESS CERTIFICATE N° 003/003 /UN/D.ENSAI/DAACRS

Les soussignés

Vu le procès verbal du jury en date du **19 juillet 2003** attestent que :

M./Mlle **DESOBGO ZANGUE Steve Carly** Matricule n° **98A005EN**

Né(e) le **02 janvier 1977** à **Douala**

Titulaire du **Diplôme des Ingénieurs des Industries Agricoles et Alimentaires**

Ayant suivi les enseignements de **DEA de la filière de Génie des Procédés (GP)** pendant l'année académique **2001-2002** a validé la totalité des Modules / Unités de Valeurs avec les performances suivantes :

Code Module/UV	Intitulé des Modules / Unités de Valeurs	Note / 20	Mention	Année
MIGP6011	Mathématiques - Informatique pour le Génie des Procédés	18,0	TB	2002
PTGP6012	Phénomènes de Transport	15,0	B	2002
OU6014GP	Opérations unitaires de séparation et de Conservation	15,50	B	2002
TEGP6015	Techniques et Procédés nouveaux pour les IAA	13,50	B	2002
GA6013GP	Propriétés Phys., Physico-chimiques et Technol. des aliments	13,46	AB	2002
TA6113GP	Techniques Analytiques avancées	11,45	AB	2002
GBGP6312	Génie Biochimique et Biotechnologique	16,00	B	2002
MRGP6016	Méthodologie de la Recherche	15,60	B	2002
	Moyenne écrit	**14,81**	B	
IRGP6017	Stage d'Initiation à la recherche	15,50	B	2003
STGP6018	Mémoire de Recherche	14,00	B	2003
	Moyenne recherche :	**15,50**		
	MOYENNE GENERALE :	**15,15**		
MENTION : Bien				

En foi de quoi ce certificat lui est délivré pour servir et valoir ce que de droit./.

Ngaoundéré le : 27 DEC. 2004

Le Chef de Division des Affaires Académiques de la Coopération, de la Recherche et de la Scolarité,

Dr. Hamza Richard

Le Directeur,

Pr. F. Medjouka

II.5) Rapport de Soutenance de Thèse de Doctorat / Ph.D en Génie des Procédés

REPUBLIQUE DU CAMEROUN
Paix-Travail-Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

Ecole Nationale des Sciences Agro-Industrielles (ENSAI)

REPUBLIC OF CAMEROON
Peace-Work-Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

National School of Agro-Industrial Sciences (ENSAI)

RAPPORT DE SOUTENANCE DE THESE DE DOCTORAT/Ph.D

Spécialité : Génie des Procédés

VIVA VOCE REPORT OF THE Ph.D Thesis

De/*of*

Desobgo Zangue Steve Carly

Matricule :98D005EN

Date: 14/09/2012

Sujet de Thèse/*Title of Thesis*

Modélisation de l'action des hydrolases sur quelques caractéristiques physico-chimiques des moûts de deux cultivars de sorgho

Pr. Nso Emmanuel Jong

Jury / Board of Examiners:

Président:	Mbofung Carl Moses, Professeur, Université de Ngaoundéré
Rapporteurs :	Ndjounekeu Robert, Professeur, Université de Ngaoundéré
	Essia Ngang Jean Justin, Maître de Conférences, Université de Yaoundé 1
Examinateurs :	Fon Abi Charles, Maître de Conférences, Université de Yaoundé 1
Co-Directeurs :	Kayem Joseph, Maître de Conférences, Université de Ngaoundéré
	Nso Emmanuel, Maître de Conférences, Université de Ngaoundéré
Invité :	Zo'obo, Directeur Process Qualité, Brasseries du Cameroun, Yaoundé

EVALUATION

Quelle mention accordez-vous par rapport à : ***Score the Viva voce on the following basis :***	**Mention /*Merit***			
	Excellent ***Excellent***	Très Bien ***Very Good***	Bien ***Good***	Assez Bien ***Fairly Good***
La clarté de la présentation / ***Clarity of the presentation***	X			
La pertinence de la recherche menée par le candidat ***Relevance of research work carried out***	X			
Défense de l'originalité de la thèse/ ***Defence of the originality of the thesis***		X		
Techniques et méthodes de recherche ***Research methods and techniques***		X		
Avancée dans la résolution du problème posé ***Contribution to the attainment of the general objectives of the thesis work***	X			
Clarification des points d'ambiguïté dans la thèse ***Clarification of points of ambiguity***		X		
Contribution à la Connaissance Scientifique ***Contribution to knowledge***	X			
Possibilité de publication ***Potential of publishing results obtained***	X			

Autres commentaires et Mention du Diplôme/ *Other comments and Merit of Degree*: Travail très intéressant à fort potentiel de valorisation industrielle et une opportunité pour la filière des céréales locales. La poursuite des travaux est à encourager. Le volume des résultats obtenus est important et a donné lieu à des publications scientifiques de très bon niveau, signe d'une reconnaissance internationale de la qualité de cette thèse. De ce qui précède, le jury reçoit la thèse de Monsieur Desobgo Zangue Steve Carly et lui décerne le diplôme de Docteur/PhD avec la mention très honorable.

Signatures :

Président(e)/*President* MBOFUNG Carl

Membres 1. ESSIA NGANG J. Justin

2. NDJOUENKEU M.

3. Dr ZO'OBO

4. FON ABI Charles

5. Prof. Kayem

6. NSO Emmanuel

7. .....

II.6) Attestation de Soutenance de Thèse de Doctorat / Ph.D en Génie des Procédés

35

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ESEIGNEMENT SUPERIEUR

REPUBLIC OF CAMEROON
Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITE DE NGAOUNDERE
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
THE NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

B.P.: 455 Ngaoundéré – Cameroun Tél.: (237) 77783840 Fax : (237) 22 15-81 89
E-mail : ensai_ngaoundere@yahoo.com Site Internet : http://www.ensai_un.africa.org

ENSAI

ATTESTATION
TESTIMONIAL

N° 2012/084 /UN/D.ENSAI/DAACRS/SSS

Le Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, soussigné,
The Director of the National School of Agro-Industrial Sciences of the University of Ngaoundere, undersigned,

ATTESTE QUE
HEREBY CERTIFY THAT

M./Mme/Mlle **DESOBGO ZANGUE STEVE CARLY** Né(e) **02 Janvier 1977** à **DOUALA**
Born on the *in*

Matricule n° **98A005EN** de sexe **Masculin** a soutenu avec la mention **très honorable** le **14 Septembre 2012** une thèse de
Reg. N° *sex* ***Male*** *has successfully defended on the* ***14 of September 2012*** *his thesis for the award of the*

Doctorat/Ph.D
Doctor of Philosophy Degree

Option: **Génie des Procédés**
in ***Process Engineering***

Le travail de recherche a porté sur: **Modélisation de l'action des hydrolases sur quelques caractéristiques physico-chimiques des moûts de deux cultivars de sorgho.**
The title of the research work is

Devant un jury dûment constitué par décision no **2012/479/UN/R/VRE-PDTIC/DAAC/DEPE** du **04 Septembre 2012** composé de:
Before the jury constituted by decision no ***2012/479/UN/R/VRE-PDTIC/DAAC/DEPE*** *of 04th September 2012 and made up of the following*

Président : **Pr. MBOFUNG Carl Moses**
President

Rapporteurs : **Pr. NSO Emmanuel JONG**
Secretaries: **Pr. KAYEM Joseph**

Membres : **Pr. NDJOUENKEU Robert**
Members **Pr. ESSIA NGANG Jean Justin**
Pr. FON ABI Charles
Dr. ZO'OBO Jean Pierre

En foi de quoi la présente Attestation est établie et délivrée pour servir et valoir ce que de droit./.
In witness whereof the present Testimonial is given with all the privileges thereunto pertaining./.

Ngaoundéré, le

Le Directeur
The Director

Le Directeur

Pr. Nso Emmanuel Jong

NB : Il n'est délivré qu'une seule attestation . Le titulaire pourra en faire autant de copies certifiées conformes qu'il voudra. Le Diplôme sera délivré ultérieurement.
Only one testimonial is issued. It is in the interest of the owner to make as many certified true copies as he/she may desire. The Certificate will be issued later.

III) ACTES ADMINISTRATIFS

III.1) Décision de recrutement

REPUBLIQUE DU CAMEROUN
******
Paix – Travail - Patrie
****
UNIVERSITE DE NGAOUNDERE
****
BP: 454
****
RECTORAT
****
VICE -RECTORAT CHARGE DES ENSEIGNEMENTS, DE LA PROFESSIONNALISATION ET DU DEVELOPPEMENT DES TECHNOLOGIES DE L'INFORMATION ET DE LA COMMUNICATION
****
DIRECTION DES AFFAIRES ACADEMIQUES ET DE LA COOPERATION

REPUBLIC OF CAMEROON
****
Peace-Work-Fatherland
****
THE UNIVERSITY OF NGAOUNDERE
****
P.O Box : 454
****
RECTOR'S OFFICE
****
THE VICE RECTORATE IN CHARGE OF TEACHING, PROFESSIONALIZATION AND DEVELOPMENT OF INFORMATION AND COMMUNICATION TECHNOLOGIES
****
DIRECTION OF ACADEMIC AFFAIRS AND CO-OPERATION

2008/229

Décision N°...../UN/R/VR-EPDTIC/SG/DAAC/DEPE/SSPE

Portant recrutement de Monsieur DESOBGO ZANGUE Steve Carly en qualité d'Assistant au Département de Génie Alimentaire et Contrôle Qualité de l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE,
RAPPORTEUR DU CONSEIL D'ADMINISTRATION

Vu la Constitution ;
Vu la Loi n°2007/005 du 26 décembre 2007 portant Loi de Finances de la République du Cameroun pour l'exercice 2008 ;
Vu l'Ordonnance n°62/OF/4 du 07 février 1962 portant Régime Financier du Cameroun et les textes modificatifs subséquents ;
Vu le décret n° 2005/142 du 29 avril 2005 portant organisation du Ministère de l'Enseignement Supérieur ;
Vu le décret n° 92/74 du 13 avril 1992 transformant les Centres Universitaires de Ngaoundéré et Buéa en Universités ;
Vu le décret n°93/026 du 19 janvier 1993 portant création des Universités ;
Vu le décret n° 93/027 du 19 janvier 1993 portant dispositions communes applicables aux Universités, modifié et complété Par le décret n° 2005/342 du 10 septembre 2005;
Vu le décret n° 93/035 du 19 janvier 1993 portant statut spécial des personnels de l'Enseignement Supérieur, modifié et complété par le décret n° 2000/048 du 15 mars 2000;
Vu le décret n°93/028 du 19 janvier 1993 portant organisation administrative et académique de l'Université de Ngaoundéré ;
Vu le décret n° 93/028 du 19 janvier 1993 modifiant la rémunération des Fonctionnaires et Agents de l'Etat ;
Vu l'arrêté n° 2000/050 du 15 mars 2000 fixant les modalités de rémunération du personnel Assistant des Universités ;
Vu le décret n° 2000/209 du 27 juillet 2000 fixant la valeur du point d'indice des Fonctionnaires de l'Etat
Vu le décret n°2000/212 du 27 juillet 2000 modifiant certaines dispositions du décret n°91/324 du 09 juillet 1991 fixant les conditions d'attribution des logements administratifs ;
Vu le décret n ° 2008/099 du 07 mars 2008 portant revalorisation de la rémunération mensuelle de base des personnels civils et militaires ;
Vu le décret n° 2008/100 du 07 mars 2008 portant revalorisation du taux de l'indemnité de non logement servie aux personnels civils et militaires ;
Vu le décret n° 2003/049 du 16 septembre 2003 portant nomination des Recteurs dans les Universités d'Etat ;
Vu les résolutions de la Commission Consultative de Recrutement des Assistants de l'Université de Ngaoundéré en sa séance du 23 janvier 2008 ;
Vu la décision du Conseil de l'Université de Ngaoundéré lors de la vingt-deuxième session en date du 24 janvier 2008 ;
Vu l'avis favorable émis par le Conseil d'Administration de l'Université de Ngaoundéré lors de sa vingt unième session en date du 25 janvier 2008 ;
Vu la lettre n° 08/01866/L/MINESUP/SG/DDES/SGE/CEA1/ne du 31 mars 2008 portant autorisation de mise en service des Assistants et des ATER recrutés lors de la CCRA du 23 janvier 2008 ;
Vu les prévisions budgétaires de l'exercice 2008.

Ministère des Finances – Direction Générale du Budget – 31 JUIL 2008 – Services Rattachés de l'Université de NGAOUNDERE – VISA BUDGETAIRE

DECIDE :

Article 1er : Monsieur DESOBGO ZANGUE Steve Carly titulaire d'un Diplôme d'Etudes Approfondies (DEA) en Génie des Procédés est pour compter du 16 avril 2008, date effective de sa prise de service, recruté en qualité d'Assistant, indice 1E/465, au Département de Génie Alimentaire et Contrôle Qualité de l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

Article2: L'Intéressé sera pris en charge par le budget de l'Etat Chap. 18 Art 102 Par 000 (18-102-000).

Article 3: La présente décision sera enregistrée et communiquée partout où besoin sera.

Ngaoundéré, le 09 JUIL. 2008

LE RECTEUR

Le Recteur

Pr. Amvam Zollo Paul Henri

Ampliations
MINESUP
- MINFI-SOLDE-TRESOR
- MINFOPRA/DPE/SDPFSE/SAPE
- RECTEUR-UN
- VR-EPDTIC / VR-CIE
- SG UN / DAAC / DEPE / SSPE
- DAAF-UN / AC -UN
- CHEF D'ETABLISSEMENT

III.2) Contrat de travail

REPUBLIQUE DU CAMEROUN
PAIX-TRAVAIL-PATRIE

REPUBLIC OF CAMEROON
PEACE-WORK-FATHERLAND

UNIVERSITE DE NGAOUNDERE

THE UNIVERSITY OF NGAOUNDERE

CONTRAT DE TRAVAIL - *CONTRACT OF ENGAGEMENT*

2008/031 &

N°...../UN/R/VR-EPDTIC/SG/DAAC/DEPE/SSPE

Entre les Soussignés :

L'Université de Ngaoundéré, représentée par le **Recteur**
d'une part,

et Monsieur **DESOBGO ZANGUE Steve Carly,** de Sexe **masculin,** né le **02 Janvier 1977** à **Douala - Cameroun,** Arrondissement de **Douala 1,** Département du **Wouri,** Province du **Littoral.**

Fils de **SOBGO Gabriel,**
et de **GUEPI TEADJIO Emilienne,**

de nationalité **camerounaise,** dont la résidence est à **Ngaoundéré**

Ministère des Finances
Direction Générale du Budget
CFS auprès de l'Université de NGAOUNDERE
07 JUIL 2008
VISA BUDGETAIRE

Ci-après dénommé Contractant
d'autre part,

conformément :

- aux dispositions prévues par la loi n° 92/007 du 14 août 1992 portant code du travail et à ses décrets et arrêtés d'application ;
- au décret n°92/74 du 13 avril 1992 transformant les centres universitaires de Ngaoundéré et Buéa en Universités ;
- aux textes régissant les universités et les institutions universitaires camerounaises, et notamment :
- le décret n° 93/028 du 19 janvier 1993 portant organisation administrative et académique de l'Université de Ngaoundéré ;
- le décret n° 93/027 du 19 janvier 1993 portant dispositions communes applicables aux universités;
- le décret n° 93/035 du 19 janvier 1993 portant statut spécial des personnels de l'Enseignement Supérieur ;
- et le décret n° 93/021 du 19 janvier 1993 portant dispositions communes applicables aux Instituts Universitaires de Technologie ;
- le décret n° 76/472 du 18 octobre 1976 portant certaines dispositions applicables aux

personnels du cadre de l'Enseignement Supérieur ;
- le décret n° 78/484 du 09 novembre 1978 fixant les dispositions communes applicables aux agents de l'Etat relevant du code de travail ;
- le décret réglementant le régime des déplacements au Cameroun ;
- l'arrêté n° 2000/050 du 15 mars 2000 fixant les modalités de rémunération du personnel Assistant des Universités ;
- le décret n° 2005/344 du 10 septembre 2005 portant nomination des Recteurs dans les Universités d'Etat ;
- les résolutions de la Commission Consultative de Recrutement des Assistants (CCRA) de l'Université de Ngaoundéré en sa séance du 23 janvier 2008 ;
- la décision du Conseil de l'Université de Ngaoundéré en sa vingt-deuxième session du 24 janvier 2008 ;
- l'avis favorable émis par le Conseil d'Administration de l'Université de Ngaoundéré lors de sa vingt- unième session en date du 25 janvier 2008 ;
- la lettre n° 08/01866/L/MINESUP/SG/DDES/SCE/CEA1/ne du 31 mars 2008 portant autorisation de mise en service des Assistants et ATER de l'Université de Ngaoundéré;
- le décret n° 2000/209 du 27 juillet 2000 fixant la valeur du point d'indice des Fonctionnaires de l'Etat ;
- le décret n°2000/212 du 27 juillet 2000 modifiant certaines dispositions du décret n°91/324 du 09 juillet 1991 fixant les conditions d'attribution des logements administratifs ;
- le décret n° 2008/099 du 07 mars 2008 portant revalorisation de la rémunération mensuelle de base des personnels civils et militaires ;
- le décret n° 2008/100 du 07 mars 2008 portant revalorisation de l'indemnité de non logement servie aux personnels civils et militaires ;
- vu le décret n° 2002/041 du 04 février 2002 fixant les montants et les modalités de paiement des primes allouées à certains personnels du Corps de l'Enseignement Supérieur ;
- vu les prévisions budgétaires de l'Etat au Chap. 18 Art. 102 par 000 (18-102-000),

Il a été arrêté et convenu d'un commun accord ce qui suit :

Article 1 : Clauses générales

Quels que soient les titres donnés au Contractant et l'emploi occupé par lui, le présent contrat ne lui confère ni la qualité de fonctionnaire, ni le droit d'être nommé dans les cadres réguliers et permanents de l'Enseignement Supérieur, sauf dans les conditions fixées par les textes statutaires en vigueur.

Article 2 : Emploi à tenir

Le Contractant, titulaire d'un **DIPLÔME D'ETUDES APPROFONDIES (DEA),** est appelé à remplir les fonctions d'**ASSISTANT, indice 1E/465 au Département de Génie alimentaire et Contrôle Qualité de l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.**

Toutefois, conformément au décret n°93/027 du 19 janvier 1993, le Ministre de l'Enseignement Supérieur peut, pour nécessités de service, affecter le Contractant dans une autre Institution Universitaire camerounaise.

Article 3 : **Rémunération**

Le Contractant percevra une rémunération mensuelle calculée sur la base de l'indice **1E/465**. Outre la rémunération ci-dessus, le Contractant percevra mensuellement :

- une prime de technicité d'un montant de **TRENTE MILLE (30 000) Francs CFA** en vertu du décret n°2002/041 du 04 février 2002 fixant les montants et les modalités de paiement des primes allouées à certains personnels du Corps de l'Enseignement Supérieur ;
- une prime de l'Enseignement Supérieur d'un montant de **QUATRE VINGT DIX MILLE (90 000) Francs CFA** en vertu du décret n°2002/041 du 04 février 2002 susvisé ;
- une allocation mensuelle de logement non soumise à impôt dont le taux est égal à 20 % du salaire de base indiciaire ou catégoriel en vertu du décret n° 2008/100 du 07 mars 2008.
- il pourrait prétendre annuellement à une prime de recherche, conformément à la réglementation en vigueur.

Article 4 : **Durée du Contrat**

La durée du présent contrat est de deux (02) ans renouvelable deux (02) fois.

Toutefois les Assistants non titulaires d'une thèse de doctorat au moment de leur recrutement peuvent, sur décision des Recteurs, bénéficier d'une période supplémentaire de deux (02) ans, pour soutenir leur thèse de doctorat.

Article 5 : **Congés**

La période de service effectif ouvrant droit aux congés est de douze (12) mois. Toutefois, le Contractant bénéficiera annuellement de ses congés pendant les périodes d'interruption des classes, conformément à la réglementation en vigueur.

Article 6 : **Voyages-Transport**

A l'occasion de ses congés, le Contractant de nationalité camerounaise, a droit pour lui même et sa famille au transport Aller et Retour gratuit conformément aux dispositions du décret n°91/134 du 22 février 1991 réglementant la prise en charge sur le budget de l'Etat des frais de déplacement des fonctionnaires et agents civils de l'Etat du lieu de service à leur localité d'origine entendue comme lieu de résidence habituelle justifiée par une attestation délivrée par le Préfet ;

a) au cas où le Contractant désirerait prendre ses congés ailleurs qu'à sa résidence habituelle, l'Université de Ngaoundéré n'aura à supporter que les frais exposés par l'intéressé sans que ceux-ci puissent excéder les frais qu'aurait nécessité son voyage Aller et Retour et éventuellement, celui de sa famille de son lieu de service à sa résidence habituelle.

b) le Contractant de nationalité étrangère bénéficie du transport Aller et Retour gratuit pour lui-même et sa famille à l'intérieur du Cameroun dans une ville de son choix.

c) la Contractante de nationalité étrangère épouse d'un Camerounais bénéficie du transport Aller et Retour gratuit à l'intérieur du pays dans les conditions de l'alinéa 1 de l'article 6 du présent contrat, s'il est prouvé qu'elle n'a pas bénéficié des congés au titre d'épouse dans l'Administration de son mari.

Les voyages et transports sont effectués par l'une des voies normales de transport selon la réglementation en vigueur.

Par famille, il faut entendre la conjointe légitime non divorcée, ni séparée et les enfants mineurs à charge.

Le Contractant ne peut toutefois prétendre au transport gratuit de sa conjointe, qu'au cas où celle-ci n'est pas salariée de l'Etat camerounais.

Article 7 : Déplacement temporaire

En cas de déplacement temporaire pour raison de service et lorsqu'il n'est ni logé, ni nourri par l'Université de Ngaoundéré, le Contractant bénéficiera des frais de mission conformément à la réglementation en vigueur.

Article 8 :

a) Appointement

Conformément au décret n° 2000/048 du 15 mars 2000 modifiant et complétant certaines dispositions du décret n° 93/035 du 19 janvier 1993 portant statut spécial des personnels de l'Enseignement Supérieur, la charge horaire du Contractant est de 200 heures de travaux dirigés, d'exercices ou de travaux pratiques par an. Au cas où le Contractant effectuerait des heures complémentaires au-delà de sa charge d'heures réglementaires ci-dessus mentionnées, celles-ci seront rémunérées conformément aux textes en vigueur.

b) Imputation

Les émoluments divers perçus par le Contractant sont pris en charge par le budget de l'Etat EXERCICE **2008** CHAPITRE **18** ARTICLE **102** PARAGRAPHE **000**

Article 9 : Soins médicaux

Le Contractant a droit au remboursement sur les frais d'hospitalisation pour toutes les maladies ou accidents survenus du fait ou à l'occasion du travail conformément à la loi n°77/11 du 13 juillet 1997 portant réparation et prévention des accidents de travail et des maladies professionnelles. Il pourra bénéficier pour lui, sa conjointe et ses enfants mineurs à charge, des mêmes avantages que les fonctionnaires de classification correspondante en ce qui concerne les soins pour maladies et accidents survenus en dehors du travail jusqu'à l'instauration d'un régime de sécurité sociale.

Dans ce cas, l'Université de Ngaoundéré est tenue de lui verser une indemnité conformément aux dispositions du décret n° 78/484 du 09 novembre 1978.

Ministère des Finances Direction Générale du Budget CF auprès de l'Université de Ngaoundéré VISA BUDGETAIRE 07 JUL 2008

Article 10 : Résiliation

Le contrat est résilié :

1/- de plein droit et sans préavis :

a) si, après acceptation et signature du contrat, le Contractant ne rejoint pas son poste sur première réquisition de l'Université de Ngaoundéré. Dans ce cas il sera tenu au remboursement de toutes les sommes perçues ainsi que des frais engagés pour ses bagages et transports et éventuellement ceux de sa famille.

En cas de refus, il y sera contraint par toutes les voies de droit.

b) pour faute lourde, conformément à la réglementation en vigueur.

2) Avec préavis (article 34 de la loi n° 92/007 du 14 août 1992 portant code du travail).

En cas de résiliation du contrat de travail : la durée du préavis réciproque est fixée, sauf pour faute lourde, conformément aux textes en vigueur.

Indemnité de licenciement : en cas de licenciement, si le Contractant a au moins deux (02) années d'ancienneté, il bénéficiera, sauf en cas de faute lourde, d'une indemnité de licenciement distincte du préavis et calculée conformément à l'article 14 du décret n° 78/484 du 09 novembre 1978.

Article 11 : Obligation du secret professionnel

Le Contractant s'engage à consacrer tout son temps et toute son activité, dans la limite de la réglementation en vigueur aux fonctions qui lui seraient confiées, à se conformer à toutes les instructions du présent contrat et à ne fournir aucune information de nature confidentielle dont il aurait connaissance à l'occasion de son travail.

CLAUSES PARTICULIÈRES

NEANT

ARTICLE 12 :

Le Contractant déclare formellement être libre de tout engagement antérieur.

Il déclare en outre avoir pris connaissance des clauses et conditions du présent contrat et en accepter sans réserve toutes les dispositions.

ARTICLE 13 :

Le présent contrat qui prend effet pour compter du **16 Avril 2008,** date effective de sa prise de service, est exempt de tous droits de timbre et d'enregistrement./-

Ngaoundéré, le 09 JUIL. 2008

LE RECTEUR,

LU ET APPROUVÉ

LU ET APPROUVE'

LE CONTRACTANT

Le Recteur

Pr. Amvam Zollo Paul Henri

AMPLIATIONS

MINESUP
- MINFI-SOLDE-TRESOR
- MINFOPRA/DPE/SDPFSE/SAPE
- RECTEUR-UN
-VR-EPDTIC-VR-CIE
- SG- UN/DAAC/DEPE/SSPE
- DAAF –UN/ AC -UN
- CHEF D'ETABLISSEMENT
- INTERESSÉ- CHRONO - ARCHIVES

III.3) Certificat de prise de service

REPUBLIQUE DU CAMEROUN
****
Paix – Travail - Patrie
****
UNIVERSITE DE NGAOUNDERE
****

REPUBLIC OF CAMEROON
****
Peace - Work – Fatherland
****
THE UNIVERSITY OF NGAOUNDERE
****

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE DE NGAOUNDERE

B.P. 455 NGAOUNDERE – Tél. 77 11 22 20 & 99 85 13 82

Le Directeur

Ngaoundéré, le 16 AVR. 2008

N° 2008/011/UN/D.IUT

CERTIFICAT DE PRISE DE SERVICE

Le Directeur de l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré soussigné, certifie que **Monsieur DESOBGO ZANGUE Steve Carly** né le 02 **Janvier 1977** à Douala, actuellement en cours de recrutement, a effectivement pris service à l'Institut Universitaire de Technologie le 16 Avril 2008 en qualité d'**Assistant** au Département de Génie Alimentaire et Contrôle Qualité.

En foi de quoi ce certificat est délivré à l'intéressé pour servir et valoir ce que de droit.

Ampliation:
-Chrono/Archives.

LE DIRECTEUR,

Dr-Ing. Ali Ahmed

III.4) Actes d’avancements

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
UNIVERSITE DE NGAOUNDERE
BP 454
RECTORAT

REPUBLIC OF CAMEROON
Peace - Work - Fatherland
THE UNIVERSITY OF NGAOUNDERE
P.O. Box 454
RECTOR'S OFFICE

2010/687

MINISTERE DES FINANCES
DIRECTION GENERALE DU BUDGET
24 NOV 2010
C.F.S. auprès Université
VISA BUDGETAIRE

DECISION N°----------/UN/R/VR-EPDTIC/SG/DAAC/DEPE/SSPE
Portant avancement d'échelon indiciaire de Monsieur DESOBGO ZANGUE Stève Carly, Assistant à l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE

Vu la Constitution ;
Vu la Loi n°2009/018 du 15 décembre 2009 portant loi de finances de la République du Cameroun pour l'exercice 2010 ;
Vu l'Ordonnance n°62/OF/4 du 07 février 1962 portant Régime Financier du Cameroun et les textes modificatifs subséquents ;
Vu le Décret n°2004/320 du 08 décembre 2004 portant organisation du gouvernement ;
Vu le Décret n°2004/322 du 08 décembre 2004 portant formation du gouvernement, modifié et complété par le décret n° 2007/269 du 07 septembre 2007 et le décret n° 2009/223 du 30 juin 2009 portant réaménagement du gouvernement;
Vu le Décret n°2005/142 du 29 avril 2005 portant Organisation du Ministère de l'Enseignement Supérieur ;
Vu le Décret n°93/026 du 19 janvier 1993 portant création d'Universités ;
Vu le Décret n° 93/027 du 19 janvier 1993 portant dispositions communes aux Universités, modifié et complété par le décret n° 2005/342 du 10 septembre 2005 ;
Vu le Décret n° 92/74 du 13 avril 1992 transformant les Centres Universitaires de Buéa et Ngaoundéré en Universités;
Vu le Décret n° 93/028 du 19 janvier 1993 portant Organisation administrative et académique de l'Université de Ngaoundéré ;
Vu le Décret n° 2005/383 du 17 octobre 2005 fixant le régime financier applicable aux universités ;
Vu le Décret n°2005/344 du 10 septembre 2005 portant nomination des Recteurs des Universités ;
Vu le Décret n°93 /035 du 19 janvier 1993 portant Statut Spécial des Personnels de l'Enseignement Supérieur, modifié et complété par le décret n°2000/048 du 15 mars 2000 ;
Vu le Décret n°2000/049 du 15 mars 2000 fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur ;
Vu le Décret n°2008/099 du 07 mars 2008 revalorisant la rémunération mensuelle de base des personnels civils et militaires;
Vu le Décret n°2008/100 du 07 mars 2008 revalorisant le taux de l'indemnité de non logement servie aux personnels civils et militaires ;
Vu la Circulaire N°10/001/MINFI du 08 janvier 2010 portant Instructions relatives à l'Exécution et au Contrôle de l'exécution du Budget de l'Etat et des Organismes subventionnés pour l'Exercice 2010.
Vu les Résolutions du Conseil d'Administration de l'Université de Ngaoundéré, en sa session du 10 juillet 2010 ;
Vu les prévisions budgétaires de l'exercice 2010.

DÉCIDE :

Article 1er : Monsieur **DESOBGO ZANGUE Stève Carly**, Matricule **652 117-M**, **Assistant 1E/465** depuis le 16/04/2008 est à compter du **16/04/2010**, avancé au grade d'**Assistant 2E/530.**

Article 2 : L'Intéressé percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice **530** correspondant à son grade et pourra prétendre aux avantages accordés aux Enseignants du même grade.

Imputation : Budget de l'Etat, Exercice 2010 Chap.18, Art.102, Para. 000.

Article 3 : La présente décision sera enregistrée et publiée partout où besoin sera./-

Fait à Ngaoundéré, le 09 DEC. 2010

LE RECTEUR

Le Recteur

Amvam Zollo Paul Henri

AMPLIATIONS
- MINESUP
- MINFI/SOLDE/TRÉSOR
- MINFOPRA/DPE/SDPFSE/SAPE
- VR-EPDTIC/ VR-CIE
- SG/ DAAF/ DAAC/DEPE/SSPE
- DIRECTEUR- IUT/ CF
- INTÉRESSÉ.

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
UNIVERSITE DE NGAOUNDERE
BP 454
RECTORAT

REPUBLIC OF CAMEROON
Peace - Work – Fatherland
UNIVERSITY OF NGAOUNDERE
P.O. Box 454
RECTOR'S OFFICE

12012/426

DECISION N°---------- /UN/R/VR-EPDTIC /SG/DAAC/DEPE/SSPE
Portant avancement d'échelon indiciaire de Monsieur DESOBGO ZANGUE Steve Carly, Assistant à l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE

Vu la Constitution;
Vu la Loi n°2011/020 du 14 décembre 2011 portant loi de finances de la République du Cameroun pour l'exercice 2012;
Vu l'Ordonnance n°62/OF/4 du 07 février 1962 portant Régime Financier du Cameroun et les textes modificatifs subséquents ;
Vu le Décret n°2011/410 du 09 décembre 2011 portant formation du gouvernement ;
Vu le Décret n°2011/408 09 décembre 2011 portant Organisation du Ministère de l'Enseignement Supérieur ;
Vu le Décret n°93/026 du 19 janvier 1993 portant création d'Universités ;
Vu le Décret n° 93/027 du 19 janvier 1993 portant dispositions communes aux Universités, modifié et complété par le décret n° 2005/342 du 10 septembre 2005 ;
Vu le Décret n° 92/74 du 13 avril 1992 transformant les Centres Universitaires de Buéa et Ngaoundéré en Universités;
Vu le Décret n°93/028 du 19 janvier 1993 portant Organisation administrative et académique de l'Université de Ngaoundéré ;
Vu le Décret n° 2005/383 du 17 octobre 2005 fixant le régime financier applicable aux universités ;
Vu le Décret n°2005/344 du 10 septembre 2005 portant nomination des Recteurs des Universités ;
Vu le Décret n°93 /035 du 19 janvier 1993 portant Statut Spécial des Personnels de l'Enseignement Supérieur, modifié et complété par le décret n°2000/048 du 15 mars 2000 ;
Vu le Décret n°2000/049 du 15 mars 2000 fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le Décret n°2008/099 du 07 mars 2008 revalorisant la rémunération mensuelle de base des personnels civils et militaires ;
Vu le Décret n°2008/100 du 07 mars 2008 revalorisant le taux d'indemnité de non logement servie aux personnels civils et militaires ;
Vu la Circulaire N°0001/MINFI du 10 janvier 2012 portant Instructions relatives à l'Exécution, au suivi et au Contrôle de l'exécution du Budget de l'Etat, des Etablissements Publics Administratifs, des Collectivités Territoriales Décentralisées et des autres Organismes subventionnés pour l'Exercice 2012;
Vu les résolutions du Conseil d'Administration de l'Université de Ngaoundéré, en sa session du 03 février 2012 ;
Vu les prévisions budgétaires de l'exercice 2012.

MINISTERE DES FINANCES DIRECTION GENERALE DU BUDGET 07 AOU 2012 CONTROLE FINANCIER Université de Ngaoundéré SECRETAIRE REGION ADAMAOUA CAMEROUN

DÉCIDE:

Article 1er : Monsieur **DESOBGO ZANGUE Steve Carly,** Matricule **652 117-M, Assistant 2E/530** depuis le 16/04/2010, est à compter du 16/04/2012, avancé au grade d'**Assistant 3E/605.**

Article 2 : L'Intéressé percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice **605** correspondant à son grade et pourra prétendre aux avantages accordés aux Enseignants du même grade.

Imputation : Budget de l'Etat, Exercice 2012 Chap.18, Art.102, Para. 000.

Article 3 : La présente décision sera enregistrée et publiée partout où besoin sera. /-

Fait à Ngaoundéré, le 14 AOUT 2012

LE RECTEUR

REPUBLIQUE DU CAMEROUN REPUBLIC OF CAMEROON Le Recteur UNIVERSITE DE NGAOUNDERE UNIVERSITY OF NGAOUNDERE

Pr. Amvam Zollo Paul Henri

AMPLIATIONS
- MINESUP
- MINFI/SOLDE/TRÉSOR
- MINFOPRA/DPE/SDPFSE/SAPE
- VR-EPDTIC/ VR-CIE
- SG/ DAAF/ DAAC/DEPE/SSPE
- CHEF D'ÉTABLISSEMENT/CF
- INTERRESSE

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
UNIVERSITE DE NGAOUNDERE
BP 454
RECTORAT

REPUBLIC OF CAMEROON
Peace - Work – Fatherland
UNIVERSITY OF NGAOUNDERE
P.O. Box 454
RECTOR'S OFFICE

DECISION N° 2013/232 /UN/R/VR-EPDTIC /SG/DAAC/DEPE/SSPE

Portant bonification d'échelon indiciaire de Monsieur DESOBGO ZANGUE Steve Carly, Assistant à l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE

Vu la Constitution;
Vu la loi n°2012/014 du 21 décembre 2012 portant loi de finances de la République du Cameroun pour l'exercice 2013;
Vu l'ordonnance n°62/OF/4 du 07 février 1962 portant Régime Financier du Cameroun et les textes modificatifs subséquents ;
Vu le décret n°2011/410 du 09 décembre 2011 portant formation du gouvernement ;
Vu le décret n°2011/408 09 décembre 2011 portant Organisation du Ministère de l'Enseignement Supérieur ;
Vu le décret n°93/026 du 19 janvier 1993 portant création d'Universités ;
Vu le décret n° 93/027 du 19 janvier 1993 portant dispositions communes aux Universités, modifié et complété par le décret n° 2005/342 du 10 septembre 2005 ;
Vu le décret n° 92/74 du 13 avril 1992 transformant les Centres Universitaires de Buéa et Ngaoundéré en Universités;
Vu le décret n°93/028 du 19 janvier 1993 portant Organisation administrative et académique de l'Université de Ngaoundéré ;
Vu le décret n° 2005/383 du 17 octobre 2005 fixant le régime financier applicable aux universités ;
Vu le décret n°2005/344 du 10 septembre 2005 portant nomination des Recteurs des Universités :
Vu le décret n°93 /035 du 19 janvier 1993 portant Statut Spécial des Personnels de l'Enseignement Supérieur, modifié et complété par le décret n°2000/048 du 15 mars 2000 ;
Vu le décret n°2000/049 du 15 mars 2000 fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le décret n°2008/099 du 07 mars 2008 revalorisant la rémunération mensuelle de base des personnels civils et militaires ;
Vu le décret n°2008/100 du 07 mars 2008 revalorisant le taux d'indemnité de non logement servie aux personnels civils et militaires ;
Vu la circulaire N°13/001/C/MINFI du 08 janvier 2013 portant Instructions relatives à l'Exécution, au suivi et au Contrôle de l'exécution du Budget de l'Etat, des Etablissements Publics Administratifs, des Collectivités Territoriales Décentralisées et des autres Organismes subventionnés pour l'Exercice 2013;
Vu les résolutions du Conseil d'Administration de l'Université de Ngaoundéré, en sa session du 19 mars 2013 ;
Vu les prévisions budgétaires de l'exercice 2013.

MINISTERE DES FINANCES
DIRECTION GENERALE DU BUDGET
25 JUN 2013
C.F.S. auprès de l'Université de Ngaoundéré
VISA BUDGETAIRE

DÉCIDE:

Article 1er : **Monsieur DESOBGO ZANGUE Steve Carly,** Matricule **652 117-M, Assistant 3E/605** depuis le 16/04/2012, est à compter du 14/09/2012, date de soutenance de sa Thèse, avancé au grade d'Assistant **2E/665.**

Article 2 : L'Intéressé percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice **665** correspondant à son grade et pourra prétendre aux avantages accordés aux Enseignants du même grade.

Imputation : Budget de l'Etat, Exercice 2013 Chap.18, Art.102, Para. 000.

Article 3 : La présente décision sera enregistrée et publiée partout où besoin sera./-

Fait à Ngaoundéré, le 01 JUIL 2013

LE RECTEUR

REPUBLIQUE DU CAMEROUN REPUBLIC OF CAMEROON
Le Recteur
UNIVERSITY OF NGAOUNDERE UNIVERSITE DE NGAOUNDERE

Pr. Amvam Zollo Paul Henri

AMPLIATIONS
- MINESUP
- MINFI/SOLDE/TRESOR
- MINFOPRA/DPE/SDPFSE/SAPE
- VR-EPDTIC/ VR-CIE
- SG/ DAAF/ DAAC/DEPE/SSPE
- CHEF D'ÉTABLISSEMENT/CF
- INTERRESSE

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

SECRÉTARIAT GÉNÉRAL

DIRECTION DU DÉVELOPPEMENT DE L'ENSEIGNEMENT SUPÉRIEUR

CELLULE DE L'EVALUATION ET DE LA PROMOTION DE L'ENSEIGNANT

CHARGÉ D'ETUDES ASSISTANT N°1

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTERE DES FINANCES
Direction Générale du Budget
05 DEC 2014
Contrôle Financier Central auprès du MINESUP
VISA BUDGETAIRE
14/0910

ARRETE N° _____ /MINESUP/SG/DDES/CEPE/CEA1

Portant promotion de Monsieur DESOBGO ZANGUE Stève Carly, au grade de Chargé de Cours.

MINESUP C.E. VISA B.E.J

LE MINISTRE DE L'ENSEIGNEMENT SUPERIEUR,

Vu la Constitution;
Vu la loi n°005 du 16 Avril 2001 portant orientation de l'Enseignement Supérieur;
Vu la loi n° 2007/006 du 26 décembre 2007 portant régime financier de l'Etat;
Vu la loi n° 2013/017 du 16 décembre 2013 portant loi des Finances de la République du Cameroun pour l'exercice 2014;
Vu le décret n° 41/77du 03 février 1977 fixant les attributions et organisant les Contrôles Financiers ;
Vu le décret n°2005/383 du 17 octobre 2005 fixant les règles financières applicables aux Universités;
Vu le décret n°93/035 du 19 janvier 1993 portant Statut Spécial des Personnels de l'Enseignement Supérieur, modifié et complété par le décret n° 2000/048 du 15 mars 2000;
Vu le décret n° 75/459 du 26 juin 1975 déterminant le régime de rémunération des personnels civils et militaires, modifié et complété par le décret n° 79/64 du 03 mars 1979;
Vu le décret n°2000/049 du 15 mars 2000 fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le décret n° 2008/099 du 07 mars 2008 portant revalorisation de la rémunération mensuelle de base des personnels civils et militaires;
Vu le décret n° 2008/100 du 07 mars 2008 portant revalorisation du taux de l'indemnité de non logement servie aux personnels civils et militaires;
Vu le décret n° 2011/408 du 09 décembre 2011 portant organisation du Gouvernement;
Vu le décret n° 2011/410 du 09 décembre 2011 portant formation du Gouvernement;
Vu le décret n° 2012/433 du 01 Octobre 2012 portant Organisation du Ministère de l'Enseignement Supérieur;
Vu l'arrêté n°253 du 31 octobre 1994 portant Organisation et Fonctionnement du Comité Consultatif des Institutions Universitaires;
Vu la Circulaire N° 0001/C/MINFI du 06 janvier 2014 portant instructions relatives à l'exécution des lois de finances, au suivi et au contrôle de l'exécution du Budget de l'Etat, des établissements publics administratifs, des collectivités territoriales décentralisées et des autres Organismes subventionnés pour l'exercice 2014;
Vu l'arrêté n° 12/0675/MINESUP/SP-CCIU du 17 décembre 2012 portant inscription sur la liste d'aptitude aux grades de Chargé de Cours, Maître de Conférences et Professeur dans les Institutions Universitaires (session du 27 au 30 novembre 2012);
Vu les résolutions du Conseil d'Administration de l'Université de Ngaoundéré en sa session du 19 mars 2013,

ARRETE :

Article 1er : Monsieur DESOBGO ZANGUE Stève Carly (Mle 652117-M), né le 02 janvier 1977 à Douala, Assistant d'Université de 2ème classe 2ème échelon (indice 665) depuis le 14 septembre 2012 est, à compter du 30 novembre 2012, date retenue par le Conseil d'Administration de l'Université, promu (e) au grade de Chargé de Cours de 2ème classe, 1er échelon (indice 715) de l'Enseignement Supérieur.

Article 2 : L'intéressé (e) percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice de son grade de Chargé de Cours et pourra prétendre à tous les avantages accordés aux enseignants du même grade.

Article 3 : La dépense totale résultant des dispositions de l'article 1er ci-dessus , est imputée sur le budget de l'Etat (Exercice 2014, Chapitre 18, Article 102 , Paragraphe 000)

Article 4 : Le présent arrêté sera enregistré et communiqué partout où besoin sera./-

Direction Générale du Budget
05 DEC 2014
Contrôle Financier Central auprès du MINESUP
VISA BUDGETAIRE

C.F.C.M.
VISA
B.E.J

Yaoundé, le 11 DEC 2014

AMPLIATIONS

- SG/PM
- MINESUP/CAB/IGS/IGA
- SG/MINESUP
- MINFI
- MINFOPRA
- Recteur/UN
- DDES/CEPE
- DAG/SIGIPES/SDPSP
- INTERESSE/DOSSIER
- CHRONO/ARCHIVES./-

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON

Jacques Fame Ndongo

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
UNIVERSITE DE NGAOUNDERE
BP 454
RECTORAT

REPUBLIC OF CAMEROON
Peace - Work – Fatherland
UNIVERSITY OF NGAOUNDERE
P.O. Box 454
RECTOR'S OFFICE

2015/184

DECISION N°---------- /UN/R/VR-EPDTIC /SG/DAAC/DEPE/SSPE
Portant avancement d'échelon indiciaire de Monsieur DESOBGO ZANGUE Stève Carly, Chargé de Cours l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE

MINISTERE DES FINANCES
DIRECTION DU BUDGET
12 MAI 2015
VISA BUDGETAIRE

Vu la Constitution;
Vu la loi n°2014/026 du 23 décembre 2014 portant loi de finances de la République du Cameroun pour l'exercice 2015;
Vu l'ordonnance n°62/OF/4 du 07 février 1962 portant Régime Financier du Cameroun et les textes modificatifs subséquents ;
Vu le décret n°2011/410 du 09 décembre 2011 portant formation du gouvernement ;
Vu le décret n°2011/408 09 décembre 2011 portant Organisation du Ministère de l'Enseignement Supérieur ;
Vu le décret n°93/026 du 19 janvier 1993 portant création d'Universités ;
Vu le décret n° 93/027 du 19 janvier 1993 portant dispositions communes aux Universités, modifié et complété par le décret n° 2005/342 du 10 septembre 2005 ;
Vu le décret n° 92/74 du 13 avril 1992 transformant les Centres Universitaires de Buéa et Ngaoundéré en Universités;
Vu le décret n°93/028 du 19 janvier 1993 portant Organisation administrative et académique de l'Université de Ngaoundéré ;
Vu le décret n° 2005/383 du 17 octobre 2005 fixant le régime financier applicable aux universités ;
Vu le décret n°2005/344 du 10 septembre 2005 portant nomination des Recteurs des Universités ;
Vu le décret n°93 /035 du 19 janvier 1993 portant Statut Spécial des Personnels de l'Enseignement Supérieur, modifié et complété par le décret n°2000/048 du 15 mars 2000 ;
Vu le décret n°2000/049 du 15 mars 2000 fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le décret n°2008/099 du 07 mars 2008 revalorisant la rémunération mensuelle de base des personnels civils et militaires ;
Vu le décret n°2008/100 du 07 mars 2008 revalorisant le taux d'indemnité de non logement servie aux personnels civils et militaires ;
Vu la circulaire N° 00000683/C/MINFI du 31 décembre 2014 Portant Instructions relatives à l'Exécution des lois de finances, au suivi et au Contrôle de l'exécution du Budget de l'Etat, des Etablissements Publics Administratifs, des Collectivités Territoriales Décentralisées et des autres Organismes Subventionnés, pour l'Exercice 2015;
Vu les résolutions du Conseil d'Administration de l'Université de Ngaoundéré, en sa session du 06 mars 2015 ;
Vu les prévisions budgétaires de l'exercice 2015.

DÉCIDE:

Article 1er : **Monsieur DESOBGO ZANGUE Stève Carly,** Matricule **652 117-M, Chargé de Cours 2C/1E/715** depuis le 30/11/2012, est à compter du 16/04/2014, avancé au grade de **Chargé de Cours 2C/2E/785.**

Article 2 : L'Intéressé percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice **785** correspondant à son grade et pourra prétendre aux avantages accordés aux Enseignants du même grade.

Imputation : Budget de l'Etat, Exercice 2014 Chap.18, Art.102, Para. 000.

Article 3 : La présente décision sera enregistrée et publiée partout où besoin sera./-

Fait à Ngaoundéré, le 12 MAI 2015

LE RECTEUR

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON
Le Recteur
UNIVERSITY OF NGAOUNDERE
UNIVERSITE DE NGAOUNDERE

Amvam Zollo Paul René

AMPLIATIONS
- MINESUP
- MINFI/SOLDE/TRÉSOR
- MINFOPRA/DPE/SDPFSE/SAPE
- VR-EPDTIC/ VR-CIE
- SG/ DAAF/ DAAC/DEPE/SSPE
- CHEF D'ÉTABLISSEMENT/CF
- INTERRESSÉ

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
UNIVERSITE DE NGAOUNDERE
BP 454
RECTORAT

REPUBLIC OF CAMEROON
Peace - Work – Fatherland
UNIVERSITY OF NGAOUNDERE
P.O. Box 454
RECTOR'S OFFICE

Ministère des Finances
15 [illegible] 2017
CONTRÔLE SECRÉTAIRE

2017/210

DECISION N°---------- /UN/R/VR-EPDTIC /SG/DAAC/DEPE/SSPE
Portant avancement d'échelon indiciaire de Monsieur DESOBGO ZANGUE Stève Carly,
Chargé de Cours à l'Institut Universitaire de Technologie de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE,

Vu la Constitution;
Vu La loi n° 99/016 du 22 décembre 1999, portant statut général des établissements publics et des entreprises du secteur public et parapublic;
Vu la loi n° 005 du 16 avril 2005 portant orientation de l'enseignement supérieur;
Vu la loi n° 2007/006 du 26 décembre 2007, portant régime financier de l'Etat ;
Vu la loi n° 2016/018 du 14 décembre 2016 portant loi de finances de la République du Cameroun pour l'exercice 2017;
Vu le décret n° 77/41 du 03 février 1977 fixant les attributions et l'organisation des contrôles financiers ;
Vu le décret n° 92/74 du 13 avril 1992, transformant les Centres Universitaires de Buéa et Ngaoundéré en Universités;
Vu le décret n° 93/028 du 19 janvier 1993, portant Organisation administrative et académique de l'Université de Ngaoundéré ;
Vu Le décret n° 2000/048 du 15 mars 2000 modifiant et complétant certaines dispositions du décret n° 93 /035 du 19 janvier 1993, portant Statut Spécial des Personnels de l'Enseignement Supérieur;
Vu le décret n° 2000/049 du 15 mars 2000, fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le décret n° 2003/250 du 16 septembre 2003 portant nomination du Recteur de l'Université de Ngaoundéré;
Vu le décret n° 2005/342 du 10 septembre 2005 modifiant et complétant le décret n° 93/027 du 19 janvier 1993, portant dispositions communes aux Universités;
Vu le décret n° 2005/383 du 17 octobre 2005, fixant le régime financier applicable aux universités ;
Vu le décret n° 2008/099 du 07 mars 2008, revalorisant la rémunération mensuelle de base des personnels civils et militaires ;
Vu le décret n° 2008/100 du 07 mars 2008, revalorisant le taux d'indemnité de non logement servie aux personnels civils et militaires ;
Vu la décision n° 000721 MINFI du 11 novembre 2016, portant nomination du contrôleur financier à l'Université de Ngaoundéré ;
Vu la circulaire n° 001/C/MINFI du 28 décembre 2016 Portant Instructions relatives à l'Exécution des lois de finances, au suivi et au Contrôle de l'Exécution du Budget de l'Etat, des Etablissements Publics Administratifs, des Collectivités Territoriales Décentralisées et des autres Organismes Subventionnés, pour l'Exercice 2017;
Vu la résolution n° 05/CA/12/08/2016 du Conseil d'Administration de l'Université de Ngaoundéré, en sa session du 12 août 2016, entérinant les résolutions prises lors de la 35è session du conseil d'Université (bonifications et avancements d'échelon indiciaires des enseignants) ;
Vu La résolution n° 11/CA/08/02/2017, portant approbation du budget de l'Université de Ngaoundéré, pour l'exercice 2017.

DÉCIDE:

Article 1er : **Monsieur DESOBGO ZANGUE Stève Carly,** né le 02 janvier 1977 à Dschang, Matricule 652 117-M, Chargé de Cours 2ème classe, 2ème échelon (indice 785) depuis le 16 avril 2014, est à compter du 16avril 2016, avancé au grade de Chargé de Cours, 2ème classe, 3ème échelon (indice 870).

Article 2 : L'intéressé percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice **870** correspondant à son grade et pourra prétendre aux avantages accordés aux Enseignants du même grade.

Imputation : Budget de l'Etat, Exercice 2017 Chap.18, Art.102, Para. 000.

Article 3 : La présente décision sera enregistrée et publiée partout où besoin sera./-

Fait à Ngaoundéré, le 19 JUIN 2017

LE RECTEUR

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON
Le Recteur
UNIVERSITY OF NGAOUNDERE
UNIVERSITE DE NGAOUNDERE

N. Amwam Zollo Paul Henri

AMPLIATIONS
- MINESUP ;
- MINFI/SOLDE/TRÉSOR ;
- MINFOPRA/DPE/SDPFSE/SAPE ;
- RECTEUR;
- VR-EPDTIC;
- SG/ DAAF/ DAAC/DEPE/SSPE;
- CHEF D'ÉTABLISSEMENT ;
- CF/UN ;
- AC/UN ;
- INTERRESSÉ;
- ARCHIVES/CHRONO.

UNIVERSITÉ DE NGAOUNDÉRÉ

RECTORAT

SÉCRÉTARIAT GÉNÉRAL

DIRECTION DES AFFAIRES ACADÉMIQUES
ET DE LA COOPÉRATION

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

2019/163

DECISION N° _____ /UN/R/VR-EPDTIC/SG/DAAC/DEPE/SSPE

Portant avancement d'échelon de Monsieur DESOBGO ZANGUE Steve Carly, Chargé de Cours.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE,

Vu la Constitution;
Vu la loi n°005 du 16 avril 2001 portant orientation de l'enseignement supérieur;
Vu la loi n°2007/006 du 26 décembre 2007, portant régime financier de l'Etat;
Vu la loi n°2017/010 du 12 juillet 2017, portant statut général des établissements publics;
Vu la loi n°2017/021 du 20 décembre 2017 portant loi de Finances de la République du Cameroun pour l'exercice 2018;
Vu le décret n°77/41 du 03 février 1977, fixant les attributions et l'organisation des contrôles financiers;
Vu le décret n°92/74 du 13 avril 1992 transformant les Centres Universitaires de Buéa et Ngaoundéré en Universités;
Vu le décret n°93/028 du 29 janvier 1993 portant Organisation Administrative et Académique de l'Université de Ngaoundéré;
Vu le décret n°2000/048 du 15 mars 2000, modifiant et complétant certaines dispositions du décret 93/035 du 19 janvier 1993 portant statut spécial des personnels de l'enseignement supérieur;
Vu le décret n°2000/049 du 15 mars 2000, fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le décret n°2005/342 du 10 septembre 2005, modifiant et complétant certaines le décret n°93/027 du 19 janvier 1993 portant dispositions communes aux universitaires;
Vu le décret n°2005/383 du 17 octobre 2005 fixant le régime financier applicable aux Universités;
Vu le décret n°2008/099 du 07 mars 2008, revalorisant la rémunération mensuelle de base des personnels civils et militaires;
Vu le décret n° 2017/318 du 27 juin 2017 portant nomination d'un "Vice-Chancellor" et des Recteurs dans certaines Universités d'Etat;
Vu la décision n° 000721/MINFI du 11 novembre 2016 portant nomination du contrôleur financier à l'Université de Ngaoundéré;
Vu la Circulaire n° 001/C/MINFI du 02 janvier 2018 portant Instructions relatives à l'Exécution des lois de Finances, au Suivi et au Contrôle de l'Exécution du Budget de l'Etat, des Etablissements Publics Administratifs, des Collectivités Territoriales Décentralisées et des autres Organismes Subventionnés, pour l'Exercice 2018;
Vu la résolution n°05/CA/10/07/2018, entérinant les résolutions et recommandations de la 38ème session du Conseil d'Université de l'Université de Ngaoundéré;
Vu la résolution n°06/CA/10/01/2018, portant approbation du budget de l'Université de Ngaoundéré, pour l'exercice 2018,

DECIDE :

Article 1er : Monsieur DESOBGO ZANGUE Steve Carly (Mle 652117-M), Chargé de Cours de 2ème classe 3ème échelon (indice 870), depuis le 16 avril 2016, est à compter du 16 avril 2018, avancé(e) au grade de Chargé de Cours, 4ème échelon de la 2ème classe (indice 940).

Article 2 : L'intéressé (e) percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice 940 correspondant à son grade et pourra prétendre aux avantages accordées aux enseignants de même grade.

Article 3 : La présente décision sera enregistrée et communiquée partout où besoin sera./-

AMPLIATIONS

- - MINESUP/MINFOPRA/MINFI
  - CAB/R
    - VREPTIC/VRRC/VRI
      - SG/DAAC/DAAF
        - Etablissements
        - DEPE/SSPE
        - CFS/AC
          - Interessé(e)
          - Chrono

Ngaoundéré, le 06 MARS 2019

Le Recteur

P.r. Ubale Chinje Melo

III.5) Acte de promotion au grade de Chargé de Cours

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

SECRÉTARIAT GÉNÉRAL

DIRECTION DU DÉVELOPPEMENT DE L'ENSEIGNEMENT SUPÉRIEUR

CELLULE DE L'EVALUATION ET DE LA PROMOTION DE L'ENSEIGNANT

CHARGÉ D'ETUDES ASSISTANT N°1

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTERE DES FINANCES
Direction Générale du Budget
05 DEC 2014
Contrôle Financier Central auprès du MINESUP
VISA BUDGETAIRE
14/0910

ARRETE N° _____ /MINESUP/SG/DDES/CEPE/CEA1

Portant promotion de Monsieur DESOBGO ZANGUE Stève Carly, au grade de Chargé de Cours.

MINESUP CE VISA B.E.J

LE MINISTRE DE L'ENSEIGNEMENT SUPERIEUR,

Vu la Constitution;
Vu la loi n°005 du 16 Avril 2001 portant orientation de l'Enseignement Supérieur;
Vu la loi n° 2007/006 du 26 décembre 2007 portant régime financier de l'Etat;
Vu la loi n° 2013/017 du 16 décembre 2013 portant loi des Finances de la République du Cameroun pour l'exercice 2014;
Vu le décret n° 41/77du 03 février 1977 fixant les attributions et organisant les Contrôles Financiers ;
Vu le décret n°2005/383 du 17 octobre 2005 fixant les règles financières applicables aux Universités;
Vu le décret n°93/035 du 19 janvier 1993 portant Statut Spécial des Personnels de l'Enseignement Supérieur, modifié et complété par le décret n° 2000/048 du 15 mars 2000;
Vu le décret n° 75/459 du 26 juin 1975 déterminant le régime de rémunération des personnels civils et militaires, modifié et complété par le décret n° 79/64 du 03 mars 1979;
Vu le décret n°2000/049 du 15 mars 2000 fixant l'échelonnement indiciaire du corps de l'Enseignement Supérieur;
Vu le décret n° 2008/099 du 07 mars 2008 portant revalorisation de la rémunération mensuelle de base des personnels civils et militaires;
Vu le décret n° 2008/100 du 07 mars 2008 portant revalorisation du taux de l'indemnité de non logement servie aux personnels civils et militaires;
Vu le décret n° 2011/408 du 09 décembre 2011 portant organisation du Gouvernement;
Vu le décret n° 2011/410 du 09 décembre 2011 portant formation du Gouvernement;
Vu le décret n° 2012/433 du 01 Octobre 2012 portant Organisation du Ministère de l'Enseignement Supérieur;
Vu l'arrêté n°253 du 31 octobre 1994 portant Organisation et Fonctionnement du Comité Consultatif des Institutions Universitaires;
Vu la Circulaire N° 0001/C/MINFI du 06 janvier 2014 portant instructions relatives à l'exécution des lois de finances, au suivi et au contrôle de l'exécution du Budget de l'Etat, des établissements publics administratifs, des collectivités territoriales décentralisées et des autres Organismes subventionnés pour l'exercice 2014;
Vu l'arrêté n° 12/0675/MINESUP/SP-CCIU du 17 décembre 2012 portant inscription sur la liste d'aptitude aux grades de Chargé de Cours, Maître de Conférences et Professeur dans les Institutions Universitaires (session du 27 au 30 novembre 2012);
Vu les résolutions du Conseil d'Administration de l'Université de Ngaoundéré en sa session du 19 mars 2013,

ARRETE :

Article 1er : Monsieur DESOBGO ZANGUE Stève Carly (Mle 652117-M), né le 02 janvier 1977 à Douala, Assistant d'Université de 2ème classe 2ème échelon (indice 665) depuis le 14 septembre 2012 est, à compter du 30 novembre 2012, date retenue par le Conseil d'Administration de l'Université, promu (e) au grade de Chargé de Cours de 2ème classe, 1er échelon (indice 715) de l'Enseignement Supérieur.

Article 2 : L'intéressé (e) percevra à ce titre une rémunération mensuelle calculée sur la base de l'indice de son grade de Chargé de Cours et pourra prétendre à tous les avantages accordés aux enseignants du même grade.

Article 3 : La dépense totale résultant des dispositions de l'article 1er ci-dessus , est imputée sur le budget de l'Etat (Exercice 2014, Chapitre 18, Article 102 , Paragraphe 000)

Article 4 : Le présent arrêté sera enregistré et communiqué partout où besoin sera./-

Direction Générale du Budget
05 DEC 2014
Contrôle Financier Central auprès du MINESUP
VISA BUDGETAIRE

C.F.C. VISA B.E.J

AMPLIATIONS

- SG/PM
- MINESUP/CAB/IGS/IGA
- SG/MINESUP
- MINFI
- MINFOPRA
- Recteur/UN
- DDES/CEPE
- DAG/SIGIPES/SDPSP
- INTERESSE/DOSSIER
- CHRONO/ARCHIVES./-

Yaoundé, le 11 DEC 2014

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON

Jacques Fame Ndongo

III.6) Attestation de présence effective

REPUBLIQUE DU CAMEROUN
****
Paix – Travail - Patrie
****
UNIVERSITE DE NGAOUNDERE
****

REPUBLIC OF CAMEROON
****
Peace - Work – Fatherland
****
THE UNIVERSITY OF NGAOUNDERE
****

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE
THE UNIVERSITY INSTITUTE OF TECHNOLOGY
NGAOUNDERE
B.P. 455 NGAOUNDERE - Tél. 00 (237) 677 11 22 20 / 242 25 40 23
Fax : 00 (237) 242 25 40 01
Site Web: www.iut.univ-ndere.cm

Le Directeur

N° =12=2019 UN/IUT/D/am

Ngaoundéré, le 16 SEP 2019

ATTESTATION DE PRESENCE EFFECTIVE

****

Le Directeur de l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré soussigné ***Pr. MOHAMMADOU Bouba Adji,***

Atteste que **Dr. DESOBGO ZANGUE Steve Carly**, Chargé de Cours, Matricule **652 117-M**, exerce la profession d'enseignant chercheur dans ledit Institut depuis le 16 Avril 2008, date de sa prise de service. Il est effectivement présent à son poste.

En foi de quoi la présente attestation est établie pour servir et valoir ce que de droit.

Ampliation
- Chrono/archives

Le Directeur

Pr. Mohammadou Bouba Adji

IV) ACTIVITES ACADEMIQUES

IV.1) Contribution à l'enseignement, à la recherche, au développement de la science et de la culture ainsi qu'à la gouvernance de l'Université, de l'enseignement supérieur et de la nation

IV.1.a) Contribution à l'enseignement

Dès mon recrutement à l'Institut Universitaire de Technologie de l'Université de Ngaoundéré avec prise de service le 16 avril 2008, la technologie alimentaire et les sciences de l'ingénieur ont constitué les principaux axes de mes enseignements, les autres aspects liés à la formation des étudiants (les enseignements scientifiques de base et autres spécialités entre autres) étant dédiés aux autres collègues. Cette activité continue à m'occuper à plein temps. J'ai bénéficié de l'expérience de plusieurs équipes enseignantes aussi bien au niveau national (Chargés de Cours, Maîtres de Conférences et Professeurs à l'IUT et à l'ENSAI) qu'au niveau international (Université de Johannesburg, Doornfontein et Auckland Park Campus). Ceci m'a permis de veiller à la bonne adéquation de mes enseignements avec la maitrise des technologies alimentaires (plus spécifiquement tout ce qui tourne autour des boissons). La conséquence étant une facilitation à l'intégration des étudiants de l'IUT de Ngaoundéré au concours de l'ENSAI.

Bien que le déficit en enseignant et mon background d'Ingénieur IAA (Industries Agricoles et Alimentaires) a permis que l'on me confie d'autres enseignements, mon activité pédagogique cadre parfaitement avec mon axe principal de recherche sur les technologies des boissons. J'ai souvent eu un rôle majeur dans la mise en place des enseignements et de son environnement pédagogique en technologie alimentaire (poste pour lequel j'ai été recruté). Il faut signaler qu'au fur et à mesure et suivant le recrutement des jeunes collègues, j'ai du cédé comme tous les autres des enseignements à ces derniers. Malgré tout, ma charge horaire annuelle tourne aux alentours de 400 heures à l'IUT. Cette compétence m'a valu d'être pris comme enseignant missionnaire à l'ENSAI où j'ai plus de 100 heures de cours.

IUT de Ngaoundéré

Au niveau 1 en GBIO (génie biologique),

J'interviens dans la formation des étudiants au niveau des éléments constitutifs enzymologie et Dessin Technique et Schéma des Procédés (Cours, TD, TP), comme l'atteste la liste signée par le Chef de département.

- *Enzymologie (CM : 30h ; TP : 16h)*: Le lien entre ce cours et ma recherche est que, l'enzyme est un maillon essentiel dans la transformation des denrées alimentaires (fruits, céréales etc…) en boissons.

L'enseignement doit amener l'étudiant à examiner quelques données fondamentales concernant la catalyse et les catalyseurs. L'application immédiate de ces connaissances aux systèmes enzymatiques.

Concernant le contenu de l'enseignement, on explore la structure et nomenclature des enzymes, la cinétique enzymatique et mesure de l'activité enzymatique, la notion de site actif, la cinétique classique à un substrat ainsi que celle à plusieurs substrats, les notions d'activateurs, d'inhibiteurs, d'allostérie et la sémiologie enzymatique.

- *Dessin Technique et Schéma des Procédés (CM : 15h ; TP : 32h)* : Toute présentation scientifique nécessite un schéma du procédé clair et conforme pour que l'approche méthodologique soit comprise

L'enseignement a pour objectif d'amener les étudiants à la maitrise des schémas de procédés et de leurs représentations dans les canons mondiaux de l'ingénierie.

Dans le contenu, il est présenté les symboles des équipements, des tuyauteries, des raccords pompes et tous autres éléments permettant une lecture compréhensible d'un procédé. En plus de la symbolique, il y a les différentes présentations des procédés (block diagram, process flow diagram etc…)

Au niveau 2 en GBIO (DUT),

A ce niveau, je suis intervenu (parce qu'ayant cédé certains) et j'interviens au niveau des éléments constitutifs suivants en Cours TD et/ou TP : Fruits et légumes, TP de technologies alimentaires intégrées, Malterie/Brasserie, Céréales et amidonnerie, hygiène industrielle, sucrerie et jus de fruits et enfin projet d'intégration.

- *Fruits et légumes (CM : 15h ; TP : 16h)* : Ces éléments font partie des matières premières que j'utilise et transforme durant mes recherches. J'ai aidé à établir la plaquette de cet enseignement comme suit :

Comme objectif, il s'agit de faire connaître la filière fruits et légumes. Un accent spécial est mis sur la transformation des fruits et légumes.

Le contenu de l'enseignement explore la transformation et conservation des aliments à base des fruits (jus de fruits et conserves des fruits) ainsi que, la transformation et conservation des Légumes (conserves de légumes, séchage, blanchiment etc…).

- *Céréales et amidonnerie (CM : 15h ; TP : 16h)* : Il s'agit d'une filière qui me permet dans le cadre des recherches d'obtenir des boissons alcoolisées et non alcoolisées.

L'objectif dans cet enseignement est de permettre aux étudiants de maîtriser la filière céréales et amidonneries. Un accent spécial sera mis sur l'importance du rôle que jouent les céréales et les amidons dans la ration alimentaire.

Dans le contenu de l'enseignement, on élucide les transformations des amidons. Céréales, tubercules et racines amidonnées comme sources principales de l'amidon. Extraction de l'amidon/farine et transformation (sirop, le pain et autres produits).

- *Malterie/Brasserie (CM : 15h ; TP : 16h)* : C'est la filière majeure de mon axe de recherche.

Il est question de permettre aux étudiants de Maîtriser la filière de production du malt et de la bière.

Pour ce qui est du contenu, on explore le maltage de céréales (sorgho inclus) dont les étapes du procédé sont le trempage, la germination et le touraillage. Après l'obtention du malt, les étapes de fabrication de la bière sont exposées aux étudiants : le concassage de grains, le brassage, la filtration de la maïsche, le houblon, l'houblonnage et autres procédés d'amérisation du moût utilisant les plantes locales amères et la cuisson du moût, refroidissement du moût, aération du moût inoculation et la fermentation du moût, filtration de la bière, carbonatation, pasteurisation (en vrac et en tunnel) et soutirage.

- *Sucrerie (CM : 15h ; TP : 16h)* :

Le but de l'enseignement est de donner aux étudiants des connaissances en production sucrière, les plantes sucrières notamment la betterave sucrière et la canne à sucre. Maitriser le processus de production du sucre depuis la matière première.

Comme contenu : Connaissance de la canne à sucre et de la betterave (origine, variétés, description, composants et teneurs) ; Process en sucrerie de canne (préparation, extraction, sulfi-chaulage, évaporation, cristallisation, malaxage-turbinage, séchage, emballage) ; Le raffinage du sucre (transport du sucre brut, lavage, clarification, décoloration, cristallisation, malaxage, turbinage, séchage)

- *Hygiène industrielle (CM : 45h ; TP : 16h)* : Ceci fait partie des cours qui m'avaient été attribués à cause de mon background d'ingénieur IAA et suite au déficit d'enseignant. J'ai aidé à définir la plaquette de cours comme suit :

Les objectifs de ce cours sont de doter le futur titulaire de DUT d'outils suffisants lui permettant d'identifier et évaluer le risque, de mettre en œuvre les méthodes de prévention appropriées et de contrôler la réalité et l'efficacité des dispositifs mis en place.

Le contenu s'articule comme suit : Environnement de travail : facteurs physiques et physiologiques ; effets physiologiques des ambiances de travail, réglementation et normes ; risques au poste de travail ; moyens de prévention et de protection ; notions d'hygiène et de nettoyage industriel. Introduction à l'évaluation et à la maîtrise des risques, Analyse des accidents : danger, risque, acteurs de la prévention, indicateurs relatifs aux accidents du travail (taux de fréquence, taux de gravité) et aux maladies professionnelles, risques liés à une situation de travail, arbre des causes, document technique unifié (DTU). Prévention et prévision face aux risques technologiques et environnementaux : Risque chimique, risque radiologique, risque biologique, Sécurité des installations et des équipements ; installations : équipements sous pression, équipement de travail (machines dangereuses et appareils de manutention et de levage), équipements de protection individuels. Sécurité Incendie : modes de propagation ; phases d'un incendie, classifications internationales des matériaux, modes de détection et d'extinction incendie

Au niveau 3 en GBIO (Licence de Technologie),

Dans ce niveau 3 qui, est le niveau terminal de formation l'IUT de Ngaoundéré, je suis intervenu et j'interviens dans les éléments constitutifs suivants en Cours, TD et TP : vins et spiritueux, malterie/brasserie (en approfondi), biostatistiques, ingénierie des équipements, enzymes industrielles et applications.

- *Malterie/Brasserie (CM : 30h ; TP : 16h)*

La différence entre ce qui est fait ici et ce qui est fait au niveau 2 est que, j'insiste ici sur la biochimie du maltage, du brassage de l'ébullition du moût, de la fermentation et de la maturation. J'insiste également sur les différentes altérations possibles de la bière, la qualité de l'eau de brassage et son influence sur la qualité de la bière.

- *Vins et spiritueux (CM : 30h ; TP : 16h)* : Cet enseignement est important dans mon axe de recherche dans la mesure où il entre en droite ligne dans la valorisation des fruits et céréale dans le domaine des boissons alcoolisées.

L'objectif de ce cours de maîtriser les filières vins de fruits et fruits tropicaux et production des spiritueux à base céréales tropicales

Comme contenu on a : la vinification (extraction et fermentation des jus de fruits tropicaux afin d'obtenir les vins) ; la fabrication des spiritueux à base des céréales tropicales (brassage, fermentation, distillation, maturation).

- *Enzymes industrielles et applications (CM : 30h ; TP : 16h)* : Cet enseignement est en droite ligne avec mes recherches dans la mesure où l'on présente l'intérêt des enzymes et leurs applications sur le plan industriel. On exploite les sources végétales d'enzymes dont l'extraction et la purification aurait une application dans l'industrie des boissons.

Il est question d'amener les étudiants à s'accoutumer avec les grandes classes des enzymes industrielles et de bien assimiler leurs applications dans les entreprises agro-alimentaires et biotechnologiques et assimilées.

Le contenu de l'enseignement est comme suit : L'ingénierie de la réaction biocatalytique (techniques d'extraction et de purification), les enzymes de la transformation agroalimentaire, application des enzymes libres et immobilisées en industries pharmaceutiques et chimiques, application analytique des enzymes comme sondes en analyses cliniques, de procédés et environnementales.

- *Biostatistiques (CM : 30h)* : Ce cours est le socle de mon approche de la recherche dans la mesure où il permet par le biais de certains outils de réaliser des modélisations qui permettent de faire des prévisions et de comprendre voire expliciter les phénomènes biochimiques qui se passent au cours d'un procédé de transformation.

Objectifs : Savoir déterminer les tests à utiliser en fonction des observations réalisées. Savoir utiliser des logiciels pour mettre en œuvre les tests statistiques sur les données. Savoir utiliser les outils de la planification d'expérience par le biais de la méthodologie des surfaces de réponses.

Contenu : Tests statistiques. Tests paramétriques. Tests non paramétriques, signification et comparaison. Logiciels d'analyse de données : SPSS, StatBox ou Statistica. Logiciels des plans d'expérience/modélisation : Minitab, Systat, Statgraphics, Mathcad. Logiciels de représentation graphique : Sigmaplot, OriginLab, TableCurve 2D.

- *Ingénierie des équipements (CM : 30h ; TP : 16h)* : la production qualitative et quantitative en agro-industrie est étroitement liée à la compréhension du fonctionnement des équipements, ainsi qu'à l'optimisation (modélisation des phénomènes biologiques et biochimiques) fonctionnelle de ces derniers. Cet enseignement est donc en étroite ligne avec le

domaine de recherche car l'équipement est un élément essentiel de la production. La plaquette de cours présentée à ce niveau est comme suit :

Comme objectif, il est question de familiariser les étudiants aux principes de fonctionnement des machines utilisées dans les procédés et des conséquences de leur utilisation.

Comme contenu, on expose : la description des machines utilisées dans le transport des solides et des fluides (convoyeurs, élévateurs, pompes), dans la transformation des produits : de façon mécanique (broyage, tamisage), thermique (distillation, évaporation), dans la production de l'énergie (chaudières) et dans les risques liés à l'utilisation de ces matériaux (corrosion). Enfin, la compréhension des phénomènes (biologiques et biochimiques) qui s'y passent par le biais des modèles théoriques.

- *Projet professionnel et personnel*

Ce module va dans le sens de permettre à l'étudiant d'effectuer une réalisation personnelle pouvant déboucher sur un projet de fin d'études ou un projet de vie. Il vise à encourager toutes les activités créatives et porteuses d'une découverte sur le plan scientifique, technique ou technologique.

ENSAI de Ngaoundéré

Les cours que je dispense à l'ENSAI, sont au niveau Ingénieur, Master 1 et Master 2. Ces cours sont les suivants comme l'atteste la note signée du Chef de département Génie des Procédés et Ingénierie (section IV.2.b) : Boissons (IAA 2), Projet professionnel et personnel (IAA 2), Opérations unitaires de transfert (Master 1), Planification d'expérience (sous forme de séminaire en Master 2 et pour les étudiants en Doctorat Ph.D en Génie des Procédés), Avancées en génie de maltage et procédés de boissons (Master 2 GP). Le cours de boissons en IAA 2 *(CM : 22,5 h)* concerne uniquement la filière brasserie où, j'introduis uniquement les notions de brassage, fermentation, garde et embouteillage. De la même façon, le projet professionnel concerne les projets étudiants innovants et ayant un contenu scientifique et technologique. Pour ce qui est des opérations unitaires de transfert *(CM : 45 h)*, cet enseignement vise à préparer l'étudiant aux calculs des opérations unitaires de transfert. Comme contenu, on étudie les opérations d'évaporation, extraction, distillation, cristallisation et séchage. Pour ce qui est des Avancées en génie de maltage et procédés de boissons *(CM : 60 h)*, nous explorons les filières vin, bière, spiritueux et jus de fruits.

Dr DESOBGO ZANGUE Steve Carly

IV.1.b) Contribution à la recherche, au développement de la science et de la culture

La réalisation des travaux de recherche suppose l'appartenance à une équipe de recherche et ou à des laboratoires. De ce fait, j'appartiens et je suis en collaboration avec les chercheurs du Laboratoire de Génie et Technologie Alimentaire (LAGETA) de l'ENSAI de l'Université de Ngaoundéré, du Laboratoire de BioProcédés (LBP) de l'IUT de l'Université de Ngaoundéré, du le laboratoire de Biophysique, Biochimie Alimentaire et Nutrition (LABBAN). A l'étranger, je suis en collaboration et chercheur associé du Laboratoire de Technologie Alimentaire et Biotechnologie et, du Laboratoire de Chimie Appliquée tous, de l'Université de Johannesburg (Afrique du Sud) ou j'ai eu le privilège d'effectuer deux années de postdoctorat.

La collaboration avec tous ces laboratoires et équipes de recherche a conduit à un point focal qui est basé sur les sciences de l'ingénieur appliquées au développement agroindustriel.

A l'IUT, j'encadre les étudiants en cycle DUT (Bacc+2, plus de 50 d'étudiants ayant déjà soutenus) et en Licence de technologie (Bacc+3, plus de 40 d'étudiants ayant déjà soutenus). A l'ENSAI par contre, j'encadre les étudiants en cycle Ingénieur (24 étudiants déjà ayant soutenus), Master II (5 Masters soutenus) et Doctorat/PhD (5 étudiants en thèse de Doctorat PhD dont 3 sont en phase terminale et pourraient soutenir en 2020/2021).

Contexte et problématique

Depuis 2008, mon activité scientifique s'est intéressée à la valorisation des matières premières locales dans le domaine des boissons. Ainsi, je me suis attaché à comprendre et modéliser l'effet des facteurs du process sur les caractéristiques physicochimiques des boissons obtenues. Durant ma thèse de doctorat Ph.D, j'ai étudié aussi bien expérimentalement que par le biais des simulations théoriques les phénomènes de brassage utilisant les cultivars de sorgho camerounais (*Madjeru, Safrari* et *S.35*). L'outil exploité était la planification d'expérience utilisant la méthodologie de surface de réponses (MSR). Cet outil s'est avéré très efficace dans la compréhension et l'explicitation de l'impact des facteurs sur les caractéristiques physicochimiques des moûts au cours du brassage du sorgho ceci, par le biais d'une

modélisation mathématique et statistique. C'est donc ainsi que j'ai décidé de poursuivre avec cette approche méthodologique (MSR) qui présente un avantage de permettre un minimum d'expérience en laboratoire et en même temps un niveau de fiabilité très élevé. La MSR a également contribué à faire des prévisions sur le comportement de ces sorghos durant le brassage.

C'est ainsi que par la suite, en 2012, je me décide à avoir deux approches concernant les boissons. Une approche nationale qui consiste à valoriser les matières pouvant entrer dans la fabrication des boissons. L'approche internationale quant à elle est née des bourses postdoctorales que j'ai obtenues au courant de la même année. Cette approche a consisté cette fois ci à répondre aux soucis posés par les brasseries multinationales. Ces soucis étant liés à la qualité de leurs boissons. Une autre approche a consisté à contribuer à la publication des livres toujours dans le domaine des boissons.

Pour ce qui est de l'approche nationale, on est parti du constat selon lequel, le Cameroun qui est un pays en voie de développement, compte aussi sur l'industrie des boissons pour son décollage. En effet, de part la diversité de ressources agroalimentaires qu'il possède, ce pays a un potentiel certain pour l'amorce réel de sa croissance. Malheureusement, d'une part l'industrie locale des boissons est phagocytée par les multinationales évoluant dans le même domaine. Ceci entrainant une sous valorisation des boissons où de sources locales pouvant contribuer de façon significative à l'amélioration de la qualité de ces boissons. D'autres part, la non maitrise des procédés et aussi, la non compréhension des phénomènes biochimiques gouvernant ces processus de transformation conduisent à des boissons de qualité douteuse. L'une des véritables limites dans le procédé de fabrication des boissons est sans équivoque de travailler sous des conditions en dessous de l'optimalité. Cela entraine des désagréments de plusieurs ordres à savoir : des pertes de matière, de temps et d'énergie. Les facteurs influençant le procédé n'étant pas à leurs optimaux, la qualité de la boisson n'est pas par ricochet celle qui atteindrait des sommets en termes de standard. Je me suis donc intéressé pour apporter ma contribution à la recherche nationale, aux boissons alcoolisées et non alcoolisées, à base de céréales (moût et bière) et à base de fruits (jus et vins). Ainsi que les intrants de l'industrie des boissons (enzymes et autres).

L'approche internationale a consisté toujours dans le domaine des boissons (filière brasserie), à contribuer en l'élimination du dimethyl sulfide (DMS) en modélisant plusieurs approches technologiques d'ébullition du moût. Par la suite, la participation à la rédaction des

livres où, ma contribution a consisté à énoncer les approches théoriques de modélisation des phénomènes (fermentations entre autres) se déroulant au cours de l'utilisation des équipements utilisés pour la fabrication des boissons.

Ainsi, quelque soit l'approche (national et international), le fil conducteur de mes travaux de recherche est aligné sur le thème central qui est : **Modélisation mathématique et compréhension des phénomènes biochimiques pour l'amélioration de la qualité des boissons**

Ce thème central s'articule en 3 sous-thèmes notamment :

1) Investigation des intrants d'intérêt pour la fabrication des boissons

2) Optimisation des variables de process de fabrication des boissons

3) Optimisation de l'élimination des arômes indésirables des moûts de brasserie

Sur le plan national

1) Investigation des intrants d'intérêt pour la fabrication des boissons

Nso, E.J., Aseaku, J.N., Desobgo, Z.S.C., Ngulewu, C., Aleambong, D.K. & Taira, A., 2013. Comparison of the mashing and brewing potentials of crude extracts of Abrus precatorius, Burnatia enneandra and Cadaba farinosa. Journal of Brewing and Distilling. 4 (2), 46-50

L'utilisation d'enzymes techniques a grandement facilité et amélioré le traitement des aliments au cours des dernières décennies. Le brassage avec de grandes quantités d'adjuvants ou avec des malts d'orge mal modifiés utilisant des enzymes exogènes dans l'industrie brassicole améliore les rendements en extraits. On sait que le sorgho malté présente de faibles taux d'enzymes brassicoles importantes, telles que l'α-amylase et la β-amylase, mais qu'il peut être brassé facilement avec des enzymes commerciales adéquates. Ces enzymes et d'autres sont extraites de micro-organismes et de plantes et, commercialisées en tant qu'enzymes techniques. Dans le nord du Cameroun, les bouillies d'amidon à base de sorgho, de maïs et de riz sont traditionnellement sucrées à l'aide d'extraits bruts de plantes *Abrus precatorius*, *Burnatia enneandra* et *Cadaba farinosa*. Ceci pourrait traduire la présence d'enzymes amylolytiques. Dans le but de valoriser ces plantes, il a été question d'évaluer le potentiel brassicole et le brassage avec les extraits bruts de ces plantes en utilisant du sorgho *Safrari* non malté comme matière première.

Résultats : Les activités d'alpha-amylase des extraits ont fluctué entre 18 et 122 U / g, tandis que le pouvoir diastasique et les activités de β-carboxypeptidase se situaient entre 83 et 123 WK, et 16 et 63 mg FAN / min / µL, respectivement. Un temps de brassage plus long (180 min) était nécessaire pour obtenir des rendements plus élevés en extraits. L'extrait obtenu était de 18,7 °P pour le *Safrari* malté, de 14,6 °P pour l'orge maltée et de 9,5, 13,5 et 11,4 °P après brassage de *Safrari* non malté avec les extraits de *Abrus precatorius*, *Burnatia enneandra* et *Cadaba farinosa*, respectivement. Des niveaux similaires de sucres réducteurs compris entre 60 et 65 g/L ont été obtenus lors du brassage avec *A. precatorius*, *B. enneandra* et des extraits bruts, mais environ 50 g/L ont été obtenus pour *C. farinosa*. La teneur en acides aminés libres a fluctué entre 56 et 72 mg/L pour *C. farinosa* et *B. enneandra*, respectivement, mais était aussi bas que 17 mg/L pour *A. precatorius*. La fermentabilité était faible pour les moûts obtenus après brassage de *Safrari* en utilisant les extraits des trois plantes, en comparaison avec les moûts de *Safrari* et d'orge malté.

Taira, A., Desobgo, Z.S.C.*, Nso, E.J., 2015. Partial purification of α-amylase from Burnatia enneandra Micheli. Part 1: Extraction using statistical model. International Journal of Research in Biotechnology and Biochemistry. 5 (1), 13-19

Burnatia enneandra Micheli est une plante herbacée de la région soudano-sahélienne appartenant à la famille des *Alismataceae*. Au Cameroun, cette plante pousse principalement dans les zones marécageuses du nord et de l'extrême nord. Les noms communs de cette plante sont connus chez les Tupuri comme "tigna'ri" et chez les Peuls comme "Anjakooje". Ces tubercules de *Burnatia enneandra* Micheli séchés et broyés sont utilisés pour "adoucir" le lisier pendant le pâturage en raison de l'éloignement des zones de pâturage. Enfin, le latex blanc est couramment utilisé pour traiter les blessures et certains parasites intestinaux des enfants. Avec l'utilisation traditionnelle de ce tubercule, des travaux scientifiques ont été réalisés. Ces travaux ont montré que ces tubercules avaient une très faible teneur en sucre simple, ce qui suppose que le tubercule de *Burnatia enneandra* n'est pas sucré et que la bouillie sucrée ne serait pas due à sa haute teneur simple en sucre mais plutôt aux substances à potentiel amylolytique. Ceci suggère la présence dans le tubercule d'enzymes amylolytiques. D'autres travaux préliminaires liés à la zone de brassage ont porté, sur la caractérisation des moûts obtenus par saccharification de la maïsche de sorgho par des extraits de *Burnatia enneandra* Micheli. Ces études ont montré que les extraits enzymatiques obtenus à partir de ces tubercules étaient capables d'hydrolyser l'amidon de sorgho. L'objectif général est d'extraire l'α-amylase de l'extrait brut de *Burnatia*

enneandra Micheli. Plus précisément, il s'agira de modéliser le processus d'extraction de l'αamylase du tubercule et d'optimiser les conditions d'extraction.

Résultats : L'impact du pH, de la vitesse d'agitation et du temps de centrifugation a été testé sur l'activité spécifique de l'α-amylase des tubercules de *Burnatia enneandra* du Cameroun. La méthodologie de surface de réponse utilisant le plan expérimental de Doehlert comme instrument a été utilisée pour établir, valider et optimiser le modèle mathématique permettant de comprendre l'influence des facteurs d'extraction (pH, vitesse d'agitation et temps de centrifugation) singuliers ou en interactions. Il a été montré que le pH comme facteur singulier et, dans son premier degré (X_1) a fourni 12% de l'activité spécifique de l'α-amylase bien que la vitesse d'agitation (X_2) et le temps de centrifugation (X_3) fournissaient 3% et 10% respectivement. On a également observé que l'augmentation du pH réduisait l'activité spécifique de l'α-amylase tandis qu'une augmentation du temps de centrifugation augmentait l'activité spécifique de l'α-amylase. L'effet combiné (interaction) du pH/temps de centrifugation et de la vitesse d'agitation/temps de centrifugation était significatif avec une contribution de 25% et 9% respectivement. Pour l'optimisation, un triplet théorique (pH, 4,02 ; vitesse d'agitation, 147,3 tr/min et temps de centrifugation, 10 min) a été obtenu et a donné 49,33 ± 1,9 U/mg comme activité spécifique maximale de l'amylase de *Burnatia enneandra*.

Nguemogne A. C., Desobgo Z. S.C.*, Nso E. J. 2017. Comparative study of limit dextrinase potential of three sorghum cultivars (Safrari, Madjeru and S.35). Journal of the American Society of Brewing Chemists. 75(3), 255-261

Le sorgho est une céréale africaine native, très bien adaptée aux conditions semi-arides et soudano-sahéliennes de l'Afrique. Comme le riz et l'orge, le sorgho appartient à la famille des *Gramineae*. La disponibilité du sorgho et sa teneur élevée en amidon et en protéines devraient encourager l'utilisation locale. Son moût nourrissant lui permet d'être l'un des meilleurs choix en tant que matière première dans le processus de brassage. Bien que le sorgho ait été utilisé pendant des siècles pour brasser la bière traditionnelle (opaque) en Afrique, ces dernières années, le brassage de la bière de sorgho a été développé dans les brasseries. Ces types de bières sont différents des bières européennes parce qu'ils contiennent de grandes quantités de matériaux qui ne sont pas respectivement solubilisés et fermentés pendant le brassage et la fermentation. Plusieurs travaux ont été publiés sur le sorgho, le malt de sorgho et la technologie de brassage du sorgho. Ces publications se sont concentrées sur des problèmes remarquables de brassage propres aux caractéristiques des grains de sorgho et du malt. Parmi

les problèmes généralement mis en évidence, il y a l'insuffisance d'enzymes, en particulier celles qui hydrolysent l'amidon. Des essais sur l'amélioration des propriétés de brassage du sorgho ont été écrits pour les procédés de maltage et de brassage dans le but de permettre le développement d'enzymes hydrolysant l'amidon telles que l'α-amylase, la β-amylase, et la limite dextrinase. Le rôle principal joué par la limite dextrinase sur le clivage de l'amidon α1,6-glycosidique de l'amidon a été reconnu depuis des années. De nombreuses études ont été menées pour isoler et purifier cette enzyme des céréales et pour caractériser son action sur l'amylopectine et ses produits de dégradation. Cela a été principalement fait sur l'orge et d'autres céréales comme le maïs, le riz et le sorgho. Les résultats de l'étude menée sur les propriétés de trois cultivars de sorgho utilisés pour la production de boisson *bili-bili* dans le nord du Cameroun ont révélé un fort potentiel enzymatique du malt de sorgho local. Le but de ce travail était donc d'extraire la limite dextrinase du malt de trois cultivars de sorgho (*Madjeru*, *Safrari* et *S.35*) produits au Cameroun et de comparer son activité spécifique par modélisation et optimisation.

Résultats : La limite dextrinase extraite de trois malts de cultivars de sorgho (*Safrari, S.35* et *Madjeru*) utilisés pour la production de *bili-bili*, une bière traditionnelle dans le nord du Cameroun, a été comparée en utilisant la dextrine comme substrat. Un plan d'expérience de Doehlert à quatre facteurs a été utilisé pour construire un modèle afin d'optimiser l'impact des facteurs (température, pH, concentration du tampon et temps d'incubation) impliqués dans l'extraction de la limite dextrinase libre du sorgho. La méthodologie de surface de réponse a révélé que l'action de ces facteurs était différente pour chaque cultivar de sorgho, avec un comportement plus proche entre *Safrari* et *S.35*. *Madjeru* s'est révélé être complètement différent. L'optimisation des actions concertées des facteurs sur l'activité spécifique de la dextrinase limite a donné les combinaisons suivantes : pour *Safrari*, 43 ° C, pH 4, 135 mM et 300 min, avec une activité spécifique maximale de 3.10 U/µg; pour *Madjeru*, 35 ° C, pH 5,77, 50 mM et 60 min, avec une activité spécifique maximale de 1,51 U/ug; et pour *S.35*, 50 ° C, pH 4, 191 mM et 205 min, avec une activité spécifique maximale de 3,05 U/ug.

Fali, M. H., Desobgo, Z.S.C.* & Nso, E.J., 2019. Sorghum coffee–lactose stout production and its physico-chemical characterization. Beverages. 5 (20), 1-21

Le sorgho est la quatrième culture de l'Afrique en termes de tonnage après le maïs, le riz et le blé. Dans certaines régions d'Afrique et d'Inde, le grain de sorgho a été utilisé traditionnellement pour la production de porridge, de boissons alcoolisées et pour la fabrication

de pain. Plus de 300 millions de personnes dans les pays en développement dépendent du sorgho comme source d'énergie. C'est le cas au Cameroun où le sorgho est la plus grande source d'énergie dans la partie nord du pays avec une production annuelle importante de 1 102 000 tonnes. Compte tenu de la concurrence des entreprises multinationales, le sorgho semble être la meilleure alternative à la production de bière blonde. L'orge est devenue la matière première de base du brassage pour les pays producteurs d'orge non producteurs d'orge tels que le Cameroun. Le processus de brassage de bière blonde avec des céréales autres que l'orge est en train de devenir une pratique courante, en particulier dans les pays non producteurs d'orge, en raison de divers inconvénients liés à l'orge. L'orge est une céréale tempérée et le climat africain ne convient pas à sa culture. Cela pose un problème majeur. Le grain d'orge ou le malt d'orge doivent être importés, d'où la flambée des prix due à la vigueur de la demande mondiale et aux coûts d'expédition élevés, qui se traduit par des taux de change précieux et une augmentation du prix de la bière hors de portée de la plupart des Africains. L'importation désavantage également les agriculteurs locaux car elle leur refuse des marchés potentiels. Cela se produit au Cameroun et cela oblige les industries à repenser leurs investissements pour remplacer le maltage dans d'autres céréales. Le sorgho peut être utilisé efficacement au Cameroun pour la production de bière. La composition chimique du sorgho le rassure en tant que céréale alternative à l'orge dans la production de bière de type lager. On croyait auparavant que la bière ne pourrait pas être produite sans orge. Cependant, il est bien connu que les céréales comme le sorgho pourraient constituer un substrat alternatif pour la fabrication de la bière traditionnelle. Les travaux de recherche sur le sorgho progressent rapidement et les bières de sorgho commercialement acceptables, aussi bien en lager qu'en ale. Le Nigéria, l'Afrique du Sud, l'Ouganda, la Tanzanie, la Zambie et le Zimbabwe brassent avec succès la lager et la bière de sorgho commerciales. L'utilisation de matières cultivées localement comme matériau de brassage est rentable et peut potentiellement stimuler l'économie régionale du Cameroun. Cela profiterait aux producteurs de sorgho à revenu garanti et réduirait donc le chômage. De plus, l'utilisation d'une culture indigène réduirait les coûts logistiques pour les fabricants, ce qui réduirait les prix de vente de la bière. Les fabricants seraient en mesure de négocier avec le gouvernement des taxes moins élevées sur les bières à base de sorgho, ce qui contribuerait à une autre réduction importante des coûts présentant des avantages particuliers pour le consommateur. Cela aiderait à créer de la bière blonde abordable pour les consommateurs pour qui ce type de bière est inabordable. Ces facteurs entraîneraient donc une croissance accrue de l'industrie brassicole. La bière de sorgho ne contient pas de gluten et peut être utilisée par les

cœliaques. Afin de valoriser le sorgho, nous avons imaginé produire un stout café-lactose-sorgho. Le choix du café et du lactose n'est pas anodin. Les consommateurs de bière ont manifesté leur intérêt pour une telle bière. Une plante amère (*Vernonia amygdalina*) a été utilisée comme substitut du houblon.

Résultats : Le sorgho (*Safrari*) a été valorisé en stouts de sorgho aromatisé au café-lactose en utilisant *Vernonia amygdalina* comme ingrédient amérisant. Ces grains de sorgho et le malt pâle de sorgho qui en a résulté ont été testés pour déterminer s'ils étaient acceptables dans le secteur brassicole. Les résultats obtenus sont une capacité germinative de 99,29 ± 0,58%, une énergie germinative de 98,56 ± 1,79%, un poids de mille grains égal à 48,08 ± 0,02 g pour les grains et un pouvoir diastatique de 187,44 ± 7,89 WK pour le malt de sorgho. Les moûts et les bières produits ont été caractérisés et ont été jugés appropriés. De plus, la teneur en alcool des bières fortes obtenues était comprise entre 8,8% et 9,4%. L'évaluation sensorielle a été effectuée sur des bières avec 30 panélistes et la meilleure combinaison était celle qui utilisait 50% de lactose (250 g) et 50% de café (250 g) dans 5 L de moût chauffé pendant l'ébullition du moût.

2) Optimisation des variables de process de fabrication des boissons

Desobgo, Z.S.C.* & Nso, E.J., 2013. Optimization of the impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the turbidity of Madjeru sorghum cultivar wort. International Journal of Applied Research and Studies. 2 (1), 1-10.

La disponibilité du sorgho en Afrique génère un développement économique vital, il est essentiel que la recherche appliquée se concentre sur la capacité à faire de cette céréale l'outil de la sécurité alimentaire en Afrique. Sa faible quantité en enzymes due à leur développement insuffisant au cours du maltage impose souvent l'utilisation des enzymes brassicoles commerciales en complément pour obtenir les meilleures caractéristiques des moûts. En effet, des différences ont été signalées sur la composition et la qualité brassicole des cultivars de sorgho malté. Ceci pourrait toutefois être attribué à la variété de sorgho utilisée pour le maltage. Ce constat est également observé après la filtration maïsche liée à la qualité du malt de sorgho. Le rôle des enzymes industrielles dans la facilitation des procédés de brasserie est basé sur le fait qu'elles ont une grande capacité catalytique, même lorsqu'elles sont utilisées en très petite quantité (traces). Les modèles observés dans la littérature sont complexes et difficiles à mettre en œuvre, et ils concernent presque exclusivement l'orge et non le sorgho. La bière de sorgho étant connue pour être opaque, il est nécessaire d’essayer de la rendre plus

claire en agissant sur les enzymes industrielles à ajouter, dans l'optique de rapprocher la qualité du bili-bili (bière traditionnelle de mil ou sorgho) de celle des bières conventionnelles.

Résultats : L'optimisation des actions concertées des trois enzymes sur la turbidité des moûts du cultivar *Madjeru* non malté a donné une combinaison de 0 U; 298,25 BGU et 0 mg pour Hitempase 2XL, Bioglucanase TX et Brewers Protease respectivement. Cela a donné une turbidité minimale de 0,00 NTU. La meme étude faite sur le cultivar Madjeru malté a donné plutôt une combinaison enzymatique de 1387.50 U; 0 BGU et 32,23 mg pour Hitempase 2XL, Bioglucanase TX et Brewers Protease respectivement, donnant une turbidité minimale de 5,27 NTU. Ceci démontre que l'on pourrait bien avoir des bières de sorgho aussi claire que les bières conventionnelles d'orge malté.

Makebe, C. W., Desobgo, Z. S. C.*, Nso, E. J. 2017. Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains. Beverages. 3(2), 1-18.

Il y a un abus généralisé des bananes, en particulier celles qui ne répondent pas aux normes de qualité pour l'exportation. En raison de la façon dont le fruit banane/plantain est organiquement dynamique et complète la transpiration, la maturation et d'autres exercices biochimiques même après la récolte, les pertes sont élevées. Ce phénomène s'est déplacé pour briser la nature des aliments à feuilles, les rendant invendables. Le gaspillage des fruits de banane plantain en raison d'une mauvaise manutention ou d'une sur-maturation après récolte reste un problème notable aujourd'hui. Le changement de plantain trop mûr en d'autres éléments importants a été le principal moteur de notre questionnement. On a choisi de se concentrer sur la production de vin à partir de plantains sur-matures. Ceci s'est fait en utilisant la méthodologie de la surface de réponse et en appliquant des enzymes industrielles pour extraire quantitativement le jus de plantain, en déterminant les paramètres pour un rendement optimal et en analysant certains paramètres physico-chimiques avant et après la fermentation.

Résultats: Les conditions optimales pour l'extraction du jus de la pulpe de plantain étaient: température: 25 ° C; concentration enzymatique: 5%; taux de dilution: 1,10; et temps d'extraction: 24 h. La mise en œuvre de ces conditions a permis d'obtenir un rendement en moût supérieur à 70% et Brix compris entre 10 °Bx et 15 °Bx. Les polyphénols et les flavonoïdes totaux étaient de 7,70 ± 0,99 mg GAE / 100 g et 0,4 ± 0,01 µg rutine / g pour le moût et 17,01 ± 0,34 mg GAE / 100 g et 4 ± 0,12 µg rutin / g et 7,70 ± 0,99 pour le vin, a indiqué la présence d'une activité antioxydante dans le vin produit. D'autre part, les solides solubles totaux se

situaient entre 16,06 ± 0,58 °Bx et 1,5 ± 0,10 ° Bx, ce qui permettait d'obtenir un vin à faible teneur en alcool.

Adebo, O. A., Njobeh, P. B., Mulaba-Bafubiandi, A. F., Adebiyi, J. A., Desobgo, Z. S. C., Kayitesi, E., 2018. Optimization of fermentation conditions for ting production using response surface methodology. Journal Food Processing and Preservation. 42: e13381. https://doi.org/10.1111/jfpp.13381

Ting, est un produit de sorgho fermenté couramment consommé au Botswana, en Afrique du Sud et dans d'autres pays voisins. Il est connu pour son goût aigre et sa saveur unique et il est utilisé comme aliment de sevrage (boisson) pour les nourrissons et consommé pendant les cérémonies. Différentes conditions de fermentation pour la préparation de ting ont été rapportées dans la littérature, avec des variations dans leur processus de fermentation, qui n'ont pas de conditions standardisées ou optimisées disponibles. Une procédure d'optimisation largement acceptée est la méthodologie de surface de réponse (RSM), qui est une collection de méthodes statistiques et mathématiques pour obtenir les conditions optimales de facteurs pour des réponses souhaitables. Le plan de surface de réponse de Doehlert est facilement appliqué pour optimiser des variables plus efficacement car elles ont la capacité d'explorer l'ensemble d'un domaine expérimental (Ferreira, dos Santos, Quintella, Neto, et Bosque-Sendra, 2004).

Résultats : L'optimisation numérique multi-réponse des paramètres a suggéré des conditions de fermentation optimales à 34 °C pendant 24 heures. La caractérisation physicochimique d'échantillons utilisant la microscopie électronique à balayage (MEB), la diffraction des rayons X (DRX) et la spectroscopie infrarouge à transformée de Fourier (IRTF) ont montré de légères modifications de la morphologie, de la similitude des diagrammes de diffraction et de la présence de différents groupes fonctionnels. Les résultats de cette étude pourraient fournir des informations pour la commercialisation d'un Ting de qualité.

Ninga, K.A., Sengupta, S., Jain, A., Desobgo, Z.S.C., Nso, E.J., De, S., 2018. Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice. Journal of Food Engineering. 221, 158-166.

Le jus de goyave contient des colloïdes qui sont principalement des polysaccharides (pectine, cellulose, hémicellulose et lignine), des protéines et des tanins. Ces particules peuvent se déposer pendant le stockage, conduisant à l'hétérogénéité du jus. La pectine rend difficile la clarification du jus, car elle est généralement associée à des polymères végétaux et des débris

cellulaires ayant une structure moléculaire analogue à une fibre, créant ainsi un encrassement pendant la filtration. La présence de pectine rend le jus de goyave visqueux et trouble. Les polysaccharides pectiques sont des molécules polygalacturonate, dans lequel les chaînes d'acides 1e4-d-galacturonique sont liés avec les branches de résidus L-rhamnopyranosyle, et des chaînes latérales neutres de L-arabinose, D-galactose et le D-xylose. Ce sont les principaux composants de la paroi cellulaire et de la lamelle moyenne des tissus végétaux. La pectine subit des changements structuraux au cours du développement et de la maturation des fruits, contribuant ainsi de manière significative au ramollissement de la texture des fruits charnus en train de mûrir. La teneur en pectine de la goyave mûrie se situe entre 0,58% et 0,66%. La viscosité et la turbidité du jus de goyave peuvent être diminuées par la dépectinisation enzymatique, la dégradation de la pectine et des polysaccharides. La pectinase hydrolyse la pectine et provoque la floculation des complexes de pectine/protéine, de sorte que le jus résultant a peu de pectine et une viscosité beaucoup plus faible, facilitant le processus de filtration subséquent. L'hydrolyse enzymatique des substances pectiques dépend de plusieurs facteurs de fonctionnement tels que la concentration enzymatique, le temps d'incubation et la température. Dans la plupart des cas, le pH n'est pas pris en compte car l'hydrolyse est effectuée au pH naturel du jus de fruit. Il y a eu une étude explorant la cinétique de l'hydrolyse enzymatique de la pectine pure en général. En outre, des études existent sur la cinétique de la dépectinisation du jus extrait de divers fruits, comme la pomme, la groseille, le cassis, la betterave sucrière et la passion. Mais, dans toutes ces études, la pectine a été isolée de leurs sources avant d'étudier la cinétique de l'hydrolyse. La cinétique d'hydrolyse de ces pectines extraites ainsi que de la pectine pure a montré un comportement de type Michaelis-Menten. Dans un cadre industriel pratique, l'extraction de la pectine du jus de fruit et son hydrolyse deviennent inutilement complexes et coûteuses. Ainsi, dans un scénario de vie réelle, la dépectinisation doit être entreprise sur du jus de fruit réel. Cependant, dans le cas de la dépectinisation du jus de goyave réel, l'hydrolyse de la pectine devient compliquée en présence d'autres polysaccharides, comme la cellulose, l'hémicellulose, la lignine, etc. Ces composés peuvent accélérer ou inhiber la réaction d'hydrolyse. Ces interactions complexes n'ont pas été prises en compte dans les études. Sur la base de ces interactions complexes, l'hydrolyse des molécules de pectine peut ou non présenter un comportement hyperbolique, tel que décrit par la cinétique de Michaelis-Menten. Les chercheurs ont étudié dépectinisation dans les jus de fruits de la vie réelle, mais ils ont analysé le système en utilisant la méthodologie de surface de réponse pour obtenir les conditions optimales de fonctionnement. Comme mentionné, les

analyses basées sur la surface de réponse n'ont pas provoqué le mécanisme de réaction sousjacent, ni établi la cinétique de la réaction, qui est obligatoire pour concevoir un réacteur avec succès. Cela sera tenté dans la présente étude. Au meilleur de la connaissance des auteurs, les rapports sur le mécanisme de réaction de dépectinisation du jus de goyave réel sont rares dans la littérature. Par conséquent, l'objectif de l'étude est d'étudier la cinétique de la désintégration des substances pectinacées lors du traitement enzymatique du jus de goyave ainsi que le mécanisme possible, et d'interpréter les conditions opératoires optimales de la dépectinisation.

Résultats : L'objectif des travaux est d'étudier l'hydrolyse de la matière pectinacée dans le jus de goyave et de modéliser la cinétique de dépectinisation à l'aide de la pectinase commerciale d'*Aspergillus niger*. La procédure implique un traitement enzymatique du jus de goyave à 45 °C avec une concentration en enzyme (% m/m) de 0,033, 0,055, 0,078 et 0,1. Le degré d'hydrolyse de la matière pectinacée et le taux de réaction enzymatique sont déterminés. Les résultats montrent une augmentation du degré d'hydrolyse avec le temps pour chaque concentration enzymatique. La cinétique de dépectinisation révèle un comportement allostérique et est modélisée à l'aide de l'équation de Hill. L'analyse d'image de l'échantillon par microscopie électronique à balayage à émission de champ montre un changement dans la régularité et l'homogénéité de l'échantillon, indiquant une dégradation du réseau de pectine.

Sur le plan international

3) Optimisation de l'élimination des arômes indésirables des moûts de brasserie

Desobgo, Z.S.C.*, Stafford, R.A. & Metcalfe, D.J.A., 2015. Dimethyl sulphide stripping behaviour during wort boiling using Response Surface Methodology. Journal of the American Society of Brewing Chemists. 73 (1), 84-89

Le DMS (Dimethyl sulfide) est un composé soufré reconnu comme étant une source de flaveur désagréable. Il est volatil et résulte de la conversion d'un précurseur (S-méthyl méthionine, SMM) du malt pendant l'ébullition et, dans une moindre mesure, pendant la fermentation de la bière. Il pourrait contribuer de plusieurs façons, positivement ou négativement, aux flaveurs de nombreux produits alimentaires et boissons fermentées. Il est connu comme un composant important de la flaveur de la bière, et plusieurs études ont été faites afin d'identifier, de quantifier et de comprendre sa formation et son élimination du moût et de la bière. De nombreuses techniques de détection ont été développées à cette fin. Pour une

meilleure compréhension du DMS, des modèles cinétiques ont été développés afin de prédire sa formation via SMM et son élimination lors de l'ébullition et de la fermentation du moût.

L'approche de modélisation dans la littérature était principalement empirique et axée sur le temps d'ébullition. Le but de cette étude était d'étudier le comportement affiché durant l'élimination du DMS en utilisant une approche de méthodologie de surface de réponse (RSM). La puissance de chauffe et le temps d'ébullition ont été utilisés comme variables. Deux substituts de moût (eau/DMS et eau/sucre/DMS) ont été considérés pour étudier l'impact du principal composant de moût (sucre) sur l'élimination du DMS.

Résultats : L'analyse a montré que la puissance de chauffe et le temps d'ébullition avaient un impact significatif sur le DMS résiduel lors de l'ébullition du moût, avec des contributions de 12.4 et 11.9% pour l'eau/DMS et l'eau/ sucre/DMS respectivement et 45.6 et 48.8 % pour l'eau/DMS et l'eau/sucre/DMS, respectivement. L'interaction entre les deux variables a également eu un impact significatif sur le DMS résiduel pour le substitut de moût eau/DMS, avec une contribution de 2,8%. Le coefficient de volatilisation (k_2) obtenu à chaque apport de puissance n'était pas statistiquement significatif pour les deux substituts de moût mais affichait une croissance exponentielle de 0.0202 à 0.0436 min^{-1} et de 0.0143 à 0.0360 min^{-1} pour l'eau/DMS et eau/sucre/DMS substituts de moût, respectivement. Pour atteindre un objectif énergétique de 50 ppb en minimisant l'énergie consommée en fin d'ébullition, les conditions suivantes ont été retenues : pour l'eau/DMS, ébullition à 500 W pendant 123 min (3,66 MJ); pour l'eau/sucre/DMS, bouillant à 500 W pendant 174 min (5,19 MJ).

Desobgo, Z.S.C.*, Stafford, R.A. & Metcalfe, D.J.A., 2017. The derivation and application of a simultaneous volatile formation and stripping kinetics equation for wort boiling. Journal of the American Society of Brewing Chemists. 75(1), 11-21

Le dimethyl sulfide (DMS) figure parmi les arômes les plus critiques dans le processus de brassage. La volatilisation de ce composé instable est une procédure exceptionnellement complexe, et il est fait de deux réactions synchrones, qui sont le changement de Sméthylméthionine (SMM) en DMS et son élimination. Cette circonstance difficile créé de nombreuses sortes de techniques aussi bien au niveau de la forme des tanks que des équations d'ébullition afin de gérer l'élimination de DMS. Pour cette raison, le principal modèle connu pour l'extraction de DMS est celui de Mitani, qui est de forme non linéaire. De tels modèles non linéaires sont fréquemment linéarisés pour faciliter leur mise en œuvre. Dans ce travail, la dérivation détaillée d'un modèle de formation et d'élimination simultanée du DMS est décrite,

et le modèle non linéaire final est comparé avec le modèle déclaré par Mitani. Pour faciliter la mise en œuvre, la linéarisation du modèle non linéaire a été réalisée en utilisant une expansion de la série MacLaurin-Taylor.

Résultats : Le papier a montré la dérivation d'une équation pour représenter la formation et l'élimination simultanées du dimethyl sulfide (DMS) pendant l'ébullition de moût. Il a également démontré des techniques de linéarisation pour l'équation qui en résulte, ce qui devrait faciliter sa mise en œuvre. La formation et l'élimination du DMS ont été modélisées par des équations de vitesse de premier ordre avec les constantes de vitesse k_1 et k_2 représentant respectivement les constantes de vitesse pour la formation de DMS et l'élimination de DMS. Les processus simultanés de formation et d'élimination du DMS ont été représentés en utilisant un bilan de masse différentiel instantané. La solution résultante s'est révélée similaire à une équation énoncée précédemment par Mitani et al. La linéarisation du modèle dérivé de formation et d'élimination de DMS simultané a été faite en utilisant une série de MacLaurin provenant de l'expansion de la série de Taylor.

Desobgo, Z.S.C.*, Stafford, R.A. & Metcalfe, D.J.A., 2017. Modeling of dimethyl sulfide stripping behavior when applying delayed onset of boiling during wort boiling. Journal of the American Society of Brewing Chemists. 75(3), 269-275

La fabrication de la bière, qui est un processus complexe, génère une certaine saveur au cours de plusieurs traitements tels que le maltage, le brassage, l'ébullition et la fermentation. Au cours du processus de maltage, un produit chimique appelé S-méthyl méthionine (SMM), dont le niveau augmente pendant la germination, est responsable de la formation de diméthylsulfure (DMS). Une partie de SMM est transformée en DMS pendant la trempe et l'ébullition et, parce que le DMS lui-même est très volatil, il est éliminé pendant l'ébullition, et les composants de soufre provenant de ce processus sont principalement des sources de flaveurs DMS. La forte volatilité du DMS et la concentration plus faible obtenue après ébullition permettent l'utilisation de techniques multiples telles que la chromatographie pour estimer sa concentration résiduelle. Des travaux antérieurs ont démontré l'importance de l'ébullition du moût sur l'élimination du DMS, et des modèles cinétiques ont été présentés. Mais dans tous ces articles, le processus d'ébullition était continu, à l'exception du système de traitement Shoko, qui utilisait un temps de maintien chauffé. En fait, pendant l'ébullition normale du moût, un lot de moût est chauffé en continu pour atteindre le point d'ébullition, et le processus d'ébullition est réalisé à un taux d'évaporation cible pendant la durée de l'ébullition. La vitesse d'évaporation

de la cible est destinée à produire toutes les fonctions classiques d'ébullition du moût telles que la formation de matières volatiles, l'élimination des volatils, la stérilisation, l'isomérisation du houblon, la formation de la rupture à chaud et ainsi de suite. Les taux d'évaporation typiques ont graduellement été réduits au cours des années de 10-15% par heure (% volumétrique par heure) dans les années 1980 à actuellement 4-7% par heure. Le principal moteur de cette réduction a été d'économiser de l'énergie et, par conséquent, de réduire les coûts de production et l'empreinte écologique du processus de brassage. Dans cette étude, le retard d'ébullition (DOOBOIL) a été mis en œuvre et l'impact de l'alimentation en énergie et du temps d'ébullition en utilisant la méthodologie de surface de réponse a été étudié sur les coefficients d'élimination DMS et de réaction cinétique.

Résultats : La méthodologie de surface de réponse, utilisant le plan composite centré comme outil de modélisation, a été utilisée pour étudier l'impact de deux paramètres (alimentation et temps d'ébullition) et leur effet sur l'élimination du diméthylsulfure (DMS) lors de l'ébullition du moût. Il a été observé que les deux paramètres avaient un impact significatif sur l'élimination du DMS avec une contribution de 21% pour l'alimentation électrique et une contribution de 58% pour le temps d'ébullition (P = 0,000 pour les deux). Avec la conversion de la S-méthylméthionine en DMS suivant la pseudo réaction cinétique du premier ordre, k_1 a été calculé et on a obtenu 0,0054 min^{-1}, et les valeurs de k_2 étaient comprises entre 0,0151 et 0,407 min^{-1}Le temps passé à atteindre la cible de DMS résiduel de 30, 50 et 100 ppb était respectivement de 141-377, 94-295 et 60-197 min, et l'énergie utilisée pour atteindre la même cible était de 11,31-12,69, 8,46- 8,85 et 5,40-5,91 MJ, respectivement.

Desobgo, Z.S.C.*, Stafford, R.A., Ndinteh D.T., Metcalfe, D.J.A., & Meijboom R., 2017. The impact of gaseous carbon dioxide and boiling power on dimethyl sulphide stripping behavior during wort boiling. Journal of the American Society of Brewing Chemists. 75(4), 324-332.

La réduction des coûts de production d'énergie est une préoccupation majeure pour les industries alimentaires en général et pour les brasseries en particulier. L'une des principales cibles est la réduction du temps de traitement des étapes énergivores. Cette réduction du temps de traitement ne doit pas avoir d'impact négatif sur la qualité du produit, ce qui permet de développer de bonnes caractéristiques qualitatives et physicochimiques du produit. Dans le processus de brassage, l'ébullition du moût est l'une des étapes les plus gourmandes en énergie, et c'est l'une des dernières étapes de traitement dans lesquelles les caractéristiques physicochimiques du moût sont fixées avant la fermentation. Pendant l'étape d'ébullition, les

caractéristiques et le profil des moûts sont développées, comprenant la formation de nombreux arômes indésirables. Parmi la multitude de composants de mauvaise saveur, le diméthyl sulfide (DMS) est une préoccupation majeure. Le DMS se développe à partir de S-méthyl méthionine (SMM) et augmente au cours du processus de maltage. La conversion thermique du SMM en DMS, l'oxydation du DMS en diméthylsulfoxyde (DMSO) et le fait que le DMS soit volatil permettent à l'étape d'ébullition du moût d'être potentiellement une méthode d'élimination de cet arôme. De nombreux protocoles chromatographiques efficaces rapportés dans la littérature permettent l'évaluation des concentrations résiduelles de DMS après maltage, ébullition du moût et fermentation. Les procédures d'ébullition du moût dans la salle de brassage (et la recherche sur celui-ci) consistent en l'exécution d'une ébullition continue et en appliquant un modèle théorique pour estimer certains paramètres liés à l'élimination du DMS ou, plus récemment, un modèle polynomial utilisant la méthodologie de surface de réponse; De plus, une équation dérivée et l'application d'une cinétique de formation et d'élimination de ces volatils simultanés pour l'ébullition du moût ont été développées. Certaines études ont rapporté utiliser le débit d'alimentation en CO_2 pour accélérer l'élimination du DMS, mais aucun d'entre eux n'a étudié l'impact simultané du débit d'alimentation en CO_2 et de la variation de puissance d'ébullition, comme facteurs de réduction d'énergie, sur le comportement DMS.

Résultats : L'impact du débit d'alimentation en dioxyde de carbone (CO_2) sur l'élimination du diméthyl sulfide (DMS) pendant l'ébullition du moût a été étudié en appliquant une prise de 1 h entre la fin du préchauffage et le début de l'ébullition. Cela a été fait pendant l'ébullition du moût en faisant varier la puissance d'ébullition (de 500 à 1500 W), afin de réduire la consommation d'énergie pour atteindre la cible d'une concentration de DMS de 100 ppb (m/v). Lors de l'utilisation de l'équation de Mitani, qui décrit la conversion de Sméthylméthionine (SMM) en DMS et l'élimination du DMS, l'étape de pré-ebullition a permis d'obtenir un coefficient de réaction de la conversion SMM (k_1) de 0,0099 min^{-1}. Les valeurs du coefficient de vitesse de volatilisation du DMS (k_2) lors de la fourniture du CO_2 à un débit compris entre 5 et 11 L/min et de la puissance d'ébullition entre 500 et 1500 W étaient comprises entre 0,02049 et 0,07882 min^{-1}. Il a été constaté que le coefficient k_2 augmentait avec l'augmentation du débit d'alimentation en CO_2 et l'augmentation de la puissance d'ébullition. À une puissance d'ébullition fixe de 1500 W, l'utilisation du débit d'alimentation en CO_2 a permis d'atteindre l'objectif de 100 ppb dans un intervalle de 39,21 min pour 11 L/min et à 62,31 min pour 5 L/min. L'énergie économisée dans le processus d'ébullition lors de l'application du débit d'alimentation en CO_2 entre 5 et 11 L/min était de 2,49-4,57 MJ.

Chapitres de livres

En dehors des travaux de recherche qui ont donné lieu aux publications, j'ai participé de part la collaboration que j'ai avec d'autres chercheurs, à la rédaction de 3 livres dans lesquels j'ai rédigé un chapitre chacun. Deux de ces livres sont déjà publiés et le dernier a obtenu le galley proof. Il s'agit là de :

Microbial Enzyme Technology in Food Applications

Dans ce livre, j'ai rédigé en compagnie d'autres chercheurs le chapitre 25.

Desobgo, Z. S. C.*, Mishra, S. S., Behera, S. K., & Panda, S. K. 2017. Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview. In R. C. Ray & C. M. Rosell (Eds.), Microbial Enzyme Technology in Food Applications (pp. 520): CRC Press, Taylor & Francis Group.

Le but de la transformation des aliments est de produire des aliments appétissants et savoureux, de prolonger leur durée de conservation, d'augmenter la variété et de maintenir la qualité nutritionnelle et sanitaire des aliments. Pour obtenir des conditions de traitement favorables et pour la sécurité de la nourriture à consommer, l'utilisation d'enzymes microbiennes de qualité alimentaire ou de microbes (étant les biocatalyseurs naturels) est impérative. Ce livre traite des utilisations des enzymes dans le traitement des aliments et des boissons conventionnels et non conventionnels, ainsi que dans la transformation des produits laitiers, le brassage, la boulangerie et la vinification. En dehors des utilisations conventionnelles, le développement d'outils et de techniques de bioprocédés a considérablement élargi le potentiel d'application étendue d'enzymes telles que la production de peptides bioactifs, d'oligosaccharides et de lipides, d'arômes et de colorants. Certains de ces développements incluent l'utilisation prolongée des biocatalyseurs (en tant qu'enzymes immobilisées/encapsulées), des microbes (naturels et génétiquement modifiés) comme sources d'enzymes en vrac, de la technologie de fermentation à l'état solide pour la production d'enzymes. Les extrêmophiles et les micro-organismes marins sont une autre source d'enzymes de qualité alimentaire. Le livre jette la lumière sur les applications potentielles des enzymes microbiennes pour élargir la base des industries de transformation des aliments.

Innovations in Technologies for Fermented Food and Beverage Industries

Dans ce livre, j'ai rédigé le chapitre 11.

***Desobgo, Z. S. C.** 2018. Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry. In Panda, Sandeep Kumar, Halady, Prathap Kumar Shetty (Eds.), Innovations in Technologies for Fermented Food and Beverage Industries. (pp. 343) Springer International Publishing.*

La fermentation est une méthode peu coûteuse et peu énergivore de conservation de matériaux non transformés décomposables. De nombreux aliments ont des sources microbiennes ou comprennent des composants générés par la fermentation à l'aide de microorganismes. Cette procédure est utile pour étendre l'utilisation de la nourriture et des boissons, ainsi que pour améliorer les avantages pour la santé des produits. Ce chapitre examine les aspects modernes de la fermentation des aliments et des boissons dans les fermenteurs à grande échelle. Des descriptions des fermenteurs et de leur technologie sous-jacente sont fournies pour chaque cas afin de démontrer le lien entre l'équipement et le processus. Les caractéristiques d'ingénierie sont rapportées pour la mise à l'échelle du bioréacteur, y compris des problèmes importants dans la mise à l'échelle et l'exploitation des bioréacteurs. L'agitation dans les bioréacteurs est également discutée. Certains aspects associés à la conception du bioréacteur/fermenteur lorsque la simulation par ordinateur est utilisée sont signalés. Enfin, la technologie des types de bioréacteurs modernes est présentée.

Wine making: Basics and applied aspects

Dans ce livre, j'ai rédigé le chapitre 19.

***Desobgo, Z. S. C.** & Nso, E.J., 2020. Winemaking: Control, Bioreactor and Modelling of Process. In Joshi V.K. & Ramesh C. Ray (Eds.), Wine making: Basics and applied aspects. (pp. 700). CRC Press, Taylor & Francis Group. (Galley Proof)*

L'agroalimentaire est intégré aux systèmes de production ; d'où les nombreuses procédures actuelles faisant l'objet d'études approfondies sur les méthodes permettant de développer de meilleurs systèmes de sécurité et de qualité. C'est le moyen d'assurer la qualité et le respect des exigences de sécurité, des coûts de système et des effets naturels. Parmi la classification (en particulier la structuration, la préservation, la séparation et la bioconversion) des formes de produits alimentaires, la bioconversion englobe très probablement la plus grande classe de procédures. Elle est au cœur de la génération d'aliments en cours de maturation avec quelques cas exceptionnels provenant de l'usine de vinification. On considère généralement que la vinification commence avec l'assemblage des baies et l'introduction de levure pour

réaliser la fermentation. L'innovation, le broyage et une compression régulière pourraient être considérés comme les étapes finales de l'exploitation du vignoble. Le contrôle de la qualité du vin est fondamentalement essentiel. Une étude institutionnelle a accentué la nécessité d'examiner la vulnérabilité à l'oxygène, la gestion de l'extraction des substances de la peau, la surveillance de la température pendant la fermentation, l'observation de l'épuisement des sucres et la surveillance des microbes et la fermentation malolactique. À l'heure actuelle, on recherche des produits de meilleure qualité, tout en gardant à l'esprit que l'utilisation générale du vin diminue, l'intérêt pour les vins étonnement augmente. Les acheteurs boivent moins que "mieux". Les producteurs de vin du monde entier consolident les techniques de vinification de plusieurs siècles avec de nouvelles méthodologies et idées, afin de satisfaire l'intérêt de l'acheteur pour une meilleure qualité de produit et un mode de vie durable et sain.

Ce chapitre présente une vue d'ensemble de la vinification, de la surveillance, du contrôle de la sécurité et de la qualité. Il présente les activités concernant le fonctionnement de chaque unité, les caractéristiques et les utilisations du bioréacteur et, enfin, des approches novatrices visant à optimiser l'efficacité du processus.

Dr DESOBGO ZANGUE Steve Carly

IV.1.c) Contribution à la gouvernance de l'université et de l'enseignement supérieur

La gouvernance est vue comme un assemblage des systèmes et des préceptes par lesquels des communautés se gèrent, c'est-à-dire adoptent leurs résolutions, programment leur croissance, administrent leurs ressources, organisent leurs travaux, estiment leurs résultats, rendent leurs conclusions et s'affilient dans les réseaux de partenariats. Faisant partie du personnel enseignant qui à mon avis est la composante majeure d'une université, je m'assure dans le cadre de cette gouvernance, d'apporter aux apprenants (étudiants) une qualité de prestation des enseignements et de recherche. J'effectue également des missions de prospection et d'encadrement des stagiaires. J'ai aussi eu le privilège d'assurer l'interim des Chefs de départements GACQ (Génie Alimentaire et Contrôle Qualité) et ESB (Enseignement Scientifique de Base). Voir quelques notes d'interim à la suite.

La planification stratégique est une action de base pour le progrès de l'université et du MINESUP, en particulier en ce qui concerne le développement des besoins de formation et de recherche. L'exécution d'une grande pratique de la planification stratégique nécessite des capacités et une technique de diagnostic appropriées. Avec l'instauration du système LMD (Licence-Master-Doctorat) dans les institutions universitaires du Cameroun et, suite à l'arrêté N°1800522/MINESUP/DDES/DAJ/DU, du 9 Juillet 2018 portant régime des études et des évaluations à l'IUT de Ngaoundéré, je suis enrôlé dans le groupe de réflexion au sein du département GACQ (Génie Alimentaire et Contrôle Qualité) pour revoir la structuration des enseignements afin de les arrimer aux termes du LMD. Concrètement il s'agit de définir les Unités d'enseignement et pour chacune de ces unités d'enseignement, y regrouper les éléments constitutifs cohérents. Je suis depuis 2016 un des superviseurs du club GBIO (Génie Biologique) renfermant 3 mentions (IAB, ABB et GEN). Je m'occupe spécifiquement des étudiants IAB (Industries Alimentaires et Biotechnologiques).

Dr. DESOBGO ZANGUE Steve Carly

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

THE UNIVERSITY OF NGAOUNDERE

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE
Département de Génie Alimentaire et Contrôle Qualité
BP 455 - Ngaoundéré/ Tél: 699 52 37 27 / 679 32 75 96

Le Chef de Département

Ngaoundéré, le 19 Juin 2019

NOTE D'INTERIM

Pendant l'absence du Chef de Département de Génie Alimentaire et Contrôle Qualité de l'IUT de Ngaoundéré du 20 au 24 juin 2019, l'intérim sera assuré par **Dr DESOBGO ZANGUE Stève Carly**, Chargé de Cours au Département GACQ.

L'intéressé est tenu de remettre un rapport portant sur sa gestion académique et des affaires courantes du Département au Chef de Département dès son retour.

Le Chef de Département

Tatsadjieu Ngoune Léopold
Professeur

REPUBLIQUE DU CAMEROUN REPUBLIC OF CAMEROON INSTITUT UNIVERSITAIRE DE TECHNOLOGIE DEPARTEMENT DE GENIE ALIMENTAIRE ET CONTROLE QUALITE LE CHEF DE DEPARTEMENT UNIVERSITY OF NGAOUNDERE UNIVERSITE DE NGAOUNDERE

Ampliations
- Directeur de l'IUT
- Directeur Adjoint de l'IUT
- Chef de Division de la Formation Initiale
- Chefs de Division des Stages, de la Formation Continue et des Relations avec les Milieux Professionnels

Copie Dr. DESOBGO

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

THE UNIVERSITY OF NGAOUNDERE

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE DE NGAOUNDERE

DIVISION DE LA FORMATION INITIALE

DÉPARTEMENT DES ENSEIGNEMENTS SCIENTIFIQUES DE BASE
BP 455 - Ngaoundéré/ Tél: 222 25 40 70 / 677 57 04 36 / 696 66 02 09
Web : iut.univ-ndere.cm

Le Chef de Département

Ngaoundéré le 15 décembre 2017

N°.022/2017.IUT/DESB/sdo

NOTE DE SERVICE

Pendant l'absence du Chef de Département des Enseignements Scientifiques de Base en mission du 17 au 22 décembre 2017, l'intérim sera assuré par le Dr. DESOBGO Steve, Chargé de Cours au Département de Génie Alimentaire et Contrôle Qualité de l'IUT de Ngaoundéré.

L'intéressé est tenu de remettre un rapport portant sur sa gestion académique et des affaires courantes au Chef de Département dès son retour.

Le Chef de Département

Dr. Tsala
Chargé de Cours

Ampliations :

-Directeur /IUT
-Directeur-Adjoint /IUT
-Chef Division Formation Initiale
-Chef Division Stage
-Chefs de Départements
-Affichage
Archives/chrono/

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

THE UNIVERSITY OF NGAOUNDERE

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE
Département de Génie Alimentaire et Contrôle Qualité
BP 455 - Ngaoundéré/ Tél: 699 52 37 27 / 679 32 75 96

Le Chef de Département

Ngaoundéré, le 06 Mars 2015

NOTE D'INTERIM

Pendant l'absence du Chef de Département de Génie Alimentaire et Contrôle Qualité de l'IUT de Ngaoundéré en mission de prospection des stages à Douala du 8 au 13 Mars 2015, l'intérim sera assuré par **Dr DESOBGO ZANGUE Stève Carly**, Enseignant au Département GACQ.

L'intéressé est tenu de remettre un rapport portant sur sa gestion académique et des affaires courantes du Département au Chef de Département dès son retour.

Le Chef de Département

Pr. Tatsadjieu Ngouné Léopold
Microbiologiste

Ampliation :

- Directeur de l'IUT
- Directeur Adjoint IUT
- Chef de Division de la Formation Initiale
- Chef de Division des Stages, de la Formation Continue et des Relations avec les Milieux Professionnels

IV.1.d) Contribution au développement de la nation

En plus de mes contributions à l'enseignement, la recherche et la gouvernance, je contribue également au développement de la nation Cameroun. En effet, suite à la décision N°000027/MINRESI/SPCNDT/SJCG/RJC/17 signée le 04 Avril 2017 par Madame le Ministre Dr Madeleine Tchuinté, je suis membre expert du Comité National de Développement des Technologies (CNDT), commission Biotechnologie comme l'atteste le document joint à la suite. En effet, le travail qui est effectué en commission consiste à expertiser les TDRs (Termes de Références), classer par priorité ceux qui peuvent faire l'objet d'un financement au MINRESI. Ce classement se fait sur la base de l'originalité et surtout de la faisabilité qui tient compte de la vulgarisation auprès des populations. Le travail d'expert se poursuit au niveau de l'accompagnement du porteur de projet jusqu'à la réalisation complète du projet. J'ai également mené une réflexion en compagnie des autres membres de la commission, sur le thème de la conférence annuelle du CNDT. Cette édition 2018 sera une occasion de restitution des activités de chaque commission technique.

J'ai travaillé aussi avec le GIZ au bénéfice des populations rurales dans le projet cacao. Il était question d'expertiser une machine qui était destinée à la transformation du cacao au niveau des paysans afin de leur donner un supplément de revenu (Voir timesheet).

J'ai également accompagné un opérateur économique dans l'étude de mise en place d'une microbrasserie à Yaoundé. Le projet est au niveau des autorisations de la tutelle (voir invitation).

Dr. DESOBGO ZANGUE Steve Carly

REPUBLIQUE DU CAMEROUN
Paix – Travail - Patrie

MINISTERE DE LA RECHERCHE SCIENTIFIQUE ET DE L'INNOVATION

COMITE NATIONAL DE DEVELOPPEMENT DES TECHNOLOGIES

SECRETARIAT PERMANENT

BP 1457 YAOUNDE CAMEROUN
Tél/Fax (237)2 22 22 25 09/ 222 22 24 96

CP/CNDT

CNDT
COMITE NATIONAL DE DÉVELOPPEMENT DES TECHNOLOGIES
04 AVR 2017
Sur Par Le 217

REPUBLIC OF CAMEROON
Peace – Work- Fatherland

MINISTRY OF SCIENTIFIC RESEARCH AND INNOVATION

NATIONAL COMMITTEE FOR TECHNOLOGY DEVELOPMENT

PERMANENT SECRETARIAT

PO. Box 1457 YAOUNDE - CAMEROON
Tél/Fax (237) 222 22 25 09/222 22 24 96

Courriel : contact@cndtcameroon.net/cndt_minresi@yahoo.fr
www.cndtcameroon.net

000027

DECISION N° ...../MINRESI/SPCNDT/SJCG/RJC/17 du..... 04 AVR 2017
Portant désignation des Coordonnateurs Scientifiques et des Membres des Commissions Techniques du Comité National de Développement des Technologies (CNDT).

Le Ministre de la Recherche Scientifique et de l'Innovation, Président du Comité National de Développement des Technologies (CNDT),

Vu la Constitution ;
Vu la loi n° 2007/006 du 26 décembre 2007 portant régime financier de l'Etat ;
Vu le décret n°80/275 du 18 juillet 1980 portant statut des chercheurs ;
Vu le décret n° 82/126 du 18 mars 1982 modifiant et complétant le décret N° 78/109 du 1er Avril 1978 portant création et organisation du Comité National de Transfert des Technologies ;
Vu le décret n° 2011/408 du 09 décembre 2011 portant organisation du Gouvernement ;
Vu le décret n° 2011/410 du 09 décembre 2011 portant formation du Gouvernement ;
Vu le décret n° 2012/383 du 14 septembre 2012 portant organisation du Ministère de la Recherche Scientifique et de l'Innovation ;
Vu le décret n° 2015/434 du 02 octobre 2015 portant Réaménagement du Gouvernement ;
Vu le cadre d'Exécution du Budget du Comité National de Développement des Technologies ;
Vu la décision n° 0101/D/MINRESI/CNDT/16 du 30 décembre 2016 portant création, organisation et fonctionnement des Commissions du Comité National de Développement des Technologies ;
Vu la résolution n°5 approuvant la Réorganisation des Commissions Techniques du Comité National de Développement des Technologies ;
Considérant les nécessités de service,

DECIDE

Article 1.-La présente décision désigne les Coordonnateurs Scientifiques et les Membres des Commissions Techniques du Comité National de Développement des Technologies

A-COMMISSION
TECHNOLOGIES DE L'INFORMATION ET DE LA COMMUNICATION

Coordonnateur Scientifique : Jean **KAMDEM**, Professeur ;
Membres

- OMER Blaise **YENKE**, Docteur ;
- Thomas **BOUETOU BOUETOU,** Docteur ;
- Edwin **NYUYSEVES, MBINKAR,** Docteur ;
- Ebongué, **FENDI KEDIENG,** Docteur ;
- Harouna **NDAM NJOYA,** Doctorant.,

B-COMMISSION
INGÉNIERIE INDUSTRIELLE

Coordonnateur Scientifique : NGA **NTEDE**, Professeur ;
Membres

- J.R. Lucien **MEVA'A**, Professeur ;
- André **YOUMSSI**, Professeur ;
- Richard **NTENGA,** Docteur ;
- Saidjo **SAIDJO**, Doctorant ;
- M. **EYELE M EVENGA MANG,** Doctorant.

C-COMMISSION
ENERGIE ET ENVIRONNEMENT

Coordonnateur Scientifique: Joseph **KENFACK,** Professeur.
Membres

- Ruben **MOUANGUE**, Professeur ;
- Noël **NDJONGYANG**, Professeur ;
- Marcel **EDOUM**, Professeur ;
- André **TALLA**, Docteur ;
- Guy Bertrand **TCHAYA**, Docteur ;
- TOM **AHMAT**, Docteur.

D-COMMISSION
BIOTECHNOLOGIES

Coordonnateur Scientifique : Ahmed **ALI,** Professeur.
Membres

- Esther **NGAH**, Professeur ;
- Bouba **ABDOU**, Professeur ;
- Simon **BASGA**, Professeur ;
- Adji **MOHAMADOU BOUBA,** Professeur ;
- Jules **BALNA**, Docteur ;
- Carly **Stève DESOBGO**, Docteur ;
- Néhémie **DONFAGSITELI TCHINDA**, Docteur ;
- Nolasque **MEKE SOUNG,** Docteur ;
- Saidou **SAIDOU**, Docteur ;
- TIABOU **TCHINDA**, Docteur ;
- Joël **TIZE KODA**, Docteur.

E-COMMISSION
POLITIQUES SCIENTIFIQUES ET TECHNOLOGIQUES

Coordonnateur Scientifique : Joseph **FOMETEU**, Professeur ;
Membres

- Janvier **ONANA**, Professeur ;
- Georges **WANDJI**, Professeur,
- Anaba **NAAMBOW**, Doctorant.

Article 2. (1)-Les Membres des Commissions Techniques sont désignés pour une durée de deux ans renouvelable.

(2)-Les fonctions de Coordonnateur Scientifique ou de Membre d'une Commission Technique prennent fin en cas d'indisponibilité constatée par le Secrétaire Permanent du Comité National de Développement des Technologies, qui peut procéder aussitôt au remplacement du Coordonnateur Scientifique ou du Membre dont l'indisponibilité a été constatée.

Article 3. (1)-Les Commissions Techniques du Comité National de Développement des Technologies se réunissent sur convocation du Secrétaire Permanent. Celui-ci peut inviter toute personne physique ou morale à participer aux réunions des Commissions Techniques.

(2)-Les convocations, qui doivent parvenir aux Participants dans les meilleurs délais peuvent indiquer l'ordre du jour, la date, le lieu et l'heure de la tenue des réunions.

Article 4.-Les Membres des Secrétariats Techniques des Commissions Techniques du Comité National de Développement des Technologies sont désignés par une note de service du Secrétaire Permanent.

Article 5.-La présente décision, qui prend effet à compter de la date de sa signature, sera enregistrée et publiée partout où besoin sera.

Yaoundé, le 04 AVR 2017

LE MINISTRE DE LA RECHERCHE SCIENTIFIQUE ET DE L'INNOVATION, PRESIDENT DU COMITE

Dr Madeleine Tchuinte

Ampliations
- MINRESI/CAB
- SC/MINRESI
- SP/CNDT
- CFC/MINRESI
- AC/CNDT
- Intéressé(e)s
- Chronos/Archives

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE LA RECHERCHE
SCIENTIFIQUE ET DE L'INNOVATION

COMITE NATIONAL DE
DEVELOPPEMENT DES TECHNOLOGIES

SECRETARIAT PERMANENT

BP 1457 YAOUNDE CAMEROUN
Tél/Fax (+237) 222 222 496/ 222 222 509

Courriel :
cndt_minresi@yahoo.fr
www.cndtcameroun.cm

REPUBLIC OF CAMEROON
Peace – Work- Fatherland

MINISTRY OF SCIENTIFIC
RESEARCH AND INNOVATION

NATIONAL COMMITTEE FOR
DEVELOPMENT OF TECHNOLOGIES

PERMANENT SECRETARIAT

PO. Box 1457 YAOUNDE-CAMEROON
Tel/Fax (+237) 222 222 496/ 222 222 509

97

N° 000075 /MP/MINRESI/SPCNDT/SB/18 Yaoundé, le 19 NOV 2018

Le Secrétaire Permanent, Coordonnateur Exécutif de la Commission Technique « *Biotechnologies* »
The Permanent Secretary, Executive Coordinator of the Technical Commission « Biotechnologies »

A/*to*

MM & Mmes

Coordonnateur Scientifique
- Ali AHMED

Membres de la Commission
- BASGA Simon
- BALNA Jules
- MOHAMMADOU Bouba Adji
- Saidou SAIDOU
- Carly Stève DESOBGO
- Néhémie DONFAGSI I ELI TCHINDA
- Tiabou TCHINDA

Chef de Secrétariat
- Mme BILOA Dorothée Marcelle

Chef de Secrétariat Adjoint
- M. KARKA Jilhoubé Maxime

Membres du Secrétariat
- M. AMADA Brahim
- Mme MONGOUE FANCHE aminatou
- Mme NGO NGWEM Marcelline Carine
- M. PAGLAN Paul André
- Mme RAUWITTA Omabit Afoh

Objet : Commission Technique « *Biotechnologies* »

MESSAGE PORTE

HONNEUR VOUS INVITER -STOP- PRENDRE PART -STOP- REUNION VISEE A L'OBJET -STOP- **MARDI 20 NOVEMBRE 2018** - STOP- **10 HEURES PRECISES** - STOP- SALLE DE REUNION DU CNDT- STOP-

L'ORDRE DU JOUR -STOP-

1- MOT INTRODUCTIF DU SECRÉTAIRE PERMANENT DU CNDT -STOP-
2- ADOPTION DU PROJET D'ORDRE DU JOUR -STOP-
3- MOT DU COORDONNATEUR SCIENTIFIQUE -STOP-
4- LECTURE DU COMPTE RENDU DE LA DERNIÈRE COMMISSION ET SUIVI DES RECOMMANDATIONS -STOP-
5- TRAVAIL TECHNIQUE RELATIF AUX PROJETS DE LA COMMISSION :- STOP-
   - EXAMEN DES TDRS DU PROJET D'« ETUDE EN VUE DE LA PRODUCTION DU RAISIN AU CAMEROUN »-STOP-
   - EXAMEN DES TDRS ET DE LA FICHE D'ENQUÊTE DU PROJET D'«OPTIMISATION DU COMPOSTAGE DES DÉCHETS MÉNAGERS ET AGRICOLES » -STOP-
6- EXAMEN DES TDRS DU PROJET DE « MISE EN PLACE D'UNE REVUE À COMITÉ DE LECTURE AU CNDT -STOP-
7- TRANSFERT DES PROJETS RELATIFS À LA PRODUCTION DES BIOCARBURANTS À LA COMMISSION TECHNIQUE DES TECHNOLOGIES ÉNERGÉTIQUES ET DE L'ENVIRONNEMENT -STOP-
8- DIVERS -STOP ET FIN./-

Copies :
-Intéressés
-Chrono/Archives

LE SECRETAIRE PERMANENT

Dr Sylviama Patrice
Maître de Recherche

REPUBLIQUE DU CAMEROUN
Paix – Travail - Patrie

MINISTERE DE LA RECHERCHE SCIENTIFIQUE ET DE L'INNOVATION

COMITE NATIONAL DE DEVELOPPEMENT DES TECHNOLOGIES

SECRETARIAT PERMANENT

BP 1457 YAOUNDE CAMEROUN
Tél/Fax (237) 222 222 509/ 222 222 496

CNDT
COMITE NATIONAL DE DÉVELOPPEMENT DES TECHNOLOGIES
National Committee for Technology Development

Courriel :
contact@cndtcameroon.net/cndt_minresi@yahoo.fr
www.cndtcameroon.net

REPUBLIC OF CAMEROON
Peace – Work- Fatherland

MINISTRY OF SCIENTIFIC RESEARCH AND INNOVATION

NATIONAL COMMITTEE FOR TECHNOLOGY DEVELOPMENT

PERMANENT SECRETARIAT

PO. Box 1457 YAOUNDE - CAMEROON
Tél/Fax (237) 222 222 509/222 222 496

N° 000028 /MP/MINRESI/SPCNDT/SJCG/RAICG/17

Yaoundé, le 17 AVR 2017

Le Secrétaire Permanent, Coordonnateur de la Commission Technique « Biotechnologies »

A

MM. et Mmes

Coordonnateur Scientifique
Ahmed Ali

Membres de la Commission
BOUBA ABDOU
BASGA Simon
MOHAMADOU BOUBA Adji
BALNA Jules
DESOBGO Carly S.
DONFAGSITELI TCHINDA N.
MEKE SOUNG Nolasque
SAIDOU SAIDOU
TIABOU TCHINDA
Joël TIZE KODA
NGAH Esther

Chef du Secrétariat
BILOA Dorothée M.

Membres du Secrétariat
KARKA JILHOUBE M.
AMADA BRAHIM
TOUEMBOU MAFFO
NGO NGWEM Marcelline C.
MONGOUE epse NGONKEU

Invités
Albert NGAKOU
KOUNA Jean Baptiste

Objet : Réunion de la Commission Technique « Biotechnologies ».

MESSAGE PORTE

HONNEUR VOUS INVITER -STOP- PRENDRE PART -STOP- REUNION VISEE A L'OBJET-STOP- JEUDI 20 AVRIL 2017 -STOP- 14 HEURES PRECISES -STOP- TELE CENTRE DU CNDT -STOP-

L'ORDRE DU JOUR –STOP-

1. MOT INTRODUCTIF DU SECRETAIRE PERMANENT- STOP-
2. PRESENTATION DES COORDONNATEURS ET MEMBRES DE LA COMMISSION –STOP-
3. PRESENTATION DES PROJETS EN COURS –STOP-
4. PRESENTATION ET ADOPTION DES PROPOSITIONS DE PROJETS 2018 – STOP-
5. DIVERS :
   - PROJET DE DEVELOPPEMENT D'UN BIOFERTILSANT –STOP ET FIN./-

Dr. Libiby-Baubakar, Ph.D
Chercheur

Timesheet for Short-Term Expert

Month: Year:

N° project: *14.0967.1-010.00*
N° contract: *001/2016*

Name of expert: *Dr. DESOBGO ZANGUE Steve Carly*
Position: *Consultant*,
Subject of contract : Evaluer la performance de la machine de transformation du cacao identifiée par la SNV,

Date	Hours worked	Honoraire	Description of task done	Place of performance
20/08/2016	8h-12h		Réunion de travail sur le sujet du contrat, en présence des représentants GIZ, SNV, et de l'entreprise SOCTRACAO. Définition des termes de référence et visite sur site des équipements	DOUALA
20/08/2016	16h-20h		Rédaction du rapport : Analyse des fiches techniques de chaque équipement	YAOUNDE
21/08/2016	8h-16h		Rédaction du rapport : Evaluation des rendements des machines en fonction des besoins de transformation	YAOUNDE
22/08/2016	8h-16h		Rédaction du rapport : Analyse de la qualité des matériaux en lien avec les exigences hygiéniques et sanitaires et leur disponibilité sur le marché.	YAOUNDE
23/08/2016	8h-16h		Recommandations, conclusion et remise du rapport	YAOUNDE

Total in Days: 5 jours

Date, Signature of Expert

24/08/2016

Date, Signature of GIZ project Manager

Micro Brasserie Malterie
Chaumontoise

INVITATION PERSONNELLE

Chaumont en Vexin, le 14.09.2016

Dans le cadre de notre coopération et avec celle de la microbrasserie BrewPub de Ngola, nous accueillerons le Dr DESOBGO ZANGUE Steve Carly, de l'Université de Ngaoundéré entre le 10 et le 16 octobre 2016 pour une formation sur l'utilisation du matériel que nous avons construit et, sur l'élaboration de recettes de bières.

Les frais pédagogiques seront pris en charge par la BrewPub de Ngola (SCI-la Rochelle), sur devis à établir.

Fait à Chaumont en Vexin, le 14.09.2016.

Olivier Nizon

Micro Brasserie Malterie Chaumontoise – Biodiffusion EURL au capital de 100 euros.
Bâtiment Biosenteurs. 30 Rue Paul Journée. Z.A. du Moulin d'Angean 60240 Chaumont en Vexin.
Tel : 06 31 07 12 51 - email : LaChaumontoise@sfr.fr
N° de TVA FR82 487 441 578 SIRET : + 00027 .R.C.S. et R.M de Beauvais www.brasseriechaumontoise.fr

Malterie du Château

Des Malts Spéciaux qui Rendent Vos Bières Si Spéciales

Malterie du Château S.A. /
Castle Malting
Chemin du Couloury 1
4800, Lambermont, Belgique
Tel :+32 87 662 095
Fax :+32 87 352 234

Consulat honoraire Douala
Avenue Général De Gaulle, Bonapriso
3221 Douala
Cameroun

Lambermont, le 14 septembre 2016

Messieurs,

Dans le cadre de notre coopération, nous avons le plaisir d'inviter :

- Monsieur DESOBGO ZANGUE STEVE CARLY, passeport 01777859,

A venir visiter notre société pour la période du 13-14 octobre 2016 avec la possibilité d'une seule entrée.

Tous les frais de séjour en Belgique de Monsieur DESOBGO ZANGUE STEVE CARLY, seront pris en charge par la Malterie du Château S.A..

Dans l'attente du plaisir de le recevoir,

Veuillez agréer, Messieurs, nos salutations distinguées.

Jean-Louis Dourcy
Directeur Général

Siège administratif : Chemin du Couloury 1, 4800 Lambermont, Belgique
Site de production : Rue de Mons 94, 7970 Beloeil, Belgique
Tél. : + 32 (0) 87 662095; Fax : +32 (0) 87 352234; info@castlemalting.com; www.malterieduchateau.com
RPM Tournai 79754; TVA : BE.455013439; IBAN : BE11 3700 9054 5648; BIC : BBRUBEBB

IV.2) Liste des enseignements dispensés dûment approuvée par le Chef de Département

IV.2.a) Liste des enseignements dispensés à l'IUT de l'Université de Ngaoundéré

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
****
UNIVERSITE DE NGAOUNDERE
****

REPUBLIC OF CAMEROON
Peace - Work - Fatherland
****
THE UNIVERSITY OF NGAOUNDERE
****

INSTITUT UNIVERSITAIRE DE TECHNOLOGIE
****
DEPARTEMENT DE GENIE ALIMENTAIRE ET CONTRÔLE QUALITE
B.P. 455 NGAOUNDERE Tél. (237) 699 52 37 27 / 679327596

Le Chef de Département

Ngaoundéré, le 16 SEP 2019

Eléments constitutifs (EC) dispensés par Dr DESOBGO ZANGUE Steve Carly à l'IUT de l'Université de Ngaoundéré

Eléments constitutifs (EC)	Mention/Parcours	Année académique
Enzymologie (Cours, TD, TP)	GBIO 1	Depuis 2008
Dessin Technique et Schéma des Procédés (Cours, TD, TP)	GBIO 1	Depuis 2016
Fruits et légumes (Cours, TD)	IAB 2	2011/2015
TP Technologies Alimentaires intégrées	IAB 2	Depuis 2009
Malterie Brasserie (Cours, TD)	IAB 2	Depuis 2009
Céréales et amidonnerie (Cours, TD, TP)	IAB 2	2008/2013
Hygiène industrielle (Cours, TD)	IAB 2	2008/2013
Sucrerie et jus de fruits (Cours, TD)	IAB 2	2009/2013
Projet d'intégration	IAB 2	Depuis 2009
Malterie Brasserie (Cours, TD, TP)	IAB 3	Depuis 2009
Projet professionnel et personnel	IAB 3	Depuis 2009
Huilerie (Cours, TD)	IAB 3	2011/2015
Biostatistiques (Cours, TD)	IAB 3	Depuis 2011
Ingénierie des équipements (Cours, TD)	IAB 3	Depuis 2016
Enzymes Industrielles et applications (cours, TD, TP)	IAB 3	Depuis 2009
Vins et Spiritueux (Cours, TD, TP)	IAB 3	2009/2017

Le Chef de Département,

REPUBLIQUE DU CAMEROUN REPUBLIC OF CAMEROON INSTITUT UNIVERSITAIRE DE TECHNOLOGIE DEPARTEMENT DE GENIE ALIMENTAIRE ET CONTROLE QUALITE LE CHEF DE DEPARTEMENT UNIVERSITY OF NGAOUNDERE UNIVERSITE DE NGAOUNDERE

Tatsadjieu Ngoune Léopold
Professeur

IV.2.b) Liste des enseignements dispensés à l'ENSAI de l'Université de Ngaoundéré

REPUBLIQUE DU CAMEROUN

Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON

Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES

NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundere, le 18 Septembre 2019.

Enseignements dispensés par Dr DESOBGO ZANGUE Steve Carly à l'ENSAI de l'Université de Ngaoundéré

Enseignements	Mention/Parcours	Année académique
Boissons (Cours, TD)	IAA 2	Depuis 2016
Projet professionnel et personnel	IAA 2	Depuis 2016
Opérations unitaires de transfert (Cours, TD)	Master 1	Depuis 2016
Avancées en génie de maltage et procédés de boissons (Cours, TD)	Master 2	Depuis 2016
Planification d'expérience (sous forme de séminaire)	Master 2/Ph.D	Depuis 2016

Le Chef de Département GP

Dr Kofa Guillaume Patrice

IV.3) Liste des mémoires et thèses dirigées ou codirigées + procès-verbaux de soutenance certifiés

IV.3.a) Attestations de co-encadrement des Thèses de Doctorat/Ph.D

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf : 2019/108/UN/D.ENSAI

ATTESTATION DE CO-ENCADREMENT DE THESE DE DOCTORAT/Ph.D

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, assure effectivement, sous ma supervision, le co-encadrement de Madame NGUEMOGNE Annick Chancelle, étudiante régulièrement inscrite en thèse de Doctorat/Ph.D au Département de Génie des Procédés de l'ENSAI de Ngaoundéré par décision N°2013/156/UN/R/VR-EPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI du 22 Mai 2013 de Monsieur le Recteur de l'Université de Ngaoundéré. Les travaux de cette étudiante, qui portent sur la « Modélisation de l'extraction et de la purification de la dextrinase limite du cultivar de sorgho *Safrari* », sont suffisamment avancés et permettent d'envisager la soutenance de thèse pour le début de l'année 2020.

En foi de quoi la présente attestation est délivrée pour servir et valoir ce que de droit.

Le Directeur

Pr. NSO Emmanuel Jong

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf : 2019/108/UN/D.ENSAI

ATTESTATION DE CO-ENCADREMENT DE THESE DE DOCTORAT/Ph.D

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, assure effectivement, sous ma supervision, le co-encadrement de Madame Acha Anna Affeck, étudiante régulièrement inscrite en thèse de Doctorat/Ph.D au Département de Génie des Procédés de l'ENSAI de Ngaoundéré par décision N°2013/156/UN/R/VREPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI du 22 Mai 2013 de Monsieur le Recteur de l'Université de Ngaoundéré. Les travaux de cette étudiante, qui portent sur « Modeling the production and clarification of a standardized « Nkang » beer, sont suffisamment avancés et permettent d'envisager la soutenance de thèse pour la fin de l'année 2020.

En foi de quoi la présente attestation est délivrée pour servir et valoir ce que de droit.

Le Directeur

Pr. Nso Emmanuel Jong

REPUBLIQUE DU CAMEROUN

Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON

Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES

NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf : 2019/108/UN/D.ENSAI

ATTESTATION DE CO-ENCADREMENT DE THESE DE DOCTORAT/Ph.D

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, assure effectivement, sous ma supervision, le co-encadrement de Monsieur NINGA KOMBELE Aimé, étudiant régulièrement inscrit en thèse de Doctorat/Ph.D au Département de Génie des Procédés de l'ENSAI de Ngaoundéré par décision N°2013/156/UN/R/VR-EPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI du 22 Mai 2013 de Monsieur le Recteur de l'Université de Ngaoundéré. Les travaux de cet étudiant, qui portent sur la « Modélisation et l'optimisation de la depectinisation enzymatique de la pulpe de goyave par l'utilisation des polygalacturonases extraites à partir de la banane », sont suffisamment avancés et permettent d'envisager la soutenance de thèse pour le début de l'année 2020.

En foi de quoi la présente attestation est délivrée pour servir et valoir ce que de droit.

Le Directeur

Pr. Nso Emmanuel Jong

REPUBLIQUE DU CAMEROUN

Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON

Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES

NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf : 2019/108/UN/D.ENSAI

ATTESTATION DE CO-ENCADREMENT DE THESE DE DOCTORAT/Ph.D

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, assure effectivement, sous ma supervision, le co-encadrement de Madame MAKEBE Callister WINGANG, étudiante régulièrement inscrite en thèse de Doctorat/Ph.D au Département de Génie des Procédés de l'ENSAI de Ngaoundéré par décision N°2017/047/UN/R/VR-EPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI du 02 Aout 2017 de Madame le Recteur de l'Université de Ngaoundéré. Les travaux de cette étudiante portent sur « Probiotic beverage obtained from extract of *Annona muricata* and *Strychnos spinosa* using a combination of microorganisms », sont en cours et permettent d'envisager la soutenance de thèse pour la fin de l'année 2020.

En foi de quoi la présente attestation est délivrée pour servir et valoir ce que de droit.

Le Directeur

Pr. NSO Emmanuel Jong

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf : 2019/108/UN/D.ENSAI

ATTESTATION DE CO-ENCADREMENT DE THESE DE DOCTORAT/Ph.D

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, assure effectivement, sous ma supervision, le co-encadrement de Madame WIYEH Claudette BAKISU MUALA, étudiante régulièrement inscrite en thèse de Doctorat/Ph.D au Département de Génie des Procédés de l'ENSAI de Ngaoundéré par décision N°2017/047/UN/R/VR-EPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI du 02 Aout 2017 de Madame le Recteur de l'Université de Ngaoundéré. Les travaux de cette étudiante portent sur « Probiotic beverage from infusion of *Cymbopogon citratus* and *Zingiber officinale* using a combination of microbial strains », sont en cours et permettent d'envisager la soutenance de thèse pour la fin de l'année 2020.

En foi de quoi la présente attestation est délivrée pour servir et valoir ce que de droit.

Le Directeur

Pr. Nso Emmanuel Jong

IV.3.b) Décisions portant sélection des candidats en vue de l'inscription en thèse de Doctorat/Ph.D

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

UNIVERSITE DE NGAOUNDERE
BP: 454 Tél/Fax : 22 25 40 01

RECTORAT

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES (ENSAI)

REPUBLIC OF CAMEROON
Peace – Work – Fatherland

UNIVERSITY OF NGAOUNDERE
PO Box: 454 Tél/Fax : 22 25 40 01

RECTOR'S OFFICE

NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES (ENSAI)

2013/156

DECISION N°...../UN/R/VR-EPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI

Portant sélection des candidats en vue de leur inscription à la préparation du Doctorat/PhD en « Sciences Alimentaires/Nutrition », « Chimie Industrielle et Environnement » et « Génie des Procédés » dans le Cycle des Formations Doctorales et des Spécialisations de l'Ecole Nationale Supérieure des Sciences Agro-industrielles (ENSAI) de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITE DE NGAOUNDERE

Vu la Constitution ;
Vu le décret n° 92/74 du 13 avril 1992 transformant les centres universitaires de Buea et Ngaoundéré en Universités ;
Vu le décret n° 93/026 du 19 janvier 1993 portant création des Universités ;
Vu le décret n° 93/027 du 19 janvier 1993 portant dispositions communes applicables aux Universités, modifié et complété par le décret n° 2005/342 du 10 septembre 2005 ;
Vu le décret n° 93/028 du 19 janvier 1993 portant organisation administrative et académique de l'Université de Ngaoundéré ;
Vu le décret n° 2003/250 du 16 septembre 2003 portant nomination des Recteurs dans les Universités d'Etat ;
Vu l'arrêté n° 95/061 du 03 avril 1995 portant organisation de l'Ecole Nationale Supérieure des Sciences agro – Industrielles (ENSAI) de l'Université de Ngaoundéré ;
Vu l'arrêté n°99/0081/MINESUP/DDES du 23 décembre 1999 portant organisation du cycle de doctorat ou Doctor of philosophy (Ph.D) dans les Universités d'Etat du Cameroun ;
Vu l'arrêté n°01/0030/MINESUP/DDES du 11 avril 2001 modifiant certaines dispositions des articles 5 et 13 et de l'arrêté n°99/0081/MINESUP/DDES du 23 décembre 1999 ;
Vu la décision Ministérielle n° 231 du 16 septembre 1994 relative à la sélection de candidats en vue de l'inscription en thèse dans le cycle des Formations doctorales et des Spécialisations de l'Ecole Nationale Supérieure des Sciences Agro – Industrielles (ENSAI) de l'Université de Ngaoundéré ;
Vu la décision n° 243/03/UN/R/VRE du 10 juin 2003 fixant les modalités d'inscription et de soutenance de thèse de Doctorat/PhD. A l'Université de Ngaoundéré;
Vu la note de service n° 2012/015/UN/R/VR EPDTIC/DAAC/DEPE du 13 février 2012 portant constitution du dossier de soutenance de thèse de Doctorat/PhD à l'Université de Ngaoundéré ;
Vu l'avis favorable de la commission de sélection des candidats en Master 2 et en Doctorat/PhD pour l'année académique 2012-2013 tenue le 18 janvier 2013;

Sur proposition du Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI);

DECIDE :

Article 1er : Sont, à compter de l'année académique 2012/2013, retenus en vue de l'inscription à la préparation d'une thèse de Doctorat/Ph.D en « Sciences Alimentaires/Nutrition », « Chimie Industrielle et Environnement » et « Génie des Procédés » dans le Cycle des Formations Doctorales et des Spécialisations de l'Ecole Nationale Supérieure des Sciences Agro-industrielles (ENSAI) de

l'Université de Ngaoundéré, les candidats dont les noms suivent, et la direction de leurs travaux de recherches doctorales sera assurée ainsi qu'il suit :

1. Unité de Formation Doctorale Sciences Alimentaires et Nutrition (SAN):

N°	Noms et Prénoms (Date et lieu de naissance)	Matricule	Diplôme (année d'obtention)	Moyenne (mention)	Sujet de la thèse	Directeur de thèse (Grade)	Co-Directeurs (Grades)
	ABINI Raphael Né le 14/10/1973	10S231EN	M SAN, ENSAI, 2012	13,08 (Assez Bien)	Etude de la Digestibilité in vivo et in vitro des lipides et des protéines des tourteaux de Pakira insignis et effet sur la croissance des poulets de chair	NJINTANG Y.N. (MC)	NGAH E. (CC)
1	ABOSSOLO SAKOUMA Luc Daniel Né le 15/04/1985 à Zingui	08I001EN	M SAN, ENSAI 2012	13,83 (Assez-Bien)	Prétraitement de la peau des bovins par les collagénases microbiennes et influence de la gélatine sur la flore anaérobie	ETOA F-X. (Pr)	EDIMA H. C. (CC)
2	BARBI Mathieu Née le 14/05/1975 à Dagai	06D100EN	DEA SAN, ENSAI, 2009	12,88 (Assez-Bien)	Propriétés physicochimiques, fonctionnelles et nutritionnelles des feuilles de manioc consommées au Nord-Cameroun	NDJOUENKEU R. (Pr)	TCHIEGANG C. (Pr) ABOUBAKAR DANDJOUMA (CR IRAD)
3	BELINGA Marc Né le 29/05/1979 à Yaoundé	05I042EN	M SAN, ENSAI, 2010	14,44 (Bien)	Les aptitudes technologiques des différentes variétés de corossol	ESSIA NGANG J. J. (MC)	NGAH E. (CC)
4	BILOA Dorothée Marcelle Née le 22/01/1986 à Ngaoundéré	08I005EN	M SAN, ENSAI, 2012	14,30 (Bien)	Recherche d'un starter lactique pour la production d'un beurre et d'une crème	ESSIA NGANG J. J. (MC)	EDIMA H. C. (CC)
5	BINDZI Jean Marcel Né le 19/01/1974 à Mengueme	09S182EN	M SAN, ENSAI, 2012	14,42 (Bien)	Système technique de production du Bobolo (un produit de type bâton de manioc): caractérisation et Standardisation du procédé	NDJOUENKEU R. (Pr)	GIBERT O. (MC, Montpellier)
6	DJIAZET Steve Né le 23/09/1984 à Dschang		M biochimie U Dschang, 2012	12,65 (Assez-Bien)	Valeurs d'utilisation des épices locales de l'Ouest-Cameroun	TCHIEGANG C. (Pr)	LINDER M (Nancy) MEZAJOUG KENFACK L. (CC, UM)
7	DJIOGUE MANEJO Josiane Edith Née le 04/10/1987 à Yaoundé	10S233EN	M SAN, ENSAI, 2012	14,08 (Bien)	Etude des conditions de cuisson et de mise en conserve du gâteau de pistache	NJINTANG Y. N. (MC)	TATSADJIEU N. L. (MC)
8	FOKO Joël Baudouin Née le 11/09/1985 à Ndoungué	09S183EN	M SAN, ENSAI, 2012	14,17 (Bien)	Etude de la stabilité des gels d'amidon des amylacés locaux aux contraintes des contraintes des procédés industriels.	TCHIEGANG C. (Prof)	ALI Ahmed (MC)
9	LOBE Elias EYEMBE Née le 21/10/1980 à Kumba	09S187EN	M SAN, ENSAI, 2012	13,93 (Assez-Bien)	Anti-stress property and mechanism of anti-hypercholesterolemic effet of *Pleurotus florida* extracts in rat modus	MBOFUNG C. M. (Pr)	FOMBANG E (CC)
10	MOUAFO TENE Hippolyte Née le 03/09/1988 à Yagoua	10S239EN	M SAN, ENSAI, 2012	14,31 (Bien)	Identification moléculaire des biosurfactants produits par deux souches de Lactobacillus spp. Isolées du pendidam	NDJOUENKEU R. (Pr)	MBAWALA (CC)
11	NGAHA DAMNDJA Wilfred Née le 31/10/1982	10S240EN	M SAN, ENSAI, 2012	13,96 (Assez-Bien)	Supplémentation alimentaire des femmes allaitantes de la ville de Ngaoundéré par un aliment de consommation courante en vue de	EJOH A. R. (MC)	FOMBANG (CC)

	à Douala				la réduction de la carence en vitamine A		
	NGANGOUM Eric Serge Née le 12/06/1982 à Banka-Bafang	10S241EN	M SAN, ENSAI, 2012	14,10 (Bien)	Potentiel protéolytique des extraits de *Abrus precatorius* Linn., *Burnatia enneandra* Micheli. *et Ziziphus mauritiana* Lam.	TCHIEGANG C. (Pr)	LINDER M (Pr, Nancy) MEZAJOUG KENFACK L. (CC, UM)
3	NOBOSSE Pierre Née le 18/08/1983 à Bamelo-Babadjou	08I035EN	M SAN, ENSAI, 2012	14,32 (Bien)	Exploitation des propriétés de deux ressources alimentaires locales (*Moringa oleifera et Vigna unguiculata*) pour la formulation d'une boisson fonctionnelle	MBOFUNG C. M. (Pr)	FOMBANG E (CC)
4	NOUMO NGANGMOU Thierry Née le 16/09/1985 à Banka	10S242EN	M SAN, ENSAI, 2012	13,90 (Assez-Bien)	Influence des farines de protéagineux sur les propriétés physicochimiques et texturales du pâté de boeuf	MBOFUNG C. M. (Pr)	TATSADJIEU N. L. (MC)
15	SANTSA NGUEFACK Charles Vital Née le 27/10/1979 à Fiango		M Biochimie U Dschang, 2010	12,09 (Assez-Bien)	Influence de la qualité de l'eau du bassin versant de la Dibamba sur la santé des populations de Douala : Proposition d'un modèle de gestion intégrée	NDJOUENKEU R. (Pr)	NGASSOUM M. B. (MC)
16	SIEWE Fabrice Bruno Née le 17/01/1986 à Ndoungué	10S243EN	M SAN, ENSAI, 2012	14,05 (Bien)	Elaboration des pâtés à base d'épices et de poisson locaux	TATSADJIEU N. L. (MC)	MBOUGUENG P. D. (CC)
17	SOKAMTE TEGANG Alphonse Née le 11/01/1988 à Ndoungué	10S245EN	M SAN, ENSAI, 2012	14,26 (Bien)	Conditions optimales de fumage des filets de poisson de transformation artisanale et sélection des fumées de bois aptes à améliorer leur conservation et leur qualité sensorielle	TATSADJIEU N. L. (MC)	MBOUGUENG P. D. (CC)
18	TEDOM DZUSUO William Née le 02/02/1986 à Yaoundé	10S246EN	M SAN, ENSAI, 2012	12,28 (Assez-Bien)	Formulation d'un complément alimentaire à base de l'axe hypocotyle de *Borassus aethiopum* Mart.	EJOH A. R. (MC)	FOMBANG E (CC)

2. Unité de Formation Doctorale Chimie Industrielle et Environnement (CIE):

N°	Noms et Prénoms (Date et lieu de naissance)	Matricule	Diplôme (année d'obtention)	Moyenne (mention)	Sujet de la thèse	Directeur de thèse (Grade)	Co-Directeurs (Grades)
1	MBAILAOU NGOUSSOU (né le 05 jan 1970 Tchad)		DEA (Science de l'Environnement) Sénégal,	Assez-bien	Investigation des sites contaminés par les pesticides et étude de l'impact sur l'environnement	NGASSOUM M. B. (MC)	
2	ZE ARISTIDE PARFAIT (né le 13/09/74, Ntimbé II)	08S203EN	M CIE, ENSAI, 2011	13,65 (Assez-bien)	Etude physico-chimique de l'adsorption des métaux lourds en présence de la matière organique sur la bauxite et l'alumine dérivée	KAMGA R. (Pr)	
3*	DJEBBA IRENE (né le 06/05/1984 à Kaelé)		M CIE, ENSAI,	13.81 (Assez-bien)	Influence des paramètres physico-chimiques et thermomécaniques sur la production, la stabilité et la combustion des briquettes énergétiques à base de déchets industriels végétaux	KAMGA R. (Pr)	JIOKAP N. Y. (MC)
4	NGIONGBOUNG NGUIAMBA GUY RONI (né le 08/12/1986, Cam)		M CIE ENSAI	12,6 (Assez-bien)	Préparation et caractérisation des membranes céramiques à base d'argile camerounaise : application à la filtration	NGASSOUM M.B. (MC)	CRETIN M. (Pr, France) SIELIECHI J. M. (CC)
5	NKENMOGNE KAMDEM INES ESTELLE (03/08/1987 à	08C129EN	M CIE, ENSAI, 2012	13,8 (Assez-bien)	Production d'arômes et encapsulation avec les gommes locales	NGASSOUM M. B. (MC)	NDJOUENKEU R. (Pr) VOILLEY A. (Pr, Montpellier)

	Banka-Bafang)						
6	KAMGA GUEOBU Désirée (né 02/01/1979, Cam)		M CIE	14,1 (Bien)	Caractérisation et fonctionnalité des polysaccharides des fruits de *Ziziphus* du Cameroun	KAMGA R. (Pr)	NDJOUENKEU R. (Pr)
7	AZANGUEU MAFO Johsiane Bernisse (né le 18/07/1984, Cam)		M CIE	12,9 (Assez-bien)	Extraction caractérisation et application cosmétiques des huiles et des gommes de quelques fruits locaux	KAMGA R. (Pr)	NDJOUENKEU R. (Pr)
8	SABEN BOLO Emmanuel Théophile (né le 05/05/1979, NDIKI)		M CIE, ENSAI, 04I029EN	13,7 (Assez-bien)	Etude de l'extraction et décoloration des huiles usagée	NGASSOUM M. B. (MC)	

3. Unité de Formation Doctorale Génie des Procédés (GP):

N°	Noms et Prénoms (Date et lieu de naissance)	Matricule	Diplôme (année d'obtention)	Moyenne (mention)	Sujet de la thèse	Directeur de thèse (Grade)	Co-Directeurs (Grades)
1	Acha Anna Affeck (3 juin 1975 à Guzang)	09S175EN	M2 GP, ENSAI 2012	Assez Bien	Modeling the production and clarification of a standardized « Nkang » beer	Nso E. (MC)	Desobgo S. (CC)
2	ASEAKU Jude NKENGBEZA (16 Oct 1985 à Buea)	06I003EN	M2 GP, ENSAI, 2011	Bien	Development and Characterization of an Active/ConvenienceThermoplastic Starch Packaging from Cassava Roots	Nso E. (MC)	Ngassoum B (MC)
3	Egbe Daniel Egbembang (20 mai 1986 à Douala)	08I008EN	M2 GP ENSAI, 2012	Bien	Stabilization, characterization and Engineering properties of the African snail glue	Kayem G J (MC)	Ngah E (CC)
4	Ekorong Akouan Anta Junior Franck (02/ 08/ 1987 à Yaoundé)	08I009EN	M2 GP, ENSAI 2012	Assez Bien	Modélisation de l'extraction des substances bioactives des amandes de quelques variétés de mangues du Cameroun	Ndjouenkeu R. (Pr)	Mbougueng D (CC)
5	Feudjio Dadjo Christian (19 mars 1986 à Mbouda)	08I012EN	M2, GP, ENSAI 2012	Bien	Modeling of the biocatalytic process of biogas production from corncobs and cornstalks	Nso E. (MC)	Ngassoum (MC)
6	Kameni Ngounou Michel Bernard (21 mars 1985 à Bafang)	09S179EN	M2 GP, ENSAI, 2012	Assez Bien	Etude de la décantabilité des boues des rejets latéritiques	Kayem G. J. (MC)	Ndi K. (CC)
7	Kouteu Nanssou Paul Alain (25 mai 1985 à Dschang)	09S180EN	M2 GP, ENSAI, 2012	Bien	Etude des potentialités de production du bioéthanol à partir des boutures et épluchures de différentes variétés de manioc du Cameroun	Kapseu C. (Pr),	Jiokap Nono Y. (MC) Desmorieux H. (Pr, France)
8	Maka Taga Cybèle (23 juillet 1988 à Douala	08I018EN	M2 GP, ENSAI 2012	Bien	Optimisation des propriétés rhéologiques des bouillies à base de denrées locales destinées à l'alimentation par sonde	Kapseu C. (Pr),	Pr. Jiokap Y. (MC) Desmorieux H. (Pr, France).
9	Ndi Wamba Alfred Giresse (27 Juillet 1987 à Fongo-Tongo)	08C122EN	M2 GP ENSAI 2012	Bien	Développement d'un procédé de purification des eaux contenant des micropolluants par filtration-adsorption sur pouzzolane	Kayem G. J. (MC)	Ndi K. (CC)
10	Nguémogne Annick Chancelle (04 Jan 1988 à Yaoundé)	09S181EN	M2 GP ENSAI 2012	Assez Bien	Modélisation de l'extraction et de la purification de la dextrinase limite du cultivar de sorgho de safrari	Nso E. (MC)	Desobgo S. (CC)
11	Ninga Kombele Aime (30 déc	08I032EN	M2 GP, ENSAI,	Bien	Modélisation et optimisation de la depectinisation enzymatique de la pulpe de	Nso E. (MC)	Desobgo S. (CC)

	1987 à Meiganga		2012		goyave par l'utilisation des polygalacturonases extraites à partir de la banane		
2	Taira Aurelien (02 jan 1985 à Kaelé)	07I071EN	M2 GP, ENSAI, 2012	Bien	Développement et valorisation d'une α-amylase provenant de l'extrait brut de *B. enneandra*	Nso E. (MC)	

Article 2 : (1) la durée réglementaire accordée aux candidats pour la préparation du Doctorat/Ph.D est de 6 à 10 semestres, à compter de l'année académique 2012-2013, année de la première inscription ;

(2) pendant cette durée, il sera tenu de :

- prendre chaque année une inscription qui lui confère la qualité d'étudiant ;
- participer aux séminaires de recherche organisés par son Unité de Formation Doctorale et d'y exposer périodiquement les étapes significatives de l'avancement de son travail ;

Article 3 : Les intéressés sont invités à prendre attache avec le service de la scolarité de l'Ecole Nationale Supérieure des Sciences Agroindustrielles (ENSAI) pour les formalités d'inscription.

Article 4 : La présente décision sera enregistrée et communiquée partout où besoin sera.

Ngaoundéré, le 22 MAI 2013

LE RECTEUR

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON
Le Recteur
UNIVERSITY OF NGAOUNDERE
UNIVERSITE DE NGAOUNDERE

Pr. Amvam Zollo Paul Henri

Ampliations
- Vices – Recteurs
- SG-UN
- DAAC/DEPE
- DAAF
- D.ENSAI
- CF
- AC
- Chefs de Département
- Responsables UFDs
- Les Intéressés
- Chrono/Archives

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

UNIVERSITE DE NGAOUNDERE
BP: 454 Tél/Fax : 22 25 40 01

RECTORAT

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES (ENSAI)

REPUBLIC OF CAMEROON
Peace – Work – Fatherland

UNIVERSITY OF NGAOUNDERE
PO Box: 454 Tél/Fax : 22 25 40 01

RECTOR'S OFFICE

NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES (ENSAI)

2017/047

DECISION N°...../UN/R/VR-EPDTIC/DAAC/D.ENSAI/DAACRS.ENSAI/SRADC.ENSAI
Autorisant les candidats à s'inscrire en thèse de Doctorat/Ph.D en « Sciences Alimentaires/Nutrition », « Chimie Industrielle et Environnement » et « Génie des Procédés » dans le Cycle des Formations Doctorales et des Spécialisations de l'Ecole Nationale Supérieure des Sciences Agro-industrielles (ENSAI) de l'Université de Ngaoundéré.

LE RECTEUR DE L'UNIVERSITÉ DE NGAOUNDERE,

Vu la Constitution ;
Vu la loi n°99/016 du 22 décembre 1999, portant Statut Général des Etablissements Publics et des Entreprises du Secteur Public et Parapublic ;
Vu la loi n°005 du 16 avril 2005, portant orientation de l'Enseignement Supérieur ;
Vu la loi n°2007/006 du 26 décembre 2007, portant régime financier de l'Etat ;
Vu la loi n°2016/018 du 14 décembre 2016, portant loi de finances de la République du Cameroun, pour l'exercice 2017;
Vu le décret n°77/41 du 03 février 1977, fixant les attributions et l'organisation des Contrôles Financiers ;
Vu le décret n°92/074 du 13 avril 1992, portant transformation des Centres Universitaires de Buéa et de Ngaoundéré en Universités ;
Vu le décret n°93/027 du 19 janvier 1993, portant dispositions communes aux Universités ;
Vu le décret n°93/028 du 19 janvier 1993, portant Organisation Administrative et Académique de l'Université de Ngaoundéré ;
Vu le décret n°2005/342 du 10 septembre 2005, modifiant et complétant le décret n° 93/027 du 19 janvier 1993, portant dispositions communes aux Universités ;
Vu le décret n°2005/383 du 17 octobre 2005, fixant le régime financières applicables aux universités ;
Vu le décret n°2017/318 du 27 juin 2017, portant nomination du Recteur de l'Université de Ngaoundéré ;
Vu l'arrêté n°99/0055/MINESUP/DDES du 16 novembre 1999, portant dispositions générales applicables à l'organisation des enseignements et des évaluations dans les Universités d'Etats ;
Vu l'arrêté n°99/0081/MINESUP/DDES du 23 décembre 1999, portant organisation du cycle de Doctorat ou Doctor of Phylosophy (Ph.D) dans les Universités d'Etat du Cameroun ;
Vu l'arrêté n° 01/0030/MINESUP/DDES du 11 avril 2001, modifiant certaines dispositions des articles 5 et 13, et de l'arrêté n°99/0081/MINESUP/DDES du 23 décembre 1999 ;
Vu la décision n°243/03/UN/R/VRE du 10 juin 2003, fixant les modalités d'inscriptions et des soutenances de thèse de Doctorat/Ph.D à l'université de Ngaoundéré ;
Vu la décision n°00721/MINFI du 11 novembre 2016, portant nomination d'un Contrôleur Financier à l'Université de Ngaoundéré ;
Vu la circulaire n°001/C/MINFI du 28 décembre 2016, portant instructions relatives à l'Exécution des Lois de Finances, au Suivi et au Contrôle de l'Exécution du Budget de l'Etat, des Etablissements Publics Administratifs, des Collectivités Territoriales Décentralisées et des autres Organismes Subventionnés, pour l'exercice 2017 ;
Vu la résolution portant approbation du budget de l'Université de Ngaoundéré, pour l'exercice 2017 ;
Vu la note de service n° 2012/015/UN/R/VREPDTIC/DAAC/DEPE du 13 février 2012, portant constitution du dossier de soutenance de thèse de doctorat Ph.D à l'université de Ngaoundéré ;
Vu l'avis favorable de la commission de sélection des candidats en Master et en Doctorat Ph.D pour l'année académique 2016/2017, tenu le 2 février 2017,

Sur proposition du Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI),

DÉCIDE :

Article 1er : Sont, à compter de l'année académique 2016/2017, retenus en vue de l'inscription à la préparation d'une thèse de Doctorat/Ph.D en « Sciences Alimentaires/Nutrition », « Chimie Industrielle et Environnement » et « Génie des Procédés » dans le Cycle des Formations Doctorales et des Spécialisations de l'Ecole Nationale Supérieure des Sciences Agro-industrielles (ENSAI) de l'Université de Ngaoundéré, les candidats dont les noms suivent, et la direction de leurs travaux de recherches doctorales sera assurée ainsi qu'il suit :

3. Unité de Formation Doctorale Génie des Procédés et Ingénierie (GPI):

N°	Nom et Prénoms (Date et lieu de naissance)	Matricule	Diplôme (filière, année et lieu d'obtention)	Moyenne/20 (mention)	Sujet de recherches	Directeurs/Co-directeurs (Grades)
1	FUH ADANGWA Donatien (23/09/1977 à Douala)	03I043EN	M2 GP ENSAI, 2014	13,42 A Bien	Traitement biologique des eaux usées d'origine hospitalière	NDI KOUNGOU S. (MC) BUP Divine (MC, Univ Bamenda)
2	MAKEBE Callister WINGANG (01/08/1989 à Mamfé)	11I068EN	M2 GP ENSAI, 2016	15,47 Bien	Probiotic beverage obtained from extract of *Annona muricata* and *Strychnos spinosa* using a combination of microorganisms	NSO E. (MC) DESOBGO Z. S.C. (CC)
3	NSANGOU NCHARE Abdoulaye (22/06/1990 à Foumban)	13S177EN	M2 GP ENSAI, 2016	14,66	Optimisation du procédé de compostage par une modélisation des biotransformations	KAPSEU C. (Pr) MOHAMED Hafidi (Pr, Université Cadi Ayyad/Marrakech)
4	NZEUNOU Yvan martin (08/08/1988 à Mbo Bandjoun)	13S191EN	M2 GP ENSAI, 2016	14,78 A Bien	Production et caractérisation de de briquettes énergétiques à partir des coques de cacao	JIOKAP NONO Y (MC)
5	WIYEH Claudette BAKISU MUALA (11/03/1990 à Bamenda)	11I092EN	M2 GP ENSAI, 2016	15,72 Bien	Probiotic beverage from infusion of *Cymbopogon cibraties* and *Zingiber officinale* using a combination of microbial strains	NSO E. (MC) DESOBGO Zangue S.C. (CC)

Article 2 :(1) La durée réglementaire accordée à ces candidats pour la préparation du Doctorat/Ph.D est de six (06) à dix (10) semestres, à compter de l'année académique 2016-2017, année de la première inscription ;

(2) Pendant cette durée, le candidat sera tenu de :

- prendre chaque année académique une inscription qui lui confère la qualité d'étudiant ;
- participer aux séminaires de recherche organisés par son Unité de Formation Doctorale et d'y exposer périodiquement les étapes significatives de l'avancement de son travail.

Article 3 : Les intéressés sont invités à prendre attache avec le service de la scolarité de l'Ecole Nationale Supérieure des Sciences Agroindustrielles (ENSAI) pour les formalités d'inscription.

Article 4 : Les charges y afférentes seront supportées par le Budget autonome de l'Ecole Nationale Supérieure des Sciences Agroindustrielles (ENSAI), exercice 2017 ;

Article 5 : La présente décision sera enregistrée et communiquée partout où besoin sera.

Ngaoundéré, le 02 AOUT 2017

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON
Le Recteur
UNIVERSITY OF NGAOUNDERE
UNIVERSITE DE NGAOUNDERE

LE RECTEUR,

Pr. Uphie Chinje Melo

Ampliations :

- Vice-recteurs;
- SG/UN;
- DAAC/DEPE/UN;
- D/ENSAI
- DAAF/UN;
- CF/UN ;
- AC/UN ;
- Chefs de Département ;
- Responsables UFD ;
- Intéressés ;
- Chrono/Archives.

IV.3.c) Attestation d'encadrement des mémoires de Master

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf : 2019/108/UN/D.ENSAI

ATTESTATION D'ENCADREMENT DE MEMOIRES DE MASTER

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, a co-encadré les mémoires de Master soutenus à l'ENSAI dont le détail est présenté dans le tableau ci-après :

N°	Etudiants	Thèmes	Encadreurs	Date de soutenance
1	**Kadlezir Fiacre**	Optimisation de quelques paramètres physico-chimiques au cours de l'extraction du jus d'un cultivar de datte (*Phoenix dactylifera* L.).	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	10/11/2017
2	**Makebe Calister Wingang**	Optimisation of the extraction process and investigation on must fermentation of ripe plantains.	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	17/10/2016
3	**Wiyeh Claudette Bakisu Muala**	Influence of drying and mixture conditions on some physico-chemical characteristics of lemongrass	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	17/10/2016

		(*Cymbopogon citratus*) blended with ginger (*Zingiber officinale*) tea		
4	**Tiyou Jules P.**	Application des traitements hydrothermolyse et organosolv de solubilisation des fractions hémicellulosique et lignine des tiges de sorgho en vue de la production de bioéthanol	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	30/09/2014
5	**Nkoum Sem R.**	Optimising Sugar Release by the CSLF Technology and Dilute Acid Hydrolysis from Maize (*Zea mays* L.) Stalks as a Potential for Bioethanol Production	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	30/09/2014

En foi de quoi, la présente attestation lui est délivrée pour servir et valoir ce que de droit

Le Directeur

REPUBLIQUE DU CAMEROUN Republic of Cameroon
École Nationale Supérieure des Sciences Agro-Industrielles
Le Directeur
UNIVERSITY OF NGAOUNDERE UNIVERSITE DE NGAOUNDERE

Pr. Nso Emmanuel Jong

IV.3.d) Attestation d'encadrement des mémoires d'Ingénieur

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / Tél.: 237 222 25 40 36 / 222 25 40 22 / 679 82 88 00

Ngaoundéré, le 18 SEPT 2019

N/réf: 2019/109 /UN/D.ENSAI

ATTESTATION D'ENCADREMENT DE MEMOIRES D'INGENIEURS

Je soussigné, Pr NSO Emmanuel Jong, Directeur de l'Ecole Nationale Supérieure des Sciences Agro-Industrielles (ENSAI) de l'Université de Ngaoundéré, atteste que Dr DESOBGO Zangué Steve Carly, Chargé de Cours à l'Institut Universitaire de Technologie (IUT) de l'Université de Ngaoundéré, a co-encadré les mémoires d'Ingénieurs soutenus à l'ENSAI dont le détail est présenté dans le tableau ci-après :

N°	Etudiants	Thèmes	Encadreurs	Date de soutenance
1	**Fometeu Zamo Audrey Niquème**	Standardisation des teneurs en calcium et en acides aminés libres dans le moût en sortie salle à brasser	**Dr. Desobgo, Z.S.C.** **Dr Agwanande W.**	06/11/2018
2	**Chano Kuitche Gaëlle**	Maitrise du dioxyde de soufre en brasserie	**Dr. Desobgo, Z.S.C.** **Dr Agwanande W.**	06/11/2018
4	**Awah Noella**	Study of factors influencing saccharification during	**Pr Fombang Edith** **Dr. Desobgo, Z.S.C.**	06/11/2018
3	**AYOSSA-HANTHE Lonam**	Ameliorating beer brightness : case of SABC Douala and Yaounde factories	**Dr. Desobgo, Z.S.C.** **Dr Agwanande W.**	07/11/2018

5	**Minkoumou Augustin Caleb**	Management de la levure de brasserie en vue de l'amélioration de la qualité de la bière finie	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	07/11/2018
6	**Kamche Josianna Clarence**	Formulation des compotes à base de fruits tropicaux (Ananas, banane et papaye)	**Dr. Desobgo, Z.S.C.** **Dr Ngatchic J.**	07/11/2018
7	**Tset III Steve F.**	Amélioration des durées d'étapes et réduction des pertes en extrait pendant la filtration en salle de brassage 2	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	21/10/2017
8	**Nsoh Cyril Fru**	Production of a malt drink from sorghum	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	20/10/2017
9	**Tiemuncho Habass N.**	Model-based design: A novel mash tun, mashing and fermentation process simulation software for food process applications	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	20/10/2017
10	**Makamté Mukam F.**	Analyse du processus de fermentation à l'UCB : Cas de la King Beer	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	20/10/2017
11	**Kembeu Kaleu Pavell**	Maitrise de la durée des étapes et réduction de pertes d'extrait au cours de la filtration de la maïsche en salle de brassage 1	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	20/10/2017
12	**Metutu Kakoua Bessong V.**	Evaluation of the impact of roller mills on the quality of the final product (flour)	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	19/10/2017
13	**Fali Mbeh H.**	Production of sorghum coffee-milk stouts and modelling of some physicochemical characteristics	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	16/09/2016
14	**Takela Feudjo Moïse F.**	Evaluation et réduction des consommations d'eau au brassage	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	09/11/2016
15	**Nana Njouyep Mervil**	Amélioration et maitrise de la filtration de la maïsche	**Dr. Desobgo, Z.S.C.** **Mme Amba**	10/11/2016

16	**Nomo Nomo G.**	Amélioration et maitrise de l'amertume des bières isenberg et bière mère haute densité	**Dr. Desobgo, Z.S.C.** **Dr Fombang E.**	10/11/2016
17	**Mimboe Nomo Marie J.**	Reduction du taux de O_2 et amélioration et maitrise du taux de CO_2 dans la bière filtrée	**Dr. Desobgo, Z.S.C.** **M. Agwanandé W.**	09/11/2016
18	**Mufor Njukeng L.**	Modelling parameters for the production of DRP cocoa liquor on the discontinuous barth line	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	05/11/2014
19	**Minfoulou R.**	Maitrise du procédé d'acidification en vue de définir des standards de versements en salle à brasser	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	05/11/2014
20	**Arreneke Ayuk Etobi**	Feasibility study of biogas potentials of Lobé palm oil mill waste	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	05/11/2014
21	**Detsi Djiande P.**	Improvement of SABC ISB and HTS yeasts viability	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	05/11/2014
22	**Soppo Simon R.**	Optimisation de l'extraction de beurre de cacao artisanal	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	18/05/2013
23	**Oliva Angwewah Azobi**	Analyses of thermal exchange at the level of wort boiling	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	07/12/2012
24	**Vabi Vamuloh**	Valorisation of cocoa pod husks for biogas production	**Pr Nso, E. J.** **Dr. Desobgo, Z.S.C.**	07/12/2012

En foi de quoi, la présente attestation lui est délivrée pour servir et valoir ce que de droit

Le Directeur

REPUBLIQUF DU CAMEROUN Republic of Cameroon Ecole Nationale Supérieure des Sciences Agro-Industrielles Le Directeur UNIVERSITY OF NGAOUNDERE UNIVERSITE DE NGAOUNDERE

Pr. Nso Emmanuel Jong

IV.3.e) Procès-verbaux de soutenance et Photocopies certifiées des pages de garde de 05 Masters et 24 diplômes d’ingénieur

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON
Tel : 699871266/675 856 487/242 16 65 10/ 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

REPUBLIQUE DU CAMEROUN Republic of Cameroon — Ecole Nationale Supérieure des Sciences Agro-Industrielles — UNIVERSITE DE NGAOUNDERE — Le Directeur

Pr. Nko Emmanuel Jong

FICHE DE SYNTHESE DES NOTES[23] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **FOMETEU ZAMO AUDREY NIQUEME**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : **STANDARDISATION DES TENEURS EN CALCIUM ET EN ACIDES AMINES LIBRES EN SORTIE SALLE A BRASSER**

NOTE DE FOND	Maîtrise technique du sujet	18 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	9 /10
	Qualité de la prestation orale	9 /10
	Personnalité du candidat	9 /10
TOTAL		54 /60
MOYENNE	TBF	18 /20

OBSERVATIONS : Très bonne soutenance

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NGASSOUM**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR KAPSO**		
SIGNATURE			

DATE :

[23] Moyenne des notes attribuées par chaque membre du jury.

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Services de stages et de la formation continue

B.P.455 Ngaoundere, CAMEROON
Tel: 699 87 12 66 / 679 82 88 00 /242 16 65 10/ 675 85 64 87
E-mail : ensai_stages@yahoo.fr
http// :www.ensai.univ-ndere.cù

MEMOIRE DE FIN D'ETUDES

En vue de L'obtention du diplôme d'Ingénieur des Industries Agricoles et Alimentaires

STANDARDISATION DES TENEURS EN CALCIUM ET EN ACIDES AMINES LIBRES DANS LE MOUT EN SORTIE SALLE A BRASSSER

Stage effectué du 28 mai au 24 Septembre 2018 à l'usine SABC de Koumassi (Douala)

Groupe SABC

Rédigé et soutenu Par :

FOMETEU ZAMO Audrey Niquème
DUT en Industries Alimentaires et Biotechnologiques
Matricule : 15I020EN

Encadreur industriel :
M. FOKENG Amour Fabrice
Chef d'atelier brassage

Encadreurs académiques
Dr DESOBGO Steve
Chargé de cours, IUT
Dr AGWANANDE Wilson
Chargé de cours, ENSAI

Année académique : 2017-2018

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON
Tel : 699871266/675 856 487/242 16 65 10/ 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[7] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **AYOSSA-HANTHE LONAM**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : **AMELIORATION BEER BRIGHTNESS : CASE OF SABC DOUALA AND YAOUNDE FACTORIES**

Le Directeur
Pr. Nso Emmanuel Jong

NOTE DE FOND	Maîtrise technique du sujet	18 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	9 /10
	Qualité de la prestation orale	9 /10
	Personnalité du candidat	9 /10
TOTAL		54 /60
MOYENNE		18 /20

OBSERVATIONS : MENTION: TRES BIEN avec Félicitation
Une très bonne soutenance avec une méthodologie bien menée

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NSO**	NOM : **DR AGWANANDE**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR MEZAJOUG**		
SIGNATURE			

DATE : 07/11/2018

[7] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland
MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et la Scolarité
Service des Stages et de la Formation Continue
B.P. 455 - Ngaoundéré, CAMEROUN
Tel: 699 871 266 / 675 856 487 / 242 166 510 / 679 828 800
E-mail: ensai_stages@yahoo.fr
Site web: http://www.ensai.univ-ndere.cm

END OF COURSE INTERNSHIP REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF ENGINEERING (M. ENG) DEGREE IN AGRO-FOOD PROCESS ENGINEERING

Subject:

AMELIORATING BEER BRIGHTNESS: CASE OF SABC DOUALA AND YAOUNDE FACTORIES

Carried out from June 11 to September 28, 2018 in Douala Koumassi and Yaounde

Groupe SABC

Written and defended by:

AYOSSA-HANTHE Lonam
(15I005EN)
Food bio-processing technician

Industrial supervisor:
Mr. Louis AMBOMBO
Head of production department of the group SABC

Academic supervisor:
Dr AGWANANDE AMBINDEI Wilson
Senior lecturer, ENSAI

Dr DESOBGO ZANGUE Steve Carly
Senior lecturer, IUT

Pr. Nso Emmanuel Jong

Academic year: 2017 / 2018

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON
Tel : 699871266/675 856 487/242 16 65 10/ 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[6] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **AWAH NOELLA**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : **STUDY OF THE FACTORS INFLUENCING SACCHARIFICATION DURING THE MASHING PROCESS**

Pr. Nso Emmanuel Jong

NOTE DE FOND	Maîtrise technique du sujet	16,5/20
	Présentation des résultats	8,5/10
NOTE DE FORME	Clarté de la présentation	8,5/10
	Qualité de la prestation orale	8/10
	Personnalité du candidat	8/10
TOTAL		49,5/60
MOYENNE		16,5/20

OBSERVATIONS : Très Bonne soutenance, avec des propositions correctives importantes. Correction à faire avec les membres du jury

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NSO**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR KAPSO**		
SIGNATURE			

DATE : 05/11/2018

[6] Moyenne des notes attribuées par chaque membre du jury.

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Services de Stages et de la Formation Continue
B.P.455 - Ngaoundere, CAMEROON
Tel: 699 87 12 66 / 675 85 64 87 / 242 16 65 10 / 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ.ndere.cm

END OF COURSE PROJECT REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF ENGINEERING (M. ENG) DIPLOMA IN AGRO-FOOD PROCESS ENGINEERING

STUDY OF THE FACTORS INFLUENCING SACCHARIFICATION DURING THE MASHING PROCESS

Carried out from June 1tt to September 25th, 2018
at
SABC Garoua

Groupe SABC

Written and defended by:

AWAH NOELLA
DUT. in Industrial Food Processing and Biotechnology
Matricule: 15I004EN

Industrial supervisor:
Mr. MOUKON A ANONG
Head of the Brewing workshop

Academic supervisors:
Pr. FOMBANG Edith
Associate Professor, ENSAI
Dr. DESOBGO Steve
Lecturer, IUT

2017-2018 academic year

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON
Tel : 699871266/675 856 487/242 16 65 10/ 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[30] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **MINKOUMOU AUGUSTIN CALEB**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : **MANAGEMENT DE LA LEVURE DE BRASERIE EN VUE DE L'AMELIORATION DE LA QUALITE DE LA BIERE**

NOTE DE FOND	Maîtrise technique du sujet	18 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	9 /10
	Qualité de la prestation orale	9 /10
	Personnalité du candidat	9 /10
TOTAL		54 /60
MOYENNE	Très Bien avec Félicitations	18 /20

OBSERVATIONS : Très Bon travail présenté avec Brio et maîtrise

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NDJOUENKEU**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**MEZAJOUG**		
SIGNATURE			

DATE :

[30] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROUN
Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
Division des Affaires Académiques, de la coopération, de la Recherche et de la Scolarité
Service des stages et de la formation continue
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B.P:455 – Ngaoundéré. CAMEROUN
TEL : 699 871266 / 675 85 6487/ 679 82 88 00/ 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du
DIPLOME D'INGENIEUR DE CONCEPTION DES INDUSTRIES AGRICOLES ET ALIMENTAIRES.

MANAGEMENT DE LA LEVURE DE BRASSERIE EN VUE DE L'AMELIORATION DE LA QUALITE DE LA BIERE FINIE

Groupe SABC

Stage effectué au Groupe SABC Usine de Douala - Koumassi

Du 28 Mai au 26 septembre2018

Par:
MINKOUMOU Augustin Caleb
DUT en génie thermique et énergétique

Encadreur industriel :
Ing. NGANDO EDJENGUELE Achille
(Chef de département fabrication)

Encadreurs Académiques
Pr. NSO Emmanuel JONG
(Maitre de conférences, ENSAI)

Dr. DESOBGO ZANGUE Steve C.
(Chargé de Cours, IUT)

Année académique : 2017-2018

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON
Tel : 699871266/675 856 487/242 16 65 10/ 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[26] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **KAMCHE JOSIANNA CLARENCE**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : **FORMULATION DES COMPOTES A BASE DES FRUITS TROPICAUX**

NOTE DE FOND	Maîtrise technique du sujet	17 /20
	Présentation des résultats	8,5 /10
NOTE DE FORME	Clarté de la présentation	8,5 /10
	Qualité de la prestation orale	8,5 /10
	Personnalité du candidat	8,5 /10
TOTAL		51 /60
MOYENNE	Très Bien	17 /20

OBSERVATIONS : Travail très intéressant avec des perspectives axées sur le plan de la recherche, technologique et de marché

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NDJOUENKEU**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**MME AMBA**		
SIGNATURE			

DATE :

[26] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
****
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
****
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
****
MINISTRY OF HIGHER EDUCATION
****
THE UNIVERSITY OF NGAOUNDERE

ENSAI

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
National Advanced School of Agro - Industrial Sciences
Division des Affaires Académiques, de la Recherche, de la Coopération et de la Scolarité (DAARCS)
Service des stages et de la formation continue
B.P. *455 Ngaoundéré, CAMEROUN*
Tel : 699-871-266/675-856-487/679-828-800/242-166-510
E-mail : ensai_recherche@yahoo.fr
http:// www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du diplôme d'ingénieur des Industries Agricoles et Alimentaires (IAA)

FORMULATION DES COMPOTES A BASE DE FRUITS TROPICAUX (Ananas, banane et papaye).

Stage effectué du 13 Juin au 18 Octobre au Laboratoire de Génie et Technologie Alimentaire (GETA) de l'ENSAI de Ngaoundéré

Par :

KAMCHE Josianna Clarence

(Licenciée en biochimie option biochimie clinique)

Matricule : 15I021EN

REPUBLIQUE DU CAMEROUN Republic of Cameroon — Ecole Nationale Supérieure des Sciences Agro-Industrielles — Le Directeur — UNIVERSITY OF NGAOUNDERE — UNIVERSITE DE NGAOUNDERE

P. Nso Emmanuel Jong

Encadreur industriel :

Dr. DESOBGO ZANGUE S. C.
(Chargé de cours à l'IUT)

Encadreurs académiques :

Dr. DESOBGO ZANGUE S. C.
(Chargé de cours à l'IUT)

Dr. NGATCHIC Josiane
(Chargé de cours à l'ENSAI)

Année académique : 2017/2018

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON
Tel : 699871266/675 856 487/242 16 65 10/ 679 82 88 00
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[13] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **CHANO KUITCHE GAELLE**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : **MAITRISE DU DIOXYDE DE SOUFRE EN BRASSERIE**

NOTE DE FOND	Maîtrise technique du sujet	13 /20
	Présentation des résultats	8 /10
NOTE DE FORME	Clarté de la présentation	7,5 /10
	Qualité de la prestation orale	7,5 /10
	Personnalité du candidat	7,5 /10
TOTAL		43,5 /60
MOYENNE		14,5 /20

Bien

OBSERVATIONS : Modifier le titre et se rapprocher des membres du jury pour les corrections. Sujet d'actualité pour l'entreprise mais pas suffisamment abordé par le Candidat

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NGAH**	NOM : ~~**DR AGWANANDE**~~ Dr. DEBOUGO
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR MBOUGA**		
SIGNATURE			

DATE :

[13] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN

Paix –Travail –Patrie

**

Ministère de l'Enseignement Supérieur

**

Université de Ngaoundéré

REPUBLIC OF CAMEROON

Peace –Work – Fatherland

**

Ministry Of Higher Education

**

The University of Ngaoundéré

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGROINDUSTRIELLES /NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la coopération, de la Recherche et de la Scolarité

Service des Stages et de la Formation Continue

B.P:455 Ngaoundéré, CAMEROON

Tel : 699871266 / 675 856 487/ 242 16 65 10/ 679 82 88 00

Email : ensai_stages@yahoo.fr

https://www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du Diplôme d'Ingénieur des Industries Agricoles et Alimentaires (IAA)

Thème

MAITRISE DU DIOXYDE DE SOUFRE EN BRASSERIE

Stage effectué du 01 Juin au 28 Septembre 2018 à la SABC – Usine de Yaoundé

Groupe SABC

REDIGE PAR :

CHANO KUITCHE Gaëlle (15I010EN)

Licence en Biologie Animale

Encadreur industriel :

Yves JEMMY

Chef fabrication

Encadreurs Académiques :

Dr. DESOBGO Steve. C

Chargé de Cours, ENSAI

Dr. Wilson AGWANANDE A.

Chargé de Cours, ENSAI

Année académique 2017-2018

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / FAX: +237 22-15-81-89
Tel : +237 22 16 65 00

CYCLE DES FORMATIONS MASTER
Rapport de soutenance de mémoire de Master recherche

OPTION (SAN, GP, CIE, IEAI) :.....GPI.....

Nom du candidat : .. TIYOU JULES PATRICK.. Matricule..11S199EN.....
Date de naissance :..23/05/1987..... lieu de naissance : .....MAROUA.....
Titre du mémoire : ..Application des traitements hydrothermolye et organsolv de solubilisation des fractions hémicellulose et lignine des tiges de sorgho en vue de la production du bioéthanol.....
Encadreurs : ...Pr NSO E ; Dr DESOBGO.S.....

Appréciation du jury

Pr. Nso Emmanuel Jong

A) MEMOIRE :	
Rédaction et Présentation (note/20)	16.0
Fond – Valeur Scientifique et Technique (note/30)	22.0
Total mémoire (note/50)	38.0
B) SOUTENANCE :	
i) NOTE DE FORME :	
Clarté de la présentation (note/10)	8.5
Qualité de la prestation (note/5)	4.0
Personnalité du candidat (note/5)	4.0
ii) NOTE DE FOND :	
Maîtrise scientifique et technique du sujet (note/15)	13.0
Présentation, et discussion des résultats (note/15)	12.5
Total soutenance (note/50)	42
I- Total (mémoire + soutenance) note/100	80
II- Mention Très Bien	16.0

REMARQUES DU JURY :
Réduire le volume de références à l'essentiel. Restructurer l'introduction. Reformuler les conclusions. Renforcer les perspectives.
Très bon travail exposé de manière très claire.

Décision du jury : **ADMIS/REFUSE**

LE JURY

Président KAYEM Jam **Membres** Dr. P.D. MBOUGUENG

Rapporteur Dr. Steve Cobly DESOBGO

Date de la soutenance.....

REPUBLIQUE DU CAMEROUN

Paix-Travail-Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON

Peace-Work-Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES

NATIONAL ADVANCED SCHOOL OF AGRO-INDUSTRIAL SCIENCES

BP: 455 NGAOUNDERE-CAMEROUN TEL/FAX: (+237) 22 15 81 89

DEPARTEMENT DE GENIE DES PROCEDES ET D'INGENIERIE

DEPARTMENT OF PROCESS ENGINEERING

APPLICATION DES TRAITEMENTS HYDROTHERMOLYSE ET ORGANOSOLV DE SOLUBILISATION DES FRACTIONS HEMICELLULOSIQUE ET LIGNINE DES TIGES DE SORGHO EN VUE DE LA PRODUCTION DU BIOÉTHANOL

Mémoire présenté en vue de l'obtention du Diplôme de Master en Génie des Procédés et Ingénierie

Parcours : Génie Alimentaire et Bioprocédés

Par :

TIYOU Jules Padrik

Matricule : 11S199EN

Licencié ès Sciences (Parcours Chimie)

Pr. Nso Emmanuel Jong

Sous la Direction de :

NSO EMMANUEL JONG

Maitre de Conférences

ENSAI

Université de Ngaoundéré

DESOBGO ZANGUE STEVE C.

Chargé de Cours

IUT

Université de Ngaoundéré

Année académique 2012 - 2013

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / FAX: +237 22-15-81-89
Tel : +237 22 16 65 00

CYCLE DES FORMATIONS MASTER

Rapport de soutenance de mémoire de Master recherche

OPTION (SAN, GP, CIE, IEAI) :.....GPI.....

Nom du candidat : .. NKOUM SEM RONALD.. Matricule..11S198EN.....
Date de naissance :..27/05/1988..... lieu de naissance : .....KRIBI.....
Titre du mémoire : ..Optimising sugar release by the cellulose solvent-based lignocellulosic fractionation technology and dilute acid hydrolysis from maise stalks as a potential for bioethanol production.
Encadreurs : ...~~Pr KAPSEU César ; Pr TCHEUKAM TOKO~~ Pr. NSO E. et Dr. MESOB60

Appréciation du jury

A) MEMOIRE :

Rédaction et Présentation (note/20)	15
Fond – Valeur Scientifique et Technique (note/30)	20
Total mémoire (note/50)	35

B) SOUTENANCE :

i) NOTE DE FORME :

Clarté de la présentation (note/10)	8
Qualité de la prestation (note/5)	3,75
Personnalité du candidat (note/5)	3

ii) NOTE DE FOND :

Maîtrise scientifique et technique du sujet (note/15)	13
Présentation, et discussion des résultats (note/15)	13,5
Total soutenance (note/50)	41,25
I- Total (mémoire + soutenance) note/100	82,5
II- Mention TB	TB

REMARQUES DU JURY :
L'étudiant a fait une bonne présentation des résultats. Impressionnants obtenus. Cet étudiant est d'une qualité et l'étudiant devra prendre en compte les différentes remarques des jury.

Décision du jury : **ADMIS/REFUSE**

LE JURY

Président Pr. C. KAPSEU **Membres** Dr. P.D. MBOUGUENG

Rapporteur Pr. NSO E.

Date de la soutenance....30/09/2014

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROUN
Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL ADVANCED SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B.P:455 Ngaoundéré-CAMEROUN Tel / Fax: (+237) 22 15 81 89

DEPARTEMENT DEGENIE DES PROCEDES ET INGENIERIE
DEPARTMENT OFPROCESS ENGINEERING

OPTIMISING SUGAR RELEASE BY THE CELLULOSE SOLVENT-BASED LIGNOCELLULOSIC FRACTIONATION (CSLF) TECHNOLOGY AND DILUTE ACID HYDROLYSIS FROM MAIZE (*Zeamays L.*) STALKS AS A POTENTIAL FOR BIOETHANOL PRODUCTION

Submitted in Partial Fulfilment of the Requirements for the Award of a Masters Degree in Process Engineering

Specialty: Food and Bioprocess Engineering

By:

NKOUM SEM Ronald

Matriculation number: 11S198EN
Professional Bachelors' Degree in Biological Engineering (Specialty: Food processing and Biotechnology)

Supervised by

NSO Emmanuel JONG
Associate Professor
ENSAI
University of Ngaoundere

Steve Carly DESOBGO
Senior lecturer
IUT
University of Ngaoundere

Academic year 2012 - 2013

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / FAX: +237 22-15-81-89
Tel : +237 22 16 65 00

CYCLE DES FORMATIONS MASTER
Rapport de soutenance de mémoire de Master recherche

OPTION (SAN, GP, CIE, IEAI) :.....GP.....

Nom du candidat : ..**MAKEBE Calister Wingang** .....Matricule.. .....
Date de naissance :. ..... lieu de naissance :.....
Titre du mémoire : .
Encadreurs : **Pr NSO Emmanuel et Dr DESOBGO Z.S.C.**

Pr. Nso Emmanuel Jong

Appréciation du jury

B) MEMOIRE :

Rédaction et Présentation (note/20)	18
Fond – Valeur Scientifique et Technique (note/30)	24,5
Total mémoire (note/50)	42,5

B) SOUTENANCE :

i) NOTE DE FORME :	
Clarté de la présentation (note/10)	9
Qualité de la prestation (note/5)	4,75
Personnalité du candidat (note/5)	3
ii) NOTE DE FOND :	
Maîtrise scientifique et technique du sujet (note/15)	14
Présentation, et discussion des résultats (note/15)	14
Total soutenance (note/50)	43,75
III- Total (mémoire + soutenance) note/100	87,5
IV- Mention Très Bien avec felicitation du jury	17,5

REMARQUES DU JURY :
Très bonne présentation. Travail intéressant avec de bonnes perspectives au niveau Industriel.

Décision du jury : **ADMIS/REFUSE**

LE JURY

Président Pr KAPSEU C. **Membres**

Rapporteur Pr NSO E. **Dr MBOUGUENG P.D.**

Date de la soutenance..17 10 2016.....

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité

B.P.455 Ngaoundere, CAMEROON Tel/Fax: (+237) 22 25 40 72

DEPARTEMENT DE GENIE DES PROCEDES ET D'IMGENIERIE
DEPARTMENT OF PROCESS ENGINEERING

OPTIMISATION OF THE EXTRACTION PROCESS AND INVESTIGATION ON MUST FERMENTATION OF RIPE PLANTAINS (*Musa Paradisiaca*)

A thesis submitted in partial fulfilment of the requirements for the award of a Research Master of Science and Technology Degree in Process Engineering

Specialty:
Food Engineering and Bioprocessing

By:
MAKEBE Calister WINGANG
Matriculation Nº: 11I068EN
M. Eng Agro-Food Processing

Pr NSO Emmanuel Song

Project Director:
Pr. NSO Emmanuel
(ENSAI)

Project Supervisor:
Dr DESOBGO Steve
(IUT)

Academic year: 2014-2015

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / FAX: +237 22-15-81-89
Tel : +237 22 16 65 00

CYCLE DES FORMATIONS MASTER
Rapport de soutenance de mémoire de Master recherche

OPTION (SAN, GP, CIE, IEAI) :.....GP.....

Nom du candidat : ..**WIYEH Claudette Bakisu Muala** .....Matricule.. .....
Date de naissance :. ..... lieu de naissance :.....
Titre du mémoire : .
Encadreurs : **Pr NSO Emmanuel et Dr DESOBGO Z.S.C.**

REPUBLIQUE DU CAMEROUN Republic of Cameroon — Ecole Nationale Supérieure des Sciences Agro-Industrielles — Le Directeur — UNIVERSITY OF NGAOUNDERE — UNIVERSITE DE NGAOUNDERE

Pr. Nso Emmanuel Jong

Appréciation du jury

C) MEMOIRE :	
Rédaction et Présentation (note/20)	16
Fond – Valeur Scientifique et Technique (note/30)	24
Total mémoire (note/50)	40
B) SOUTENANCE :	
i) NOTE DE FORME :	
Clarté de la présentation (note/10)	8
Qualité de la prestation (note/5)	4
Personnalité du candidat (note/5)	4
ii) NOTE DE FOND :	
Maîtrise scientifique et technique du sujet (note/15)	13
Présentation, et discussion des résultats (note/15)	13
Total soutenance (note/50)	42,5
V- Total (mémoire + soutenance) note/100	82,5
VI- Mention Très Bien	165

REMARQUES DU JURY : Très bonne présentation avec des perspectives intéressantes pour la valorisation des résultats sur les plans Agro-Industriel.

Décision du jury : **ADMIS/~~REFUSE~~**

LE JURY

Président Pr KAPSEU C.	**Membres**
Rapporteur Dr DESOBGO Z.S.C.	**Dr MBOUGUENG P.D.**

Date de la soutenance..17 10 2016.....

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité

B.P.455 Ngaoundere, CAMEROON Tel/Fax: (+237) 22 25 40 72

DEPARTEMENT DE GENIE DES PROCEDES ET D'IMGENIERIE
DEPARTMENT OF PROCESS ENGINEERING

INFLUENCE OF DRYING AND MIXTURE CONDITIONS ON SOME PHYSICO-CHEMICAL CHARACTERISTICS OF LEMONGRASS (*Cymbopogon citratus*) BLENDED GINGER (*Zingiber officinale*) TEA

A thesis submitted in partial fulfilment of the requirements for the award of a Research Master of Science and Technology Degree in Process Engineering

Specialty:
Food Engineering and Bioprocessing

By:
WIYEH CLAUDETTE BAKISU MUALA
Matriculation Nº: 11I092EN
M. Eng Agro-Food Processing

Project Director:
Pr. NSO Emmanuel
Associate professor, ENSAI

Project Supervisor:
Dr DESOBGO Steve
Senior lecturer, IUT

Academic year: 2014-2015

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
B. P. 455 – Ngaoundéré, CAMEROON / FAX: +237 22-15-81-89
Tel : +237 22 16 65 00

CYCLE DES FORMATIONS MASTER
Rapport de soutenance de mémoire de Master recherche

OPTION (SAN, GP, CIE, IEAI) :.....GP.....

Nom du candidat :. **Kadlezir Fiacre**..... Matricule... **14S173EN**.....
Date de naissance :..... lieu de naissance : .....
Titre du mémoire : **Optimisation de quelques paramètres physico-chimiques au cours de l'extraction du jus d'un cultivar de datte (*Phoenix dactylifera L.*)**
Encadreurs : Pr. NSO Emmanuel JONG ; Dr. DESOBGO ZANGUE Steve Carly

Appréciation du jury

G) MEMOIRE :

Rédaction et Présentation (note/20)	15
Fond – Valeur Scientifique et Technique (note/30)	22,5
Total mémoire (note/50)	37,5

B) SOUTENANCE :

i) NOTE DE FORME :

Clarté de la présentation (note/10)	8,5
Qualité de la prestation (note/5)	4,5
Personnalité du candidat (note/5)	4,5

ii) NOTE DE FOND :

Maîtrise scientifique et technique du sujet (note/15)	12,5
Présentation, et discussion des résultats (note/15)	12,5
Total soutenance (note/50)	40,5
XIII- Total (mémoire + soutenance) note/100	80
XIV- Mention	TB 16

REMARQUES DU JURY :
Bonne présentation avec des perspectives intéressantes pour la valorisation de la datte

Décision du jury : **ADMIS/REFUSE**

LE JURY

Président : Pr Kapseu César **Membre : Dr Mbougueng Pierre**

Rapporteur : Dr Desobgo Zangue

Date de la soutenance..10/11/17.....

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO - INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
BP: 455 Ngaoundéré, Cameroun http://ensai-iut.minesup.gov.com e-mail: ensai_stages@yahoo.fr

DEPARTEMENT DE GENIE DES PROCEDES ET INGENIERIE

Sujet

OPTIMISATION DE QUELQUES PARAMETRES PHYSICO-CHIMIQUES AU COURS DE L'EXTRACTION DU JUS D'UN CULTIVAR DE DATTE (*Phoenix dactylifera* L.)

MÉMOIRE PRESENTE EN VUE DE L'OBTENTION DU DIPLOME DE MASTER EN

GENIE DES PROCEDES ET INGENIERIE
Parcours : **Génie Alimentaire et Bioprocédés (GABP)**

Par:
Kadlezir Fiacre
Matricule: 14S173EN
Bachelor en Génie des Procédés de production et d'expertise analytique

Sous la Direction de :

Pr NSO Emmanuel JONG
Maitre de Conférences
ENSAI

Dr DESOBGO ZANGUE Steve C.
Chargé de Cours
IUT

Année académique: 2015/2016

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[48] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **TSET III Steve Ferdinand**
FILIERE : Industries Agricoles et Alimentaire
SUJET DU MEMOIRE : AMELIORATION DES DUREE D'ETAPES ET REDUCTION DES PERTES EN EXTRAIT PENDANT LA FILTRATION EN SALLE DE BRASSAGES 2

NOTE DE FOND	Maîtrise technique du sujet	16 /20
	Présentation des résultats	8 /10
NOTE DE FORME	Clarté de la présentation	8 /10
	Qualité de la prestation orale	8 /10
	Personnalité du candidat	8 /10
TOTAL		48 /60
MOYENNE		16 /20

OBSERVATIONS : Très bonne soutenance, résultats palpables

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR TIEUDJO**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR FOTSA**		
SIGNATURE			

DATE : 21/10/2017

[48] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
****
Paix – Travail – Patrie
****
Ministère de l'enseignement supérieur
****
UNIVERSITE DE NGAOUNDERE
****

REPUBLIC OF CAMEROON
****
Peace –Work – Fatherland
****
Ministry of higher education
****
THE UNIVERSITY OF NGAOUNDERE
****

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL ADVANCED SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P:455 Ngaoundéré, CAMEROUN
Tel. : 699 871 266 / 675 856 487 / 242 166 510 /679 828 800
E-mail : ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du

DIPLOME D'INGENIEUR DES INDUSTRIES AGRICOLES ET ALIMENTAIRES

AMELIORATION DES DUREES D'ETAPES ET REDUCTION DE PERTES EN EXTRAIT PENDANT LA FILTRATION EN SALLE DE BRASSAGE 2

Effectué à la SABC, Usine CP de Yaoundé
Du 23 Mai au 15 Septembre 2017

Groupe SABC

Par

TSET III Steve Ferdinand

Matricule : 14I044EN

(Licence en Biochimie)

Encadreur industriel

M. TELEWO Nicaise

Adjoint chef service fabrication

Encadreurs académiques

Pr. NSO Emmanuel

Maître de conférences, ENSAI

Dr. DESOGBO Steve

Chargé de cours ,IUT

Année académique
2016/2017

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[42] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **NSOH CYRIL FRU**
FILIERE : Industries Agricoles et Alimentaire
SUJET DU MEMOIRE : PRODUCTION OF A MALT DRINK FROM SORGHUM

NOTE DE FOND	Maîtrise technique du sujet	17/20
	Présentation des résultats	8 /10
NOTE DE FORME	Clarté de la présentation	8 /10
	Qualité de la prestation orale	8,5/10
	Personnalité du candidat	8,5/10
TOTAL		51/60
MOYENNE		17 /20

OBSERVATIONS : Très bon travail, original et pertinent. Se rapprocher des Membres du Jury pour corrections à apporter

TB

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR TCHIEGANG**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR FONGANG**		
SIGNATURE			

DATE : 20/10/2017

[42] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland
MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P. 455 – Ngaoundéré, CAMEROUN/
Tel: 699 87 12 66/ 675 856 487/679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

END OF COURSE PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of a Masters of Engineering degree in Industrial Agro-food processing (IAA)

PRODUCTION OF A MALT DRINK FROM SORGHUM GRAINS

From the 15th of May to the 15th of September, 2017 CARRIED OUT AT THE GETA LABORATORY OF ENSAI

Written and Presented By:
NSOH CYRIL FRU
Registration N°: 14I039EN
DUT. Industrie Alimentaire et Biotechnologie (IAB)

Industrial supervisor:

- **Dr. DESOBGO**
  Senior Lecturer, IUT

Academic supervisors

- **Pr. NSO**
  Associate Professor, ENSAI
- **Dr. DESOBGO**
  Senior Lecturer, IUT

Academic year 2016/2017

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[47] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **TIEMUNCHO HABASS NOULAMBEH**
FILIERE : Industries Agricoles et Alimentaire
SUJET DU MEMOIRE : MODEL - BASED DESIGN: A NOVEL MASH TUN, MASHING AND FERMENTATION PROCESS SIMULATION SOFTWARE FOR FOOD PROCESS APPLICATION

NOTE DE FOND	Maîtrise technique du sujet	18,5 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	9 /10
	Qualité de la prestation orale	9,5 /10
	Personnalité du candidat	9,5 /10
TOTAL		55,5 /60
MOYENNE		18,5 /20

OBSERVATIONS : Sujet très original et porteur, doté d'aplications pratiques conduisant à la production d'un equipement qui peut être utilisé dans la facilitation des procesus transicoles de cereales locales. Très Bien Avec Felicitations

I- **JURY**

PRESIDENT	RAPPORTEUR
NOM : **PR FOMBANG**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR FONGANG**		
SIGNATURE			

DATE : 20/10/2017

[47] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland
MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P. 455 – Ngaoundéré, CAMEROUN/
Tel: 699 871 266 / 675 856 487 / 679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

END OF COURSE PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of a Masters of Engineering degree in Industrial Food Process Engineering (IAA)

Model-Base Design: A Novel Hybrid Mash Tun, A Mashing and Fermentation Process Simulation Software for Food Process Applications

Carried out at Laboratoire de Genie Alimentaire(LAGETA) from the 15st of may to the 15th of October 2017

Written and Presented By:

TIEMUNCHO HABASS NOULAMBEH
Registration N°: 14I043EN
DUT. (Hons). Industries Alimentaires et Biotechnologies(IAB)

Academic Advisors

- **NSO EMMANUEL**
  Associate Professor, ENSAI
- **DESOBGO STEVE**
  Senior Lecturer, IUT

LAGETA

Academic year 2016/2017

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[33] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **MAKAMTE MUKAM FREDYANE**
FILIERE : Industries Agricoles et Alimentaire
SUJET DU MEMOIRE : ANALYSE DU PROCESSUS DE FERMENTATION A L'UCB : CAS DE LA KING BEER

NOTE DE FOND	Maîtrise technique du sujet	17/20
	Présentation des résultats	8,5/10
NOTE DE FORME	Clarté de la présentation	8,5/10
	Qualité de la prestation orale	9/10
	Personnalité du candidat	8/10
TOTAL		51/60
MOYENNE	TRES BIEN	17/20

OBSERVATIONS : Très bonne soutenance avec les résultats déjà appliqués. Voir les membres du jury pour les corrections

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PRÉSIDENT : PR NDI**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR AGWANANDE**		
SIGNATURE			

DATE : 20/10/2017

[33] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[30] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **KEMBEU KALEU PAVELL**
FILIERE : Industries Agricoles et Alimentaire
SUJET DU MEMOIRE : MAITRISE DE LA DUREE DES ETAPES ET REDUCTION DE PERTES D'EXTRAIT AU COURS DE LA FILTRATION DE LA MAÏSCHE EN SALLE DE BRASSAGE 1

NOTE DE FOND	Maîtrise technique du sujet	18 /20
	Présentation des résultats	9/10
NOTE DE FORME	Clarté de la présentation	9/10
	Qualité de la prestation orale	9/10
	Personnalité du candidat	9/10
TOTAL		54/60
MOYENNE	Très Bien avec félicitations du Jury	18 /20

OBSERVATIONS : Très Bonne Présentation, travail très intéressant avec une application en entreprise indéniable

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR MBAWALA**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR KOFA**		
SIGNATURE			

DATE : 20/10/2017

[30] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix-Travail-Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace-Work-Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES *AGRO*-INDUSTRIELLES
NATIONAL ADVANCED SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P: 455 Ngaoundéré, CAMEROUN
Tél : 699871266/ 675826487/ 242166510/ 679828800
Email : ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

Mémoire de stage fin d'études

En vue de l'obtention du
Diplôme d'ingénieur en Industries Agricoles et Alimentaires

THEME :

MAITRISE DE LA DUREE DES ETAPES ET REDUCTION DES PERTES D'EXTRAIT AU COURS DE LA FILTRATION DE LA MAISCHE EN SALLE DE BRASSAGE 1

Stage effectué du 22 Mai au 07 Septembre 2017 au sein de
la Société Anonyme des Brasseries du Cameroun

Groupe SABC
Centre de production de Yaoundé

Rédigé et Soutenu Par :
KEMBEU KALEU Pavell
(141029EN)
DUT en Analyses Biologiques et Biochimiques

Encadreurs industriels
Ing. JEMMY YVES
Chef service fabrication
Ing. TELEWO Nicaise
Chef atelier brassage

Encadreurs académiques
Pr. NSO Emmanuel
Maître de Conférences à l'ENSAI
Dr. DESOBGO Steve
Chargé de Cours à l'IUT de Ngaoundéré

Année académique : 2016/2017

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[36] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **METUTU KAKOUA BESSONG Vanessa**
FILIERE : Industries Agricoles et Alimentaire
SUJET DU MEMOIRE : EVALUATION OF THE IMPACT OF ROLLER MILLS ON THE QUALITY OF THE FINAL PRODUCT (FLOUR)

Mpcc

NOTE DE FOND	Maîtrise technique du sujet	/20
	Présentation des résultats	/10
NOTE DE FORME	Clarté de la présentation	/10
	Qualité de la prestation orale	/10
	Personnalité du candidat	/10
TOTAL		/60
MOYENNE	18	/20

OBSERVATIONS : Mention très bien
Très bonne soutenance pour un sujet in situ
I- JURY Bien les équipements ; Courageuse aurez su modifier les paramètres industriels et complémenté avec succès les corrections

PRESIDENT	RAPPORTEUR
NOM : **PR TCHIEGANG**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**M. AJEBESSONE**		
SIGNATURE			

DATE : 19/10/19

[36] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix -Travail-Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace-Work-Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P. 455 – Ngaoundéré, CAMEROON/
Tel: (+237) 699 871 266 / 675 856 487 / 679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

END OF COURSE PROJECT REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTERS OF ENGINEERING DEGREE IN AGRO FOOD PROCESS ENGINEERING

EVALUATION OF THE IMPACT OF ROLLER MILLS ON THE QUALITY OF THE FINAL PRODUCT (FLOUR)

Carried out from the 22nd of May to the 22nd of August 2017

Energy & Quality
LA PASTA S.A.
Certifiée ISO 9001 : 2008

Written and Presented By:

METUTU KAKOUA BESSONG VANESSA

Matriculation No. 14I024EN

BSc. (Hons). Biochemistry

INDUSTRIAL SUPERVISOR
Eng. SOULE Manou
Head of Quality Control Laboratory

ACADEMIC SUPERVISORS
Pr. NSO Emmanuel
Associate Professor, ENSAI
Dr. DESOBGO Steve
Senior Lecturer, IUT

ACADEMIC YEAR 2016/2017

REPUBLIQUE DU CAMEROUN REPUBLIC OF CAMEROON
Paix – Travail – Patrie Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR MINISTRY OF HIGHER EDUCATION
UNIVERSITE DE NGAOUNDERE THEUNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES
AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[1] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **FALI MBEH Harry**
FILIERE : Industries Alimentaires et Agricoles (IAA)
SUJET DU MEMOIRE : PRODUCTION OF SORGHUM COFFEE-MILK STOUTS AND MODELLING OF SOME PHYSICOCHEMICAL CHARACTERISTICS

NOTE DE FOND	Maîtrise technique du sujet	17 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	7 /10
	Qualité de la prestation orale	7 /10
	Personnalité du candidat	7 /10
TOTAL		54 /60
MOYENNE	TB / Félicitations	18 /20

OBSERVATIONS : Travail original, maîtrisé et très bien présenté. Très bon Jury et très recherché

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **Pr NDJOUENKEU**	NOM : **Dr DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**M. AGWANANDE**		
SIGNATURE			

DATE : 16/05/2016

[1] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[36] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **TAKELA FEUDJO MOISE F**
FILIERE : Chimie Industrielle et Génie d'Evironnement
SUJET DU MEMOIRE : EVALUATION ET REDUCTION DES CONSOMMATIONS D'EAU AU BRASSAGE

NOTE DE FOND	Maîtrise technique du sujet	16	/20
	Présentation des résultats	8	/10
NOTE DE FORME	Clarté de la présentation	8	/10
	Qualité de la prestation orale	8	/10
	Personnalité du candidat	8	/10
TOTAL		48	/60
MOYENNE		16	/20

OBSERVATIONS : Très bonne soutenance, approche théorique TP à revisiter

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NDI**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR KAMLA**		
SIGNATURE			

DATE : 09/11/2016

[36] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[29] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **NANA NJOUYEP MERVIL**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : AMELIORATION ET MAITRISE DE LA FILTRATION DE LA MAISCHE

NOTE DE FOND	Maîtrise technique du sujet	15 /20
	Présentation des résultats	7,5 /10
NOTE DE FORME	Clarté de la présentation	7,5 /10
	Qualité de la prestation orale	7,5 /10
	Personnalité du candidat	7,5 /10
TOTAL		45 /60
MOYENNE		15 /20

OBSERVATIONS : Mention Bien

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NDI**	NOM : **MME AMBA**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR FOMBANG**		
SIGNATURE			

DATE :

[29] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROUN
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service de Stages et de la Formation Continue
B.P. 455 – Ngaoundéré, CAMEROON /
Tel : 699871266 / 675856487 / 679828800 /242166510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du diplôme d'ingénieur des Industries Agricoles et Alimentaires

AMELIORATION ET MAITRISE DE LA FILTRATION DE LA MAISCHE A L'USINE SABC DE YAOUNDE

Effectué à la SABC, Usine CP de Yaoundé
Du 08 Juin au 30 Septembre 2015

Rédigé et soutenu par : NANA DJOUYEP MERVIL,
Licence ès Science option Physique-Chimie
Matricule : 13I027EN

Encadreur industriel
Ing. Nicaise TELEWO
Adjoint chef service fabrication

Encadreurs Académiques
Dr. DESOBGO
Chargé de cours à L'UIT Ngaoundéré
Mme. AMBA
Assistant ENSAI Ngaoundéré

Année Académique 2015/2016

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[35] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **NOMO NOMO GHISLAINE**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : AMELIORATION ET MAITRISE DE L'AMERTUME DES BIERES ISENBERG ET BIERE MERE HAUTE DENSITE

NOTE DE FOND	Maîtrise technique du sujet	18 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	9 /10
	Qualité de la prestation orale	9 /10
	Personnalité du candidat	9 /10
TOTAL		54 /60
MOYENNE		18 /20

OBSERVATIONS : Très Bien avec Felicitation du Jury. Très bonne soutenance, une identification des causes et application des mesures correctives ont permis à la candidate de valider le problematique et resoudre le problème en partie

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NSO**	NOM : **DR FOMBANG**
SIGNATURE :	SIGNATURE : FENAG

AUTRES MEMBRES			
NOM	**M. AGWANANDE**		
SIGNATURE			

DATE : 10/11/2016

[35] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P. 455 – Ngaoundéré, CAMEROUN /
Tel : 699 871 266 / 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http: // www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du diplôme d'ingénieur des industries agricoles et alimentaires

IDENTIFICATION ET CORRECTION DES CAUSES DE FLUCTUATION DE L'AMERTUME DE LA BIERE MERE HAUTE DENSITE A LA SABC USINE DE YAOUNDE

Effectué à la SABC, Usine de Yaoundé
Du 08 Juin au 30 Septembre 2016

Rédigé et soutenu par : NOMO NOMO Ghislaine,
Matricule : 13I034EN
Licence **ès** Biologie des Organismes animaux

Encadreur industriel

M. Robert NDOMBI,
Adjoint chef service fabrication

Encadreurs académiques

Dr. FOMBANG,
Chargé de cours à l'ENSAI
Dr DESOBGO,
Chargé de Cours à l'IUT

Année Académique 2015/2016

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tél. : : 699 871 266/ 675 856 487 /679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[26] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **MIMBOE NOMO MARIE JOSEPH**
FILIERE : Industries Agricoles et Alimentaires
SUJET DU MEMOIRE : REDUCTION DU TAUX DE 02 ET AMELIORARATION ET MAITRISE DU TAUX DE CO2 DANS LA BIERE FILTREE

NOTE DE FOND	Maîtrise technique du sujet	18 /20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	9 /10
	Qualité de la prestation orale	9 /10
	Personnalité du candidat	9 /10
TOTAL		54 /60
MOYENNE		18 /20

OBSERVATIONS : Mention Très Bien avec Félicitations

I- JURY

PRESIDENT	RAPPORTEUR
NOM : **PR NSO**	NOM : **DR DESOBGO**
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	**DR BIKE**		
SIGNATURE			

DATE : 09/11/2016

[26] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland
MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P. 455 – Ngaoundéré, CAMEROUN /
Tel: 699 871 266/ 675 856 487/ 679 828 800 / 242 166 510
ensai_stages@yahoo.fr
http: // www.ensai.univ-ndere.cm

MEMOIRE DE FIN D'ETUDES

En vue de l'obtention du diplôme d'ingénieur des industries agricoles et alimentaires

IDENTIFICATION ET CORRECTION DES CAUSES D'UNE SATURATION INSUFFISANTE EN CO_2 EN FIN GARDE ET DES PRISES ISOLEES EN O_2 DISSOUT DANS LA BIERE FILTREE A LA SABC YAOUNDE.

Effectué à la SABC, Usine de Yaoundé
Du 08 Juin au 30 Septembre 2016

Rédigé et soutenu par: MIMBOE NOMO Marie Joseph
Matricule: 13I036EN
Licence ès Biologie des Organismes animaux

Encadreur industriel

M. TELEWO Nicaise,
Adjoint chef service fabrication

Encadreurs académiques

Dr. DESOBGO Stève
Chargé de cours à l'IUT
M. AGWANANDE Wilson
Assistant à l'ENSAI

Année Académique 2015/2016

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tel : 79 82 88 00 / 22 16 65 10/ 22 25 40 72
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[26] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **MUFOR NJUKENG Lionel**
FILIERE : **IAA**
SUJET DU MEMOIRE : MODELLING PARAMETERS FOR THE PRODUCTION OF DRP COCOA LIQUOR ON THE DISCONTINUOUS BARTH LINE

NOTE DE FOND	Maîtrise technique du sujet	18	/20
	Présentation des résultats	9	/10
NOTE DE FORME	Clarté de la présentation	9,5	/10
	Qualité de la prestation orale	8,5	/10
	Personnalité du candidat	8,5	/10
TOTAL		52,5	/60
MOYENNE		17,5	/20

OBSERVATIONS : Très Bien. Très bonne présentation / 18,5 contribution remarquable pour la maîtrise du système de production.

XXVI- JURY

PRESIDENT	RAPPORTEUR
NOM : Pr. Ngassoum	NOM : Dr. Steve Bitchagno
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	Dr. SADOU		
SIGNATURE			

DATE :

[26] Moyenne des notes attribuées par chaque membre du jury.

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la scolarité
Services de stages et de la formation continue
B.P.455 - Ngaoundéré, CAMEROUN/
Tel: 79 82 88 00 / 22 25 40 72 / 22 25 40 89 72
ensai_stages@yahoo.fr

http://www.ensai.univ-ndere.cm

END OF COURSE PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTERS OF ENGINEERING DEGREE IN AGROFOOD PROCESS ENGINEERING

TOPIC: MODELLING PARAMETERS FOR THE PRODUCTION OF DRP COCOA LIQUOR ON THE DISCONTINUOUS BARTH LINE

Internship done at SIC CACAOS Douala from 10 June to 09 September 2014:

SIC CACAOS

By

MUFOR NJUKENG Lionel

Bachelor's degree in BIOCHEMISTRY
Matriculation number: 11I077EN

Industrial supervisor

- **Eng. NYAM Guy Thierry**
  Chief of Production

Academic supervisors

- **Pr. NSO Emmanuel**
  Associate Professor - ENSAI
- **Dr. DESOBGO Steve**
  Lecturer - IUT

Année académique 2013 - 2014

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tel : 79 82 88 00 / 22 16 65 10/ 22 25 40 72
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[23] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **MINFOULOU Robert**
FILIERE : **IAA**
SUJET DU MEMOIRE : MAITRICE DU PROCEDE D'ACIDIFICATION EN VUE DE DEFINIR DES STANDARDS DE VERSEMENTS EN SALLE A BRASSER

ppce

NOTE DE FOND	Maîtrise technique du sujet	/20
	Présentation des résultats	/10
NOTE DE FORME	Clarté de la présentation	/10
	Qualité de la prestation orale	/10
	Personnalité du candidat	/10
TOTAL		45 /60
MOYENNE		15 /20

OBSERVATIONS : Bonne présentation, Corrections à apporter dans le mémoire.

XXIII- JURY

PRESIDENT	RAPPORTEUR
NOM : TCHIEGANG	NOM : Dr. [illegible]
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	[illegible]		
SIGNATURE			

DATE :

[23] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN

Paix -Travail - Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR

UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON

Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES

AGRO-INDUSTRIELLES

NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité

Service des Stages et de la Formation Continue

B.P:455 – Ngaoundéré, CAMEROON/

Tel: 79 82 88 00 / 22 16 65 10 / 22 25 40 72

ensai_stages@yahoo.fr

http://www.ensai.univ-ndere.cm

Mémoire de fin d'études en vue de l'obtention du Diplôme d'ingénieur de conception des Industries Agricoles et Alimentaires (IAA)

MAITRISE DU PROCEDE D'ACIDIFICATION EN CEM, AU FLM ET EN CHM EN VUE DE DEFINIR DES STANDARDS DE VERSEMENTS EN SALLE A BRASSER

STAGE Effectué du 06 JUIN au 02 OCTOBRE 2014 à

Les Brasseries du Cameroun since 1948

Usine de GAROUA

Par **MINFOULOU Robert**

(11I074EN)

Licence ès biologie et physiologie des organismes animaux

Encadreur industriel

Ing. MANGA Mathieu Yves

Chef service fabrication

Encadreurs académiques

Pr. NSO Emmanuel JONG

Maître de Conférences, ENSAI

Dr. DESOBGO Steve

Chargé de Cours, IUT

Année académique 2013/2014

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tel : 79 82 88 00 / 22 16 65 10/ 22 25 40 72
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[4] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT
NOMS : **ARRENEKE AYUK ETOBI**
FILIERE : **CIGE**
SUJET DU MEMOIRE : FEASIBILITY STUDY OF BIOGAS POTENTIALS OF LOBE PALM OIL MILL WASTE

NOTE DE FOND	Maîtrise technique du sujet	17/20
	Présentation des résultats	9 /10
NOTE DE FORME	Clarté de la présentation	8 /10
	Qualité de la prestation orale	8 /10
	Personnalité du candidat	9 /10
TOTAL		51 /60
MOYENNE		17/20

Très Bien

OBSERVATIONS : Sujet d'une importance économique et d'actualité. Le candidat a fait preuve de maîtrise de son sujet

IV- JURY

PRESIDENT	RAPPORTEUR
NOM : P. Tchamoum N.B	NOM : Dr. DESOBGO Steve
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	Dr. BOGNE Patrice		
SIGNATURE			

DATE :
05-11-2014

[4] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland
MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la coopération, de la recherche et de la scolarité. **Service des Stages et de la Formation Continue**
B.P:455 – Ngaoundéré, CAMEROUN /
Tel: 79 82 88 00 / 22 16 65 10 / 22 25 40 72
ensai_stages@yahoo.fr
http:// www.ensai.univ-ndere.cm

END OF COURSE PROJECT REPORT

submitted in partial fulfillment of the requirements for the award of a masters of engineering degree in industrial chemistry and environmental engineering

FEASIBILITY STUDY OF BIOGAS POTENTIALS OF LOBE PALM OILMILL WASTES

Carried out from June 20 to September 30, 2014
AT
PAMOL PLANTATIONS PLC (LOBE ESTATE) /IRAD EKONA

By

ARRENEKE AYUK ETOBI (11C095EN)

BSc. (Hons) MICROBIOLOGY

Industrial supervisors:

Dr Njunkeng Gethro
(Scientific Coordinator IRAD Ekona)

Eng. Abongwa Willibrode
(Head of Lobe Mill Soap Factory)

Academic supervisors:

Pr. Nso Emmanuel
(Associate professor ENSAI)

Dr. Desobgo Steve
(Senior Lecturer ENSAI)

Academic yera 2013-2014

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROON /
Tel : 79 82 88 00 / 22 16 65 10/ 22 25 40 72
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

FICHE DE SYNTHESE DES NOTES[10] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES

ETUDIANT	
NOMS :	**DETSI DJIANDE Paul Gabin**
FILIERE :	**IAA**
SUJET DU MEMOIRE :	IMPROVEMENT OF SABC ISB AND HTS YEASTS VIABILITY

NOTE DE FOND	Maîtrise technique du sujet	16 /20
	Présentation des résultats	8 /10
NOTE DE FORME	Clarté de la présentation	8 /10
	Qualité de la prestation orale	7 /10
	Personnalité du candidat	9 /10
TOTAL		48 /60
MOYENNE	Mention Très Bien	16,00 /20

OBSERVATIONS : Travail d'un grand intérêt pour l'entreprise

X- JURY

PRESIDENT	RAPPORTEUR
NOM : Pr MBAWALA Augustin	NOM : Dr Pierre DOSSOGO
SIGNATURE :	SIGNATURE :

AUTRES MEMBRES			
NOM	Dr. BOGNE Patrice		
SIGNATURE			

DATE : 05/11/2014

[10] Moyenne des notes attribuées par chaque membre du jury.

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Services de stages et de la formation continue
B.P. 455 - Ngaoundere, CAMEROON /
Tel: 79 82 88 00 / 22 16 65 10 / 22 25 40 72
ensai_stages@yahoo.fr
http://www.ensai.univ-ndere.cm

END OF COURSE INTERNSHIP REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF ENGINEERING (M. ENG) DEGREE IN AGRO-FOOD PROCESS ENGINEERING

Improvement of SABC, ISB and HTS yeasts viability

Carried out from July 1st to September 30th, 2014
at

Les Brasseries du Cameroun since 1948 DOUALA

By

DETSI DJIANDE PAUL GABIN
B.Sc. (Hons) Biochemistry
Registration number: 11I057EN

Industrial supervisor:
Eng. Variette SIMEU Epse Mbakop
Assistant head of Production,
SABC DOUALA

Academic supervisors:
Pr. NSO Emmanuel
Associate Professor, ENSAI
Dr. DESOBGO Steve
Senior Lecturer, IUT

Academic Year: 2013-2014

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROUN
Tel : 77 78 38 40 / 22 16 65 00 / 22 16 65 10
ensai_stages@yahoo.fr

FICHE DE SYNTHESE DES NOTES[1] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES INGENIEUR

ETUDIANT	
NOMS ET PRENOM :	**Oliva ANGWEWAH AZOBI**
FILIERE :	**INDUSTRIES AGRICOLES ET ALIMENTAIRES**
SUJET DU MEMOIRE :	**ANALYSES OF THERMAL EXCHANGE AT THE LEVEL OF WORT BOILING**

NOTE DE FOND	Maîtrise technique du sujet	16/20
	Présentation des résultats	8 /10
NOTE DE FORME	Clarté de la présentation	8 /10
	Qualité de la prestation orale	8 /10
	Personnalité du candidat	8 /10
TOTAL		48 /60
MOYENNE		16/20
MENTION :	Très Bien	

OBSERVATIONS : Très bonne soutenance. Travail dont les résultats sont déjà appliqués en entreprise avec un grand impact financier

JURY

PRESIDENT	RAPPORTEUR
NOM : Laurent BITSOKA	NOM : Dr. Steve BESSAGO
SIGNATURE :	SIGNATURE :

	EXAMINATEUR	AUTRES MEMBRES	
NOM	Dr EBOUN. M.		
SIGNATURE			

DATE : 07/12/2012

[1] Moyenne des notes attribuées par chaque membre du jury.

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Services de stages et de la formation continue

B.P.455 Ngaoundere, CAMEROON Tel: 22 16 65 00 / 22 16 65 10
E-mail: ensai_stages@yahoo.fr

END OF COURSE INTERNSHIP REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF ENGINEERING (M. ENG) DEGREE IN AGRO-FOOD PROCESS ENGINEERING

ANALYSES OF HEAT EXCHANGE AT THE LEVEL OF THE PRE-HEATER AND OTHER CAUSES OF LONGER WORT BOILING TIMES

Carried out from June 20 to October 17, 2012

at

Les Brasseries du Cameroun since 1948 YAOUNDE

by

Oliva ANGWEWAH AZOBI
B.Sc. (Hons) Biochemistry
Matricule: 09I032EN

Industrial supervisor:
Eng. Louis Michel AMBOMBO
Assistant Chief of Production

Academic supervisors:
Pr. NSO Emmanuel
Associate Professor, ENSAI
Dr. DESOBGO Steve
Lecturer, IUT

Academic Year : 2011-2012

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROUN
Tel : 77 78 38 40 / 22 16 65 00 / 22 16 65 10
ensai_stages@yahoo.fr

FICHE DE SYNTHESE DES NOTES[1] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES INGENIEUR

ETUDIANT	
NOMS ET PRENOM :	**VABI VAMULOH Vilbert**
FILIERE :	**INDUSTRIES AGRICOLES ET ALIMENTAIRES**
SUJET DU MEMOIRE :	**VALORISATION OF CACAO POD HUSKS FOR BIOGAS PRODUCTION**

NOTE DE FOND	Maîtrise technique du sujet	16 /20
	Présentation des résultats	8 /10
NOTE DE FORME	Clarté de la présentation	8 /10
	Qualité de la prestation orale	8 /10
	Personnalité du candidat	8 /10
TOTAL		48 /60
MOYENNE		16,0 /20
MENTION :	T - Bien	

OBSERVATIONS : Très bonne approche de valorisation de ces produits agricoles, mais mauvaise approche modélisation et plan d'expérience.

JURY

PRESIDENT	RAPPORTEUR
NOM : Pr NJINTANG	NOM : Pr. NSO Emmanuel
SIGNATURE :	SIGNATURE :

	EXAMINATEUR	AUTRES MEMBRES	
NOM	Dr BOGNE Patrick		
SIGNATURE			

DATE :

[1] Moyenne des notes attribuées par chaque membre du jury.

RÉPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR

UNIVERSITÉ DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace - Work - Fatherland

MINISTRY OF HIGHER EDUCATION

UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO –INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Services de stages et de la formation continue

B.P.455 Ngaoundere, CAMEROON Tel/Fax: 22 16 65 00 Cell: 22 16 65 10
E-mail: ensai_stages@yahoo.fr

END OF COURSE PROJECT REPORT

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF ENGINEERING (M. ENG) DIPLOMA IN AGRO-FOOD PROCESS ENGINEERING

VALORISATION OF COCOA POD HUSKS FOR BIOGAS PRODUCTION

Carried out from 2nd July to October 26th, 2011
At
ENSAI

By

VABI Vamuloh Vilbert
B.Sc. Biochemistry
Matricule: 09I038EN

Project Supervisor
Pr. NSO Emmanuel Jong
Associate Professor, ENSAI

Project Director
Dr.Eng DESOBGO Steve Carly
Lecturer, IUT

2011 – 2012 Academic year

REPUBLIQUE DU CAMEROUN
Paix – Travail – Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work - Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES

Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B. P. 455 – Ngaoundéré, CAMEROUN
Tel : 77 78 38 40 / 22 16 65 00 / 22 16 65 10
ensai_stages@yahoo.fr

FICHE DE SYNTHESE DES NOTES[1] DE SOUTENANCE DE MEMOIRE DE FIN D'ETUDES INGENIEUR

ETUDIANT
NOMS ET PRENOM : SOPPO SIMON RODRIGUE
FILIERE : INDUSTRIES AGRICOLES ET ALIMENTAIRES
SUJET DU MEMOIRE : OPTIMISATION DE L'EXTRACTION DE BEURRE DE CACAO ARTISANAL

NOTE DE FOND	Maîtrise technique du sujet	15	/20
	Présentation des résultats	06,5	/10
NOTE DE FORME	Clarté de la présentation	8	/10
	Qualité de la prestation orale	7	/10
	Personnalité du candidat	7	/10
TOTAL		43,5	/60
MOYENNE		14,5	/20
MENTION :		Bien.	

OBSERVATIONS : Bois améliorer la langue, renforcer la bibliographie

JURY

PRESIDENT	RAPPORTEUR
NOM : Pr ASSINGANG	NOM : Pr. NSO Emmanuel
SIGNATURE :	SIGNATURE :

	EXAMINATEUR	AUTRES MEMBRES	
NOM	Dr Mbougueng D.		
SIGNATURE			

DATE : 18/05/2013

[1] Moyenne des notes attribuées par chaque membre du jury.

REPUBLIQUE DU CAMEROUN
Paix – Travail –Patrie

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR
UNIVERSITE DE NGAOUNDERE

REPUBLIC OF CAMEROON
Peace – Work – Fatherland

MINISTRY OF HIGHER EDUCATION
THE UNIVERSITY OF NGAOUNDERE

ECOLE NATIONALE SUPERIEURE DES SCIENCES AGRO-INDUSTRIELLES
NATIONAL SCHOOL OF AGRO-INDUSTRIAL SCIENCES
Division des Affaires Académiques, de la Coopération, de la Recherche et de la Scolarité
Service des Stages et de la Formation Continue
B.P.455 – Ngaoundéré, CAMEROUN/
Tel : 77 78 38 40 / 22 16 65 00 / 22 16 65 10
ensai_stages@yahoo.fr

Mémoire de fin d'études en vue de l'obtention du Diplôme d'Ingénieur des Industries Agricoles et Alimentaires (IAA)
Sous le thème :

OPTIMISATION DE L'EXTRACTION ARTISANALE DU BEURRE DE CACAO

Effectué au Laboratoire de Génie et Technologie Alimentaire (GETA) de l'ENSAI de Ngaoundéré
Du 13 août au 15 décembre 2012

Rédigé et soutenu par :

SOPPO SIMON RODRIGUE
(09I034EN)

Licence ès sciences (option Biochimie)

Encadreur académique:

DR. DESOBGO ZANGUE STEVE
Chargé de Cours, IUT

Superviseur académique:

PR. NSO EMMANUEL
Maître de Conférences, ENSAI

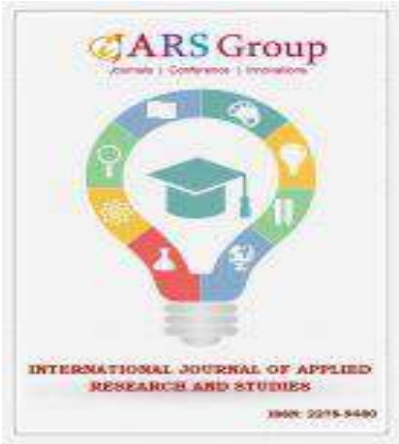
Année académique 2011-2012

IV.4) Publications au niveau national et international dans le grade

IV.4.1) Optimization of the Impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the Turbidity of *Madjeru* sorghum cultivar wort

Titre de la revue

INTERNATIONAL JOURNAL OF APPLIED RESEARCH AND STUDIES



Basic Information

Print Frequency : Monthly

Journal Name [English]	International Journal of Applied Research and Studies
Online ISSN	2278-9480
Publisher's Url	http://www.ijars.ijars... (http://www.ijars.ijarsgroup.com/)
Subject	Health Sciences
Frequency	Monthly
Access	Free

Journal Description

iJARS provides Quick and Simple publishing of articles in different areas of Agriculture, Applied Physics, Applied Chemistry, Statistics, Microbiology, Medical Sciences, Psychology, Biotechnology, Pharmacy,Environmental studies, Law, Education etc. iJARS is monthly Journal, started in 2012, by Internationally renowned publishing house, iJARS Group. IJARS is supported by a highly Prestigious Board, consisting of delegates and distinguished research scholars across the world. The manuscripts are double-blind peer reviewed by iJARS Editorial Board consisting of Scientific experts, Technocrats & Novel Literates; which imparts a higher value and holds utmost dignity for the authors. The Articles thus published in iJARS, are indexed in global referrals & gets referred by researchers spanning over 120 Countries. iJARS publishes & indexes articles within a time period of 15 days, such that every contribution is available to over million readers of iJARS upto-date & before it gets backdated, unlike never ending review processes.

Home

Comité de lecture

REVIEWERS BOARD - MULTIDISCIPLINARY

Dr. Mohammad Rafiqul Islam

PhD

Department Of Mathematics And Natural Sciences

BRAC University, Dhaka

Md. Amir Hossain

M. Phil

Department Of English

IBAIS University, Bangladesh

K. M. Anwarul Islam

MBA (Banking)

Department Of Business Administration

The Millennium University. Dhaka

Dr. K Shobha

PhD (Economics)

Department Of Economics

Government Arts College, Coimbatore, Tamil Nadu, India

Dr. Mohammad Valipour

PhD- Water Science Engineering

Sari Agricultural Sciences And Natural Resources University, Iran

Dr. J.John Peter

PhD (Human Resource Management)

National HRD Network, Indian Society Of Training & Development

Ravjeet Atwal

Department Of Political Science

Indian Council Of Social Science Research (ICSSR), Ahmedabad.

Pushpanathan .T

Ph.D.,(English)

Bharathiar University, Coimbatore

Dr. Kedar Mehta

Ismail Thamarasseri

M.D.

Department Of Community Medicine

GMERS Medical College, Vadodara

M.A.(Sociology), M.A. (English) ,M.Ed

Dept. Of Education

Central University Of Kashmir

Dr. Jatinder Pal Singh

PhD

Dept Of Physics

Government College,Chandigarh

Dr. Arun K. Behera

Phd

Dept Of English,

Sri Sathya Sai Institute Of Higher Learning

Dr V. B. Hans

Dr. Ho Soon Min

PhD(Economics)

Dean, Arts Faculty, St Aloysius Evening College, Mangalore

Ph. D (Material Chemistry)

HEAD - Center For Green Chemistry And Applied Chemistry

Senior Lecturer, INTI International University

Mohammad Jannati

PhD(Power Electronics)

Researcher

Universiti Teknologi Malaysia, Malaysia

Dr. R. S. Meena

PhD(Marketing Management)

Department Of Commerce

BHU,India

Dr. Sriram Chandramohan

Dr. Suresh Chandra Nayak

MD, MPH

Department Of Public Health

Saudi Electronic University,Saudi Arabia

Ph.D (Journalism And Mass Communication)

Faculty Of Media Studies

Manav Rachna International University,India

Jiban Shrestha

M.Sc(Agriculture)

Scientist

Nepal Agricultural Research Council, Nepal

Alireza Baghchesaraei

M.S (Architecture)

Department Of Architecture

Bahcesehir University Of Turkey,Turkey

B. Thangagiri

Dr. Sudeendra Koushik

M.Phil, M.Sc(Chemistry)

Department Of Chemistry

Anna University, India

PhD(Innovation), MBA(Marketing)

Chair IEEE (USA) Consumer Electronics Chapter Bangalore

Vice-Chair IEEE Bangalore Section,India

Dr. S. Kishore Reddy

PhD (Electronics & Communication)

School Of Electrical And Computer Engineering,

Adama University, Ethiopia

Bhojak Nimesh Pramodkumar

Dr. Hemant Sharma

Masters(Business/ Hospital Management)

Department Of Hospital Management

Hemchandracharya North Gujarat University, India

PhD(Operational & Organizational Efficiency)

Amity Business School

Amity University Haryana, India

Meshesha Make Jobo

PhD(pursuing)

University Of South Africa (UNISA)
Wolaita Sodo University, Ethiopia.

Prakash Ramadurai

Dr. Punita Soni

M.Phil.,(Biotechnology)

Department Of Biotechnology

Army College Of Medical Sciences,New Delhi - 110 010

Ph.D (Economics)

Department Of Management Studies

JIET Group Of Institutions, India

Dr. Veeresh VG

PhD(Nursing)

Department Of Nursing

Sharabheswara College Of Nursing, India

Dr. Gaurav Joshi

Abhishek Dwivedi

PhD(Business Management)

Department Of Management Studies

Lal Bahadhur Shastri Institute Of Management New Delhi, India

M.Tech (Computer Integrated Manufacturing)

Department Of Mechanical Engineering

Integral University, India

Pragati Chavan

ME (Computer Engineering)

Department Of Computer Science

MMMP Thergaon, India

Dr. Mohamed Ahmed El-Esawi

Dr.Nirmala B

PhD(Genetics And Molecular Biology)

Department Of Botany

Tanta University, Egypt

PhD(Chemistry)

Department Of Chemistry

University College Of Science, Tumkur, India

Dr. Lawrence Abraham Gojeh

PhD (Information Science)

Department Of Information Science

Jimma University, Ethiopia

Dr. L.Leo Franklin

PhD (Commerce)

Department Of Commerce

JJ College Of Arts And Science, India

Dr. Hemaloshinee

Dr. Sunar Mohammed Farooq

PhD (Human Resource Management)

Department Of Management Studies

University Technology Malaysia, Malaysia

PhD(Computer Science Engineering)

Department Of Computer Science

SEC, Jawaharlal Nehru Technological University, India

Dr. Olubodun Olaniyi OLAYIWOLA

PhD (Agricultural Economics & Farm Management)

Department Of Economics

La Cite University, Republic Of Benin

Dr. Ashish Gupta

PhD(Marketing Management)

Department Of Business Management

Dr. Hari Singh Gour Central University, India

Dr. M. Ahmed Ali Baig

Ajin R. S

PhD(Mechanical Engineering)

Department Of Mechanical Engineering

CMR, India

Masters (Geology)

Research Associate

GeoVin Solutions Pvt. Ltd,India

Dr. Manoj Kumar Jha

PhD(Corporate Excellence), MBA

Department Of Management Studies

Global Institute Of Technology And Management, India

Dr R B Sharma

PhD (Accounts), MBA(Finance)

Department Of Accounting,

College Of Business Administration,Al-kharj,Kingdom Of Saudi Arabia

Dr. Asim Khan

Dr. Navneet Singh Kathuria

PhD(Physical Education & Sports Science)

Department Of Sports Science

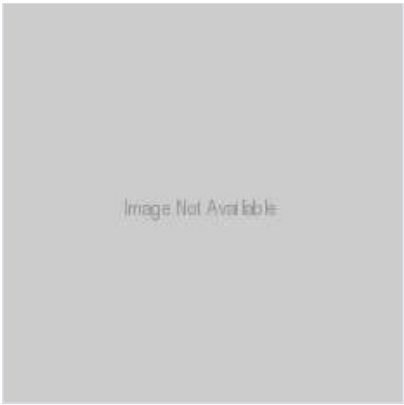
College Of Natural Science, Jimma University, Ethiopia.

PhD(Dental Science)

Department Of Oral Pathology And Microbiology

Rajasthan University Of Health Sciences,India

Dr. S. Veeramani



Masters(English Literature)

Department Of English

Bharathidasan University, India

Dr. Mukesh Chauhan

Dr. Sangeeta Maruti Gawali

PhD(Accounting), MBA - Finance

Department Of Finance

PG Govt. College, Chandigrah, India

MD- Physiology, MBBS- Medical Sciences

Department Of Physiology

B. J. Govt Medical College,India

Dr. Dibya Prakash

PhD(Physics)

Post Doctoral Fellow

Beijing Computational Science Research Center, Peoples Republic Of China

Jeril Kuriakose

PhD(Information Technology)

Department Of IT

St. John College Of Engineering,India

Dr. Karunakar Patra

Achmad Choerudin

Ph. D(Management)

Director

Rourkela Institute Of Management Studies,India

PhD(Economics & Commerce)

Department Of Management

Central Java, Indonesia

Jaskiran Arora

PhD (Macroeconomics)

Department Of Accounts And Finance

BML Munjal University, India

Dr. Haineng Xu

Dr. Yu-Chen Hu

PhD (Biochemistry)

Postdoc Fellow

University Of Pennsylvania School Of Medicine, Pennsylvania

Senior Editor, IJARS -Engineering Panel

PhD (Computer Science)

Providence University, Taiwan

Dr. Natalie Solveig Mikhaylov

PhD(Management And And Entrepreneurship)

Department Of Business Administration

Suleyman Sah University, Turkey

Dr. Hung-Chun Chien

Dr.Karthikeyan. L. M

PhD(Electronics Engineering)

Department Of Electronic Engineering

Jinwen University Of Science And Technology (JUST), Taiwan

PhD (Aerospace Engineering)

Professor

Noorul Islam University

Dr. Mihir Kumar Shome

PhD (Personnel Management And Industrial Relations)

Senate Member, Member Of Governing Body

NIT Arunachal Pradesh, India

Dr. Asha Sharma

Dr. K. K. Gaur

PhD (Accounting)

Department Of Commerce

Mahila P G Mahavidhalaya, JNVU,India

PhD (Biotechnology)

Director(SOB)

MIMT, Gr. Noida, India

Dr. Kshitij Shinghal

PhD (Wireless Sensor Networks)

Professor

MIT, Moradabad, India

Dr. Jerwin Prabu A

Dr. Piyush Kumar Pareek

PhD

Head Of Technology, R&D

Bharati Robotic System

PhD (Computer Science Engineering)

Professor

EWIT, Bangalore, India

Table des matières

Abstract Full text

Volume II "Issue 2"

IJARS/ 305 Optimization of the Impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the Turbidity of Madjeru sorghum cultivar wort.

Author/s : Desobgo Zangué Steve Carly, Nso Emmanuel Jong

Abstract Full text

IJARS/ 306 Mobile News Gathering: Media Entrepreneurship and Participation of Marginalized Communities in News Gathering Structure

Author/s : Romesh Chaturvedi, Shruti Mehrotra

Abstract Full text

IJARS/ 307 Synthesis of New Schiff-Base Complexes and Their Applications

Author/s : Dr Navneet Kumar, Pratima Sharma, Astha pareek

Abstract Full text

IJARS/ 310 Evaluation on PSO based Model for Solving JSSP

Author/s : S. Jayasankari, Dr. A. Tamilarasi, Dr. V.Thiagarasu

Abstract Full text

IJARS/ 313 Requites of Teaching the Spoken Language

Author/s : Dr. Arun K. Behera

Abstract Full text

IJRAS/ 314 Career Success Factors in Higher Education Institutions

Author/s : J. Juliet Gladies, Dr. Vijila Kennedy

Abstract Full text

IJARS/ 316 Review on Classification Algorithms in Email Domain

Author/s : Saurabh Khatri, Emmanuel M.

Abstract Full text

IJARS/ 317 Leaders fail as selective listeners

Author/s : Vinita Chopra

Abstract Full text

IJARS/ 319 A Review on Two Phase Flow in Micro channel Heat Exchangers

Author/s : Sneha S. Gosai,Vivek C. Joshi

Abstract Full text

IJARS/ 320 Survey of Data Fusion in K-Means Laplacian Clustering

Author/s : T.Kokilavani, Dr.V.Thiagarasu

Abstract Full text

IJARS/ 321 Technology in Emerging Economies

Author/s : Dr.ViswanathanGopalan

Abstract Full text

IJARS/ 325 Implementation of an Efficient Parallel Multiplier-Accumulator Based on Radix-2 Modified Booth Algorithm

Author/s : Saravana Kumari Kota, Y.Naga Supraja

Abstract Full text

IJARS/ 329 Data Compression Techniques: A Comparative Study

Author/s : Pooja Jain, Zeeshan Khan, Anurag Jain

Abstract Full text

IJARS/ 331 Design and Analysis of A-Frame for Roller Hemming Cell

Author/s : Hemming; A-Frame; FEM; Robotics; Roller cell.

Abstract Full text

IJARS/ 336 Applied Research of Outlier Discovery to Understand the Prevalence of Diabetes in Multivariate Environment

Author/s : Manish Kumar Khare, Dr. Arpita Gopal

Abstract Full text

IJARS/ 339 Employee Perception Concerning Relative Significance of Various Human Resource Functions: A Statistical Analysis

Author/s : Sanjay Gaur, Dr. Awadhesh Bhardwaj

Abstract Full text

IJARS/ 341 Outlier Mining in Large Data Set: An Efficient Unsupervised Approach

Author/s : R.Prabahari, Dr.V.Thiagarasu, P.Narendran

Abstract Full text

IJARS/ 342 Tween 20 modified sugarcane bagasse (saccharum officinarum) and sheesham sawdust (dalbergia sissoo) for Cr(VI) remediation in aqueous environment

Author/s : Lalit Sharma, Subhash Chander Sharma

Abstract Full text

IJARS/ 344 Efficacy of Iron, Zinc and Combined Iron and Zinc Supplementation in Improving Iron and Zinc Status of Female Adolescents in Chennai, India

Author/s : Anna Rangini Chellappa, Karunanidhi. S

Abstract Full text

Pages de l’article

International Journal of Applied Research & Studies ISSN 2278 – 9480

Research Article

Optimization of the Impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the Turbidity of *Madjeru* sorghum cultivar wort.

Authors

[1] Desobgo Zangué Steve Carly*, [2] Nso Emmanuel Jong

Address For correspondence:

[1]Mechanical Department of Food Processing and Quality Control, University Institute of Technology, Ngaoundere, Cameroon
[2]Department of Process Engineering, National School of Agro-Industrial Sciences, Ngaoundere, Cameroon

Abstract:— The action of three technical mashing enzymes (Hitempase 2XL, Bioglucanase TX and Brewers Protease) on the turbidity of the worts of unmalted and malted *Madjeru* sorghum mashes was modeled and analyzed using response surface methodology. The analysis showed that both Hitempase 2XL and Bioglucanase TX had significant impact on unmalted *Madjeru* worts turbidity during mashing of unmalted *Madjeru* sorghum grist, with a contribution of 15% and 11% respectively. Bioglucanase TX and Brewers Protease had significant impact on malted *Madjeru* worts turbidity, they contributed respectively for 7% and 13%. The interaction X_1X_2 also had a significant impact on wort turbidity of unmalted *Madjeru* for which it contributed 23%. The interaction X_1X_3 had a significant impact on wort turbidity of malted *Madjeru* for which it contributed 24%. Optimization of the concerted actions of the three enzymes for turbidity of unmalted *Madjeru* gave a combination of (0 U; 298.25 BGU and 0 mg) for Hitempase 2XL, Bioglucanase TX and Brewers Protease respectively. This gave a minimal turbidity of 0.00 NTU. This combination was: 1387.50 U; 0 BGU and 32.23 mg for malted *Madjeru*, giving a minimal turbidity of 5.27 NTU.

Keywords: enzymes, turbidity, response surface methodology, optimization, Madjeru

I. INTRODUCTION

Sorghum malt has a lower hydrolytic enzyme and principal extracts potential than the conventional barley malt [1]. However the availability of sorghum in Africa is vital economic development, it is essential that the applied research focuses on the capacity in making this cereal the tool of food safety in Africa. Its small quantity in enzymes due to their insufficient development during malting often imposes the use of the commercial brewery enzymes as supplements to obtain the best wort characteristics for brewing [2-16]. Indeed, differences were reported on the composition and the brewery quality of the cultivars of malted sorghums [17-20]. This however could be allotted to the variety of sorghum used for malting. This report is also observed after mash filtration related to sorghum malt quality [15, 21]. The role of the industrial enzymes in facilitating the brewery processes is based on the fact that they have a great catalytic capacity, even when used in very small quantity (traces). Moreover, they catalyze and reduce the use of chemicals and energy during mashing. These observations, although they show differences in the behavior between the cultivars of sorghum during malting, one could foresee the possibilities of modeling and optimizing the mashing of sorghum. The process of mashing was the main research theme in the field of brewery. An improvement and a control of the manufacturing process of beer led first of all to modeling at the level of the basic stage which is malting. A particular interest was related to the β-glucanes which created enormous problems on the level of mash filtration. The modeling of the action of the β-glucanase on the degradation of the β-glucanes during germination [22] is an illustration. Thereafter, there was a simulation of the modeling of the activity of the enzymes resulting from germination during kilning [23]. Works concerned with the follow-up of the quantity of fermentable sugars by using a complex modeling have been done [24]. Modeling was equally the subject of the follow-up of the activity of the β-glucanase during mashing [25]. One can moreover note the use of modeling in the kinetics of the enzymatic hydrolysis of

desobgo@yahoo.fr * Corresponding Author Email-Id

International Journal of Applied Research & Studies ISSN 2278 – 9480

the starch during mashing [26]. Another aspect of research was related to the simulation of the propagation of brewery yeasts [27] and the nonlinear modeling of industrial brewery fermentations [28]. The response surface methodology (RSM) was on the other hand used to study the effectivity of the impact of the industrial enzymes on buckwheat malt for a brewery goal [29]. The models observed in the literature are complex and difficult to implement, and they almost exclusively relate to barley and not to sorghum. The beer of sorghum being known to be opaque makes it necessary to investigate on the turbidity of wort using response surface methodology.

II. MATERIAL AND METHODS

A. *Enzymes*

The characteristics of the commercial brewery enzymes used (Hitempase 2XL, a thermo stable α-amylase from *Baccillus licheniformis*; Bioglucanase TX, an enzymatic composition of β-glucanase and hemicellulases from *Trichoderma reesei*; and Brewers protease from *Bacillus amyloliquefaciens*) are showed in Table 1.

TABLE I. CHARACTERISTICS OF COMMERCIAL BREWERY ENZYMES USED.

Designation	Origin	Activity	Description	Optimal temperature	Optimal pH	Recommended Quantity	Form
Hitempase 2XL[a]	*Bacillus licheniformis*	4416.29 ± 19.34 U/ml	α-amylase	60-95 °C	4-8	60 U/g	Solution
Bioglucanase TX[a]	*Trichoderma reesei*	750 BGU/ml	β-glucanase	60 °C	4.5-6.5	0.01 et 0.025 % (v/m)	Solution
Brewers Protease[b]	*Bacillus amyloliquefaciens*	1842.20 ± 1.8 mg AAL/min/ml	Protease	40-50°C (denatured at 85°C)	6.5-7.5	0.4-2 g/Kg	Solution

a Hitempase 2XL and Bioglucanase TX were obtained from Kerry Bioscience; Kilnagleary, Carrigaline, Co. Cork, Ireland.

b Brewers protease was obtained from DSM Food Specialities, Cedex France.

B. *Sorghum cultivar*

The biological material obtained at IRAD (Agricultural Research Institute for Development) center of Maroua (Cameroon) was *Madjeru* cultivar grains.

C. *Modeling*

Modeling was carried out as previously described [30]. A Doehlert matrix design with three factors (X_1, X_2, X_3) representing Hitempase 2XL (X_1), Bioglucanase TX (X_2) and Brewers Protease (X_3) at ranges of 0–3,000 U, 0–937.5 BGU and 0–100 mg, respectively, was used. The transformed matrix of coded variables to an experimental matrix and desired responses (extract and free amino nitrogen) are shown in Table 2. The coefficients of the models were obtained using the Systat version 12 software (Systat Software, Inc., San Jose, USA). This software also gives a statistical analysis on the model. Lastly, the curves were plotted using Sigmaplot version 11 build 11.0.0.77 software (WPCubed, GmbH, Germany).

D. *Validation of Models*

The models were validated using two procedures. The first consisted of coupling the method earlier described [30] to the absolute average deviation (AAD) method [31]. The second procedure consisted of applying the method described [32-34].

E. *Malting*

Malting was done using the method previously described [35]. About 1 kg of *Madjeru* sorghum cultivar grains were washed three times using 3 L of distilled water to remove dirt and other foreign bodies. The grains were steeped in 3 L of distilled water for 48 h at room temperature (≈25°C) with three changes of water at intervals of 12 h before steep out. Germination was carried out for 4 days in a Heraeus type oven (D-63450 Hanau, Germany) at a temperature of 25°C with water sprinkled on the grains on daily basis. The malt was then air dried at 40°C for 4 days using a CKA 2000 AUF-type dryer (Ngaoundere, Cameroon). The malt was rubbed-off of its rootlets and stored until further use.

F. *Mashing*

Mashing was done using the method previously described [35]. Two hundred and fifty ml of distilled water were put into a 600 ml beaker and 50 g of sorghum (malted or unmalted) flour (Ø < 1 mm) added with continuous stirring until a homogenous mixture was obtained. This mixture was incubated at 45°C for 1 h in a water bath with intermittent stirring at intervals of 5 min. The mix was allowed to decant and 50 ml of the supernatant withdrawn and kept aside. The temperature of the mash was then raised to boiling so as to gelatinise sorghum starch during 40 min with intermittent stirring at intervals of 5 min before cooling to 65°C. The 50 ml of supernatant, to which commercial enzymes are added according to the Doehlert experimental design of three factors, were added to the mash and mashing continued for 1 h and 30 min with intermittent stirring at intervals of 10 min. The mash was cooled and filtered at 25°C for 1 h and 30 min using Whatmann paper no. 42.

G. *Determination of turbidity*

After mashing, filtration and cooling, the wort is placed inside the HACH 2100N turbidimeter (Hach company

International Journal of Applied Research & Studies ISSN 2278 – 9480

headquarters, Loveland CO, USA). The turbidity value is obtained after stabilization of the value showed in NTU.

H. Optimization of Models

Models were optimized as previously described [30]. The optimal zone of intersection of the curves was highlighted.

III. RESULTS AND DISCUSSION

A. Modeling

Turbidity is a measurement which translates the quantity of suspended matter in wort. The follow-up of this data makes it possible to have an idea on the clearness of wort and thus of beer. Mathematical modeling of the action of the brewery enzymes during mashing would make it possible to understand the impact of each enzyme on this response.

The mathematical models obtained took account of the coded values of factors and arise as follows respectively for unmalted and malted *Madjeru*:

$$Y_{MadTU}(X_1, X_2, X_3) = 7{,}548 + 3{,}412X_1 - 2{,}389X_2 - 0{,}465X_3 - 5{,}056X_1X_2 + 0{,}774X_1X_3 + 1{,}567X_2X_3 - 2{,}036X_1^2 + 2{,}202X_2^2 - 4{,}449X_3^2 \quad (1)$$

$$Y_{MadMTU}(X_1, X_2, X_3) = 6{,}112 + 0{,}290X_1 + 0{,}730X_2 + 1{,}298X_3 + 0{,}765X_1X_2 - 2{,}407X_1X_3 + 0{,}133X_2X_3 + 2{,}164X_1^2 - 0{,}060X_2^2 - 2{,}350X_3^2 \quad (2)$$

With: Y_{MadTU} (X_1, X_2, X_3) representing the mathematical model for unmalted *Madjeru*; Y_{MadMTU} (X_1, X_2, X_3) representing the mathematical model for malted *Madjeru*; X_1, Hitempase 2XL; X_2 , Bioglucanase TX and X_3 Brewers protease.

These mathematical models are polynomials having several variables with correlation coefficients $R^2 = 0.966$ for unmalted *Madjeru* and $R^2 = 0.912$ for malted *Madjeru*. These coefficients, coupled to AAD values of 0.093 and 0.050 for unmalted and malted *Madjeru*, respectively, allowed for the validation of the models for the wort turbidity. In addition, bias factors of 0.8 and 1.02, coupled to exactitude factors of 1.13 and 1.20 for both unmalted and malted *Madjeru*, respectively, also allowed for validation of the models according to the method described [32-34].

The factors of the models were linear or of first degree (X_1, X_2 and X_3), quadratic or of the second degree (X_1^2, X_2^2 and X_3^2) and of interacting form (X_1X_2, X_1X_3 and X_2X_3). They were statistically considered significant or not if the probability (P) of increasing or decreasing turbidity was $\leqslant 0.05$ or $\geqslant 0.05$, respectively (Table 3).

TABLE II. MATRICES OF DOEHLERT, CODED AND EXPERIMENTAL VALUES

Coded values			Experimental values			*Madjeru* Turbidity					
						Unmalted			Malted		
Hit	Bio	Brew Prot	Hit (U)	Bio (BGU)	Brew Prot (mg)						
X_1	X_2	X_3	X_1	X_2	X_3	Exp[a]	Theo[b]	Res[c]	Exp[a]	Theo[b]	Res[c]
0.000	0.000	0.000	1500	468.75	50	7.680	7.548	0.132	6.317	6.112	0.205
1.000	0.000	0.000	3000	468.75	50	8.600	8.924	-0.324	8.337	8.566	-0.229
0.500	0.866	0.000	2250	937.50	50	7.300	6.138	1.162	7.953	7.716	0.237
-0.500	-0.866	0.000	750	0.00	50	6.000	6.864	-0.864	5,270	6.162	-0.892
0.500	-0.866	0.000	2250	0.00	50	15.333	14.655	0.678	6.293	5.790	0.503
-0.500	0.866	0.000	750	937.50	50	6.400	7.105	-0.705	6.320	6.764	-0.444
0.500	0.289	0.816	2250	625.18	100	4.200	4.851	-0.651	8.370	5.658	2.712
-0.500	-0.289	-0.816	750	312.32	0	4.677	3.579	1.098	5.390	2.828	2.562
0.500	-0.289	-0.816	2250	312.32	0	7.450	7.821	-0.371	7.753	4.861	2.892
0.000	0.577	-0.816	1500	781.07	0	3.100	3.582	-0.482	7.223	3.827	3.396
-0.500	0.289	0.816	750	625.18	100	2.600	2.269	0.331	10.567	7.111	3.456
0.000	-0.577	0.816	1500	156.43	100	5.900	5.580	0.320	8.323	5.103	3.220
0.000	0.000	0.000	1500	468.75	50	7.168	7.548	-0.380	6.270	6.112	0.158
-1.000	0.000	0.000	0	468.75	50	2.500	2.100	0.400	8.050	7.986	0.064
-1.000	-0.866	-0.816	0	0.00	0	0.354	0.598	-0.244	7.143	3.477	3.666
0.000	0.000	0.000	1500	468.75	50	7.800	7.548	0.252	6.317	6.112	0.205
0.000	0.000	0.000	1500	468.75	50	7.200	7.548	-0.348	6.303	6.112	0.191

a Experimental result values.

b Theoretical values (values coming from mathematical models).

c Residue.

TABLE III. ESTIMATION OF REGRESSION COEFFICIENTS FOR THE TURBIDITY OF UNMALTED AND MALTED *MADJERU*.

Effect	Coefficient		Std. deviation		t-statistics		P-value	
	Unmalted	Malted	Unmalted	Malted	Unmalted	Malted	Unmalted	Malted
CONSTANTE	7.548	6.112	0.436	0.285	17.320	21.477	0.000	0.000
X_1	3.412	0.290	0.448	0.293	7.610	0.992	0.000	0.354
X_2	-2.389	0.730	0.391	0.255	-5.292	2.477	0.001	0.042
X_3	-0.465	1.298	0.369	0.241	-1.028	4.392	0.338	0.003
X_1^2	-2.036	2.164	0.769	0.502	-2.648	4.312	0.033	0.004
X_2^2	2.202	-0.060	0.559	0.365	2.952	-0.122	0.021	0.906
X_3^2	-4.449	2.350	0.482	0.315	-6.140	4.966	0.000	0.002
X_1*X_2	-5.056	0.765	0.877	0.573	-4.991	1.157	0.002	0.285
X_2*X_3	1.567	0.133	0.772	0.504	1.434	0.186	0.195	0.858
X_1*X_3	0.774	-2.407	0.914	0.597	0.690	-3.290	0.512	0.013

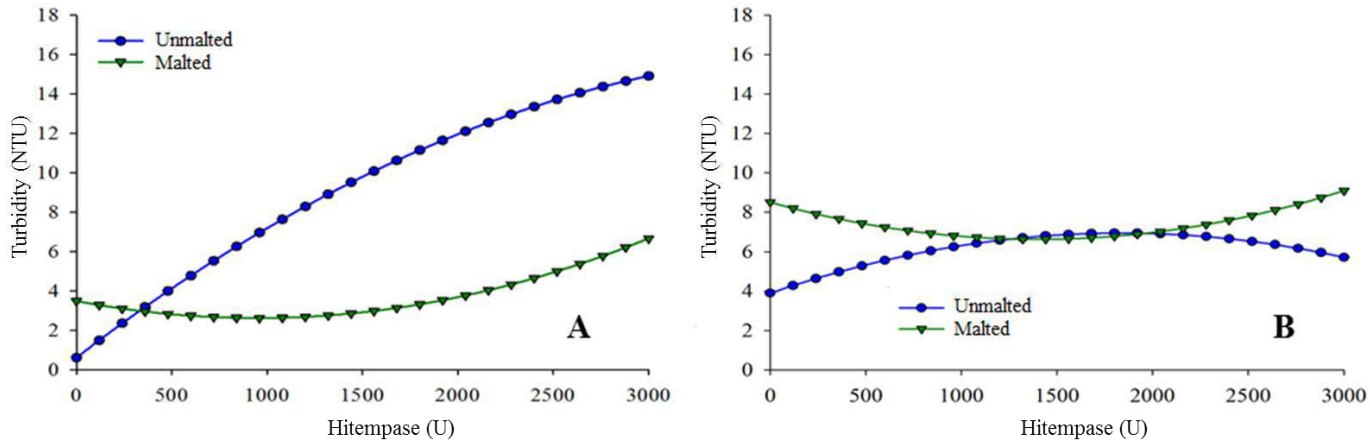


Figure 1. **(A)** : Effect of Hitempase (α-Amylase) on the evolution of *Madjeru* worts turbidity (NTU). (B) : Effect of Hitempase (α-Amylase) on the evolution of *Madjeru* worts turbidity (NTU) in the presence of Bioglucanase TX (750 BGU) and Brewers Protease (60 mg).

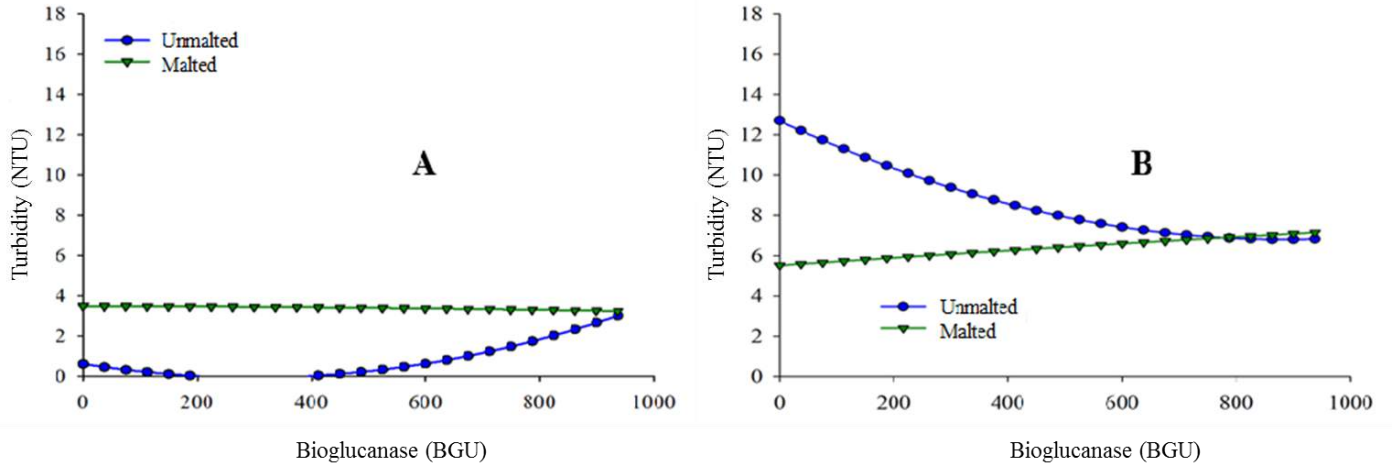


Figure 2. **(A) :** Effect of Bioglucanase (β-Glucanase) on the evolution of *Madjeru* worts turbidity (NTU). (B) : Effect of Bioglucanase (β-Glucanase) on the evolution of *Madjeru* worts turbidity (NTU) in the presence of Hitempase 2XL (1875 U) and Brewers Protease (60 mg).

Figure 1A represents the influence of Hitempase 2XL on the turbidity of unmalted and malted *Madjeru* worts. In the absence of this enzyme, turbidity was 0.59 NTU and 3.47 NTU respectively for unmalted and malted *Madjeru*. In the case of unmalted *Madjeru*, after addition of Hitempase 2XL, one observes an increase in turbidity up to a maximum value of 14.91 NTU corresponding to 3000 U. In the case of malted *Madjeru*, there was a drop of turbidity up to a minimal value of 2.61 NTU at 948.40 U; this turbidity increases thereafter up to 6.66 NTU at 3000 U. An addition of 331.24 U of Hitempase 2XL leads to obtaining worts having same turbidity as well for unmalted as for malted *Madjeru*, at 2.97 NTU.

Figure 1B represents the influence of Hitempase 2XL on the turbidity of unmalted and malted *Madjeru* worts, in the presence of Bioglucanase TX (750 BGU) and Brewers Protease (60 mg). In absence of Hitempase 2XL, the initial turbidity was 3.89 NTU and 8.50 NTU respectively for unmalted and malted *Madjeru*. In the case of unmalted *Madjeru*, after addition of Hitempase 2XL, one observes an increase in turbidity up to a maximum value of 6.94 NTU at 1835.70 U. A reduction thereafter is observed and, one reaches a minimal value of 5.71 NTU at 3000 U. In the case of malted *Madjeru*, turbidity drops up to the minimal value of 6.62 NTU at 1397.90 U; then, it increases up to 9.09 NTU at 3000 U. Additions of 1261.90 U and 1958.40 U of Hitempase 2XL leads to worts having same the turbidity both for unmalted and malted *Madjeru*, at 6.67 NTU and 6.92 NTU respectively.

The results show that the effect of Hitempase 2XL on wort turbidity would be more important for unmalted *Madjeru* than for malted *Madjeru*. This would be explained by the fact this enzyme alone (case of unmalted *Madjeru*), would be less effective in the solubilization of the major compound of the grain. It is especially the starch which would be solubilized by Hitempase 2XL and in addition, not only into simple sugars but also into oligosaccharides and dextrins (colloidal materials). Dextrins and significant amounts of proteins and other sugars

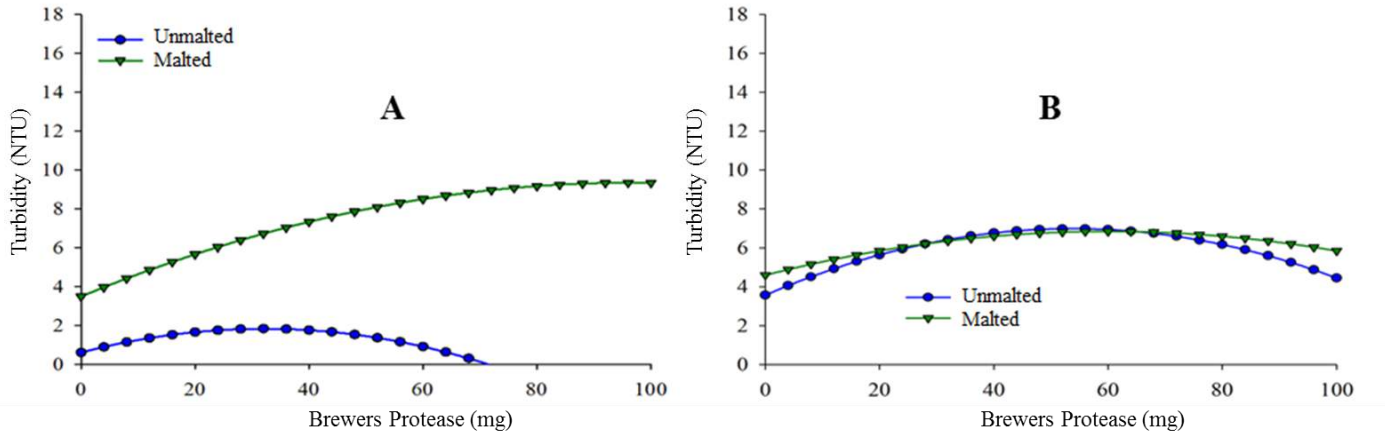


Figure 3. (A) : Effect of Brewers Protease on the evolution of *Madjeru* worts turbidity (NTU). (B) : Effect of Brewers Protease on the evolution of *Madjeru* worts turbidity (NTU) in the presence of Hitempase 2XL (1875 U) and Bioglucanase TX (750 BGU).

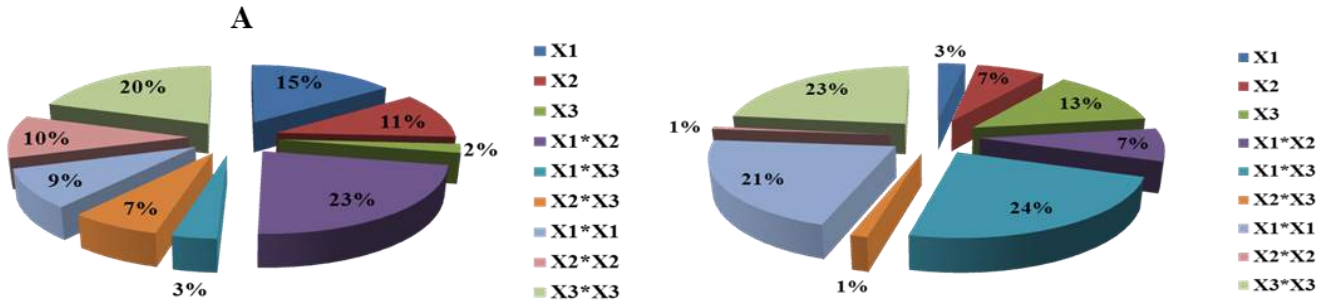


Figure 4. (A) : Contribution of each factor on the model for unmalted *Madjeru* wort turbidity (NTU). (B) : Contribution of each factor on the model for malted *Madjeru* wort turbidity (NTU).

such as the β-glucanes remain insoluble. However, during malting, (case of malted *Madjeru*) the grain is subjected to the action of a naturally balanced and variable quantity of hydrolytic enzymes which were synthetized in order to ensure

partial solubilization of the macromolecules of any nature [36, 37]. These enzymes continue to solubilize the molecules during mashing, decreasing therefore the turbidity of worts. It is nevertheless important to note that under the conditions described for Figure 1A, an increase of Hitempase 2XL in excess ($\geqslant$ 948.40 U), led to an increase in turbidity. The low turbidity observed in the absence or the presence of Hitempase 2XL (fig. 1A) at weak concentrations ($\leqslant$ 331.24 U) could be explained by the inefficiency of the enzyme at this concentration to release sufficient quantities of colloidal material by hydrolyzing starch (oligosaccharides and dextrins).

Increase in turbidity of wort up to 1835.70 U (Fig. 1B) in the case of unmalted *Madjeru* showed that at the beginning, the action of the enzyme led much more to the formation of the colloidal material (oligosaccharides and dextrins) than soluble material (monosaccharide). Beyond this concentration, the drop in turbidity would explain subsequent solubilization in particular oligosaccharides by the enzyme. The quantities of natural enzymes developed during malting, in addition to the quantities of added brewery enzymes, are sufficient to continue the solubilization of the macromolecules up to a Hitempase 2XL concentration of 1397.90 U. Any additional quantity (Hitempase 2XL) beyond this could increase the turbidity of worts.

According to the mathematical models, in its linear form (X_1), the impact of Hitempase 2XL on turbidity is significant (P = 0.000; Table 3) for unmalted *Madjeru* wort, and non-significant (P = 0.354) for malted *Madjeru* wort (Table 3). This action contributes to 15% and 3% for unmalted and malted *Madjeru* worts respectively (Fig. 4A and Fig. 4B). In its quadratic form (X_1^2), the action of Hitempase 2XL is statistically significant for the two types of wort (P = 0.033 and P = 0.004 respectively; Table 3). Its contribution to turbidity in this quadratic form (X_1^2) is indeed 9% and 21% for unmalted and malted *Madjeru* worts respectively (Fig. 4A and Fig. 4B).

Figure 2A represents the influence of Bioglucanase TX on the turbidity of unmalted and malted *Madjeru* worts. In the absence of this enzyme, the initial turbidity was 0.59 NTU and 3.47 NTU respectively. In the case of unmalted *Madjeru*, after addition of Bioglucanase TX, one observed a reduction of wort turbidity up to a value of 0.00 NTU at 201.47 BGU. After that, the curve increased to reach 3 NTU at 937.50 BGU. In the case of malted *Madjeru*, turbidity decreased slightly to reach 3.22 NTU at 937.5 BGU.

Figure 2B represents the influence of Bioglucanase TX on the turbidity of unmalted and malted *Madjeru* worts in the presence of Hitempase 2XL (1875 U) and Brewers Protease (60 mg). In the absence of this enzyme, initial turbidity was 12.70 NTU and 5.50 NTU respectively for unmalted and malted *Madjeru* worts. In the case of unmalted *Madjeru*, after addition of Bioglucanase TX, one observes a reduction of wort turbidity up to the minimal value of 6.82 NTU at 937.5 BGU. In the case of malted *Madjeru*, turbidity increases up to 7.14 NTU at 937.5 BGU. Another observation shows that an addition of 777.52 BGU of Bioglucanase TX led to the same turbidity of 6.88 NTU both for unmalted *Madjeru* and malted *Madjeru*.

A reduction in turbidity, followed an increase in the case of unmalted *Madjeru* worts, translated the fact that until the quantities in Bioglucanase TX of 201.47 BGU, this enzyme managed to solubilize β-glucanes responsible for the turbidity of worts. Beyond this concentration (as for Hitempase 2XL), an additional enzyme in the mash would constitute additional source of colloidal particles and thus increase in the turbidity of worts. In fact Bioglucanase TX hydrolyzed the β (1→3; 1→4) – glucanes link by the non-reducing ends in units of glucose, disaccharide, cellobiose and laminaribiose [37] which, would be solubilized thereafter [25]. In the case of malted *Madjeru*, the turbidity was quasi constant with increase in enzyme concentration (a light reduction of 0.23 NTU is approximately of 6%). These results showed that the effect of Bioglucanase TX on the modification of the wort turbidity profile during mashing was not important compared to that of Hitempase 2XL.

The results in the case of malted *Madjeru* show that malting mobilizes sufficient enzymes to weaken the grain and make these macromolecules more soluble so that there is no need for additional Bioglucanase TX during mashing. A contribution moreover in this enzyme did nothing but increased turbidity. On the other hand, the requirement in this enzyme during mashing of unmalted *Madjeru* is important to reduce turbidity.

The mathematical models showed, in its linear form (X_1) that, the impact of Bioglucanase TX on turbidity is significant both for unmalted *Madjeru* wort (P = 0.001; Table 3) and malted *Madjeru* wort (P = 0.042; Table 3). The increase in turbidity would be allotted to the enzymes synthesized during malting. This action contributes to 11% and 7% for unmalted and malted *Madjeru* respectively (Fig. 4A and Fig. 4B). In its quadratic form (X_1^2), the action of Bioglucanase TX (Table 3) is statistically significant for unmalted *Madjeru* (P = 0.021), and non-significant for malted *Madjeru* (P = 0.906). Its contribution to turbidity in this quadratic form (X_1^2) is indeed of 10% and 1% for unmalted and malted *Madjeru* respectively (Fig. 4A and Fig. 4B).

Figure 3A represents the influence of Brewers Protease on the turbidity of unmalted and malted *Madjeru* worts. In the absence of this enzyme, initial turbidity was 0.59 NTU and 3.47 NTU respectively. In the case of unmalted *Madjeru*, after addition of Brewers Protease, one observes an increase in turbidity up to 1.82 NTU at 32.12 mg. Thereafter turbidity decreased to reach 0.00 NTU at 71.31 mg. The case of malted *Madjeru* led to an increase in turbidity after addition of Brewers Protease, up to a maximum value of 9.34 NTU at 96.80 mg. On the other hand, at 100 mg of added enzyme, one has a turbidity of 9.33 NTU.

Figure 3B represents the influence of Brewers Protease on the turbidity of unmalted and malted *Madjeru* worts in the presence of Hitempase 2XL (1875 U) and Bioglucanase TX (750 BGU). In the absence of this enzyme, turbidity was 3.56 NTU and 4.59 NTU respectively for unmalted and malted *Madjeru* worts. After addition of Brewers Protease, one noted an increase in turbidity for both unmalted *Madjeru* worts and malted *Madjeru* worts up to respective maximum values of 6.98 NTU and 6.84 NTU at 53.73 mg and 59.98 mg

respectively. Thereafter turbidity decreased respectively to reach 4.44 NTU and 5.84 NTU at 100 mg. By adding 28.14 mg and 65.34 mg of Brewers Protease in the mash, one obtained both for unmalted and malted *Madjeru*, respective turbidity of 6.21 NTU and 6.82 NTU.

In the case of unmalted *Madjeru*, low turbidity could be explained by the colloidal matter residues which passed through the filter paper. On the Figure 3B, obtaining more important turbidity in absence of Brewers Protease, could be explained by the incomplete hydrolysis of the mash by α-amylase and protease. The action of protease on the mash of unmalted cereal was initially, the release of the starch granules while proceeding by a solubilization of protein film surrounding them. The first products are some amino-acids and especially peptides. The latter initially will increase turbidity before undergoing thereafter a solubilization under the action of Brewers Protease.

In the case of malted *Madjeru*, considering that the components of cereal already underwent a partial solubilization during malting [36-39], one had from the start higher turbidity. Additional protease only could not increase the turbidity of worts resulting from mashing.

The mathematical models showed that, in its linear form (X_1), the impact of Brewers Protease on wort turbidity was non-significant for unmalted *Madjeru* (P = 0.338; Table 3), but significant for malted Madjeru wort (P = 0.003; Table 3). The increase in turbidity would be allotted to the multitude of enzymes synthesized during malting. This action contributes to 2% and 13% for unmalted and malted *Madjeru* respectively (Fig. 4A and Fig. 4B). In its quadratic form (X_1^2), the action of Brewers Protease (Table 3) was statistically significant both for unmalted *Madjeru* (P = 0.000) and malted *Madjeru* (P = 0.002). Its contribution to turbidity in this quadratic form (X_1^2) was indeed of 20% and 23% for unmalted and malted *Madjeru* respectively (Fig. 4A and Fig. 4B).

The statistical analyzed (Table 4) present the impacts of interactions (X_1X_2, X_1X_3 and X_2X_3) between these enzymes on the turbidity of worts. The contributions were presented in the Figures 4A and 4B. They was globally statistically significant for unmalted *Madjeru* (P = 0.007), but not for malted *Madjeru* (P = 0.069).

Interaction X_1X_2 (Hitempase 2XL/Bioglucanase TX) had a significant impact on unmalted *Madjeru* wort but not-significant for that of malted *Madjeru* wort (P = 0.002 and 0.285 respectively; Table 3). It contributed to a total value of 23% for wort turbidity of unmalted *Madjeru* and to a total value of 7% for wort turbidity of malted *Madjeru* (Fig. 4A and Fig. 4B).

Interaction X_1X_3 (Hitempase 2XL/Brewers Protease) was not significant on the turbidity of unmalted *Madjeru* worts (P = 0.512; Table 3), but was significant on the turbidity of malted *Madjeru* worts (P = 0.013; Table 3). It contribution was of 3% and 24% respectively (Fig. 4A and Fig. 4B).

Interaction X_2X_3, corresponding to the couple Bioglucanase TX/Brewers Protease did not had significant impact on the turbidity both for unmalted *Madjeru* worts (P = 0.195) and malted *Madjeru* worts (P = 0.858; Table 3). It contribution was of 7% and 1% respectively (Fig. 4A and Fig. 4B).

A comparison made in Table 4 between turbidity of unmalted and malted *Madjeru* worts, showed that there is no significant difference (P = 0.232).

B. *Optimization*

The mathematical models obtained for the follow-up of unmalted and malted worts turbidity are represented by equations 5.1 and 5.2.

An optimization of these equations permitted to minimize unmalted and malted worts turbidity. These minimal characteristics are shown in Table 5. One could for unmalted and malted *Madjeru*, obtain turbidity close to 0.00 NTU and 5.27 NTU respectively.

To obtain wort whose turbidity was lower than 15 NTU both for unmalted *Madjeru* and malted *Madjeru*, it was consequently necessary to superimpose the contour plots. By maintaining the contribution in Bioglucanase at 0 BGU (-0,866), the expressions of equations 5.1 and 5.2 became:

$$Y_{MadTU}(X_1, X_3) = 11{,}268 + 7{,}790X_1 - 1{,}822X_3 + 0{,}774X_1X_3 - 2{,}036X_1^2 - 4{,}449X_3^2 \quad (6.1)$$

$$Y_{MadMTU}(X_1, X_3) = 5{,}434 - 0{,}372X_1 + 1{,}182X_3 - 2{,}407X_1X_3 + 2{,}164X_1^2 - 2{,}35X_3^2 \quad (6.2)$$

The layout of the contour plots after transformation of the coded values into real values permitted to obtain wort of turbidity lower than 15 NTU (Fig. 5)

TABLE IV. ANALYSE DE VARIANCE POUR COMPARAISON ENTRE LES TURBIDITES DES MOUTS DE MADJERU NON MALTE ET MALTE.

Source	Ddl	Sum square	Mean square	F	Probability
Inter-groups	1	9.462	9.462	1.48	0.232
Intra-groups	32	204.164	6.380		
Total	33	213.627			

TABLE V. OPTIMAL CONCENTRATION OF ENZYMES FOR MINIMAL CHARACTERISTICS OF UNMALTED AND MALTED *MADJERU* WORT.

Sorghum	Factors	Optimal Combinaisons		Response
		Coded values	Real values	Turbidity (NTU)
unmalted *Madjeru*	Hitempase 2XL	-1	0 U	0
	Bioglucanase TX	-0.315	298.25 BGU	
	Brewers Protease	-0.816	0 mg	
Malted *Madjeru*	Hitempase 2XL	-0.075	1387.50 U	5.27
	Bioglucanase TX	-0.866	0 BGU	
	Brewers Protease	-0.290	32.23 mg	

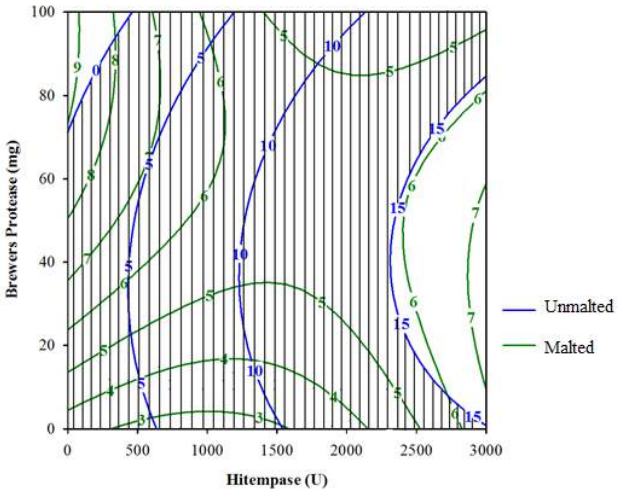


Figure 5. Aire de combinaisons enzymatiques induisant une turbidité (NTU) optimale des moûts du cultivar *Madjeru*.

IV. CONCLUSION

The effects of three commercial mashing enzymes (Hitempase 2XL, Bioglucanase TX and Brewers protease) on the turbidity were studied during the mashing of unmalted and malted *Madjeru*. Hitempase 2XL was the principal enzyme responsible for the increase of unmalted *Madjeru* wort turbidity. Optimization of mashing properties through models clearly describing the actions of individual commercial mashing enzymes, as displayed in this study using the response surface methodology, is however of interest, particularly when mashing with high amounts of sorghum adjuncts. Further studies of wort obtained after such studies should be the control of that turbidity after fermentation.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Department of Process Engineering, National School of Agro- Industrial Sciences (ENSAI) of the University of Ngaoundere (Cameroon) for providing necessary facilities for the successful completion of this research work.

.

REFERENCES

[1] O. U. EtokAkpan, "Amylolytic potentials and wort fermenting components of nigerian sorghums and barley," *World Journal of Microbiology and Biotechnology*, vol. 8, pp. 287-289, 1992.

[2] A. O. Aisien, "Enzymic modification of sorghum endosperm during seedling growth and malting," *Journal of the Science of Food and Agriculture*, vol. 33, pp. 754-759, 1982.

[3] J. R. N. Taylor, "Effect of malting on the protein and free amino nitrogen composition of sorghum,"

Journal of the Science of Food and Agriculture, vol. 34, pp. 885-892, 1983.

[4] B. K. Arri, "Problems associated with the use of sorghum for lager beer production. Industrial Utilization of sorghum," presented at the Symposium on the Current Status and Potential of Industrial Uses of Sorghum, Kano, Nigeria, 1989.

[5] G. N. Aniche and G. H. Palmer, "Development of amylolytic activities in sorghum and barley malt," *Journal of the Institute of Brewing*, vol. 96, pp. 377-379, 1990.

[6] O. U. EtokAkpan and G. H. Palmer, "Comparative studies of the development of endosperm-degrading enzymes in malting sorghum and barley," *World Journal of Microbiology and Biotechnology*, vol. 6, pp. 408-417, 1990.

[7] D. J. Evans and J. R. N. Taylor, "Extraction and assay of proteolytic activities in sorghum malt," *Journal of the Institute of Brewing*, vol. 96, pp. 201-207, 1990.

[8] D. J. Evans and J. R. N. Taylor, "Influence of cultivar and germination conditions on proteolytic activities in sorghum malt," *Journal of the Institute of Brewing*, vol. 96, pp. 399-402, 1990.

[9] J. R. N. Taylor, "Proteolysis in sorghum maltings," presented at the Proceedings of the Third Scientific and Technical Convention, Institute of Brewing, Central and South African Section, Johannesburg, 1991.

[10] J. P. Dufour, L. Melotte, and S. Srebrnik, "Sorghum malts for the production of a lager beer," *Journal of the American Society of Brewing Chemists*, vol. 50, pp. 110-119, 1992.

[11] F. Adejemilua, "Processing and profile of sorghum malt," *Technical Quarterly Master Brewers Association of the Americas*, vol. 32, pp. 15-18, 1995.

[12] R. C. Agu, A. H. Ugwu, M. U. Okenchi, I. B. Aneke, and T. U. Anyanwu, "Effect of low kilning temperatures on diastase and cellulase development of Nigerian malted sorghum (*Sorghum bicolor*)," *Process Biochemistry*, vol. 31, pp. 63-68, 1995.

[13] R. C. Agu and G. H. Palmer, "Effect of mashing with commercial enzymes on the properties of sorghum worts," *World Journal of Microbiology and Biotechnology*, vol. 14, pp. 43-48, 1998.

[14] R. C. Agu and G. H. Palmer, "Enzymic modification of endosperm of barley and sorghum of similar total nitrogen," *Brewer's Digest*, pp. 30-35, 1998.

[15] E. J. Nso, P. E. Ajebesone, C. M. Mbofung, and G. H. Palmer, "Properties of three sorghum cultivars used for the production of *Bili-Bili* beverage in Northern Cameroon," *Journal of the Institute of Brewing*, vol. 109, pp. 245-250, 2003.

[16] E. J. Nso, M. Nanadoum, and G. H. Palmer, "The effect of formaldehyde on enzyme development in sorghum malts," *Technical Quarterly Master Brewers Association of the Americas*, vol. 43, pp. 177-182, 2006.

[17] L. I. Ezeogu and B. N. Okolo, "Effects of final warm steeping and air-rest cycles on malt quality parameters of three improved nigerian sorghum cultivars," *Journal of the Institute of Brewing*, vol. 100, pp. 335-338, 1994.

[18] L. I. Ezeogu and B. N. Okolo, "Effects of air rest period on the mobilization of sorghum reserve proteins," *Journal of the Institute of Brewing*, vol. 101, pp. 463-468, 1995.

[19] B. N. Okolo and L. I. Ezeogu, "Enhancement of amylolytic potential of sorghum malts by alkaline steep treatment," *Journal of the Institute of Brewing*, vol. 102, pp. 79-85, 1996.

[20] L. I. Ezeogu and B. N. Okolo, "Relationship between some sorghum malt quality characteristics and nature of alkaline steep liquor," *Journal of the Institute of Brewing*, vol. 105, pp. 49-54, 1999.

[21] L. G. Declan, H. Catherine, and K. A. Elke, "Mashing studies with unmalted sorghum and malted barley," *Journal of the Institute of Brewing*, vol. 108, pp. 465-473, 2002.

[22] P. Kuusela, J. J. Hämäläinen, P. Reinikainen, and J. Olkku, "A simulation model for the control of beta-glucanase activity and beta-glucan degradation during germination in malting," *Journal of the Institute of Brewing*, vol. 110, pp. 309-319, 2004.

[23] J. J. Hämäläinen and P. Reinikainen, "A simulation model for malt enzyme activities in kilning," *Journal of the Institute of Brewing*, vol. 113, pp. 159-167, 2007.

[24] M. Robert, "A mathematical model of the formation of fermentable sugars from starch hydrolysis during high-temperature mashing," *Enzyme and Microbial Technology*, vol. 27, pp. 337-344, 2000.

[25] A. Kettunen, J. J. Hämäläinen, K. Stenholm, and K. Pietilä, "A model for the prediction of beta-glucanase activity and beta-glucan concentration during malting," *Journal of Food Engineering*, vol. 29, pp. 185-200, 1996.

[26] C. Brandam, X. M. Meyer, J. Proth, P. Strehaiano, and H. Pingaud, "An original kinetic model for the enzymatic hydrolysis of starch during mashing," *Biochemical Engineering Journal*, vol. 13, pp. 43-52, 2003.

[27] T. Kurz, J. Mieleitner, T. Becker, and A. Delgado, "A model based simulation of brewing yeast propagation," *Journal of the Institute of Brewing*, vol. 108, pp. 248-255, 2002.

[28] A. R. Speers, P. Rogers, and B. D. Smith, "Non-linear modelling of industrial brewing fermentations,"

Journal of the Institute of Brewing, vol. 109, pp. 229-235, 2003.

[29] N. B. Phiarais, B. D. Schehl, J. C. Oliveira, and E. K. Arendt, "Use of surface response methodology to investigate the effectiveness of commercial enzymes on buckwheat malt for brewing purpose," *Journal of the Institute of Brewing*, vol. 112, pp. 324-332, 2006.

[30] Z. S. C. Desobgo, E. J. Nso, D. Tenin, and G. J. Kayem, "Modelling and optimizing of mashing enzymes-effect on yield of filtrate of unmalted sorghum by use of response surface methodology," *Journal of the Institute of Brewing*, vol. 116, pp. 62-69, 2010.

[31] D. Baş and I. H. Boyac, "Modeling and optimization I: Usability of response surface methodology," *Journal of Food Engineering*, vol. 78, pp. 836-845, 2007.

[32] J. Baranyi, C. Pin, and T. Ross, "Validating and comparing predictive models," *International Journal of Food Microbiology*, vol. 48, pp. 159-166, 1999.

[33] T. Ross, "Indices for performance evaluation of predictive models in food microbiology," *Journal of Applied Bacteriology*, vol. 81, pp. 501-508, 1996.

[34] P. Dalgaard and L. V. Jorgensen, "Predicted and observed growth of Listeria monocytogenes in seafood challenge tests and in naturally contaminated cold smoked salmon," *International Journal of Food Microbiology*, vol. 40, pp. 105 - 115, 1998.

[35] Z. S. C. Desobgo, E. J. Nso, and D. Tenin, "Optimisation of the Action of Commercial Mashing Enzymes on Wort Extracts and Free Amino Nitrogen of the *Safrari* Sorghum Cultivar," *Technical Quarterly Master Brewers Association of the Americas*, vol. 48, pp. 77-86, 2011.

[36] G. H. Palmer, "Cereal for malting and brewing," in *Cereal science and technology*, G. Palmer, Ed., ed Aberdeen, Scotland: Aberdeen University Press, 1989, pp. 61-242.

[37] D. E. Briggs, *Malts and malting*, 1 ed. London: Blackie Academic & Professional, 1998.

[38] J. S. Hough, D. E. Briggs, R. Stevens, and T. W. Young, *Malting and brewing science*, University Press ed. vol. 2. London: Chapman and Hall, 1982.

[39] D. E. Briggs, C. A. Boulton, P. A. Brookes, and R. Stevens, *Brewing science and practice*. Cambridge: Woodhead Publishing Limited and CRC Press LLC, 2004.

Résumé de l’article

Optimization of the Impact of Hitempase 2XL, Bioglucanase TX and Brewers Protease on the Turbidity of *Madjeru* sorghum cultivar wort

Desobgo Zangué Steve Carly*, Nso Emmanuel Jong

Abstract

The action of three technical mashing enzymes (Hitempase 2XL, Bioglucanase TX and Brewers Protease) on the turbidity of the worts of unmalted and malted *Madjeru* sorghum mashes was modeled and analyzed using response surface methodology. The analysis showed that both Hitempase 2XL and Bioglucanase TX had significant impact on unmalted *Madjeru* worts turbidity during mashing of unmalted *Madjeru* sorghum grist, with a contribution of 15% and 11% respectively. Bioglucanase TX and Brewers Protease had significant impact on malted *Madjeru* worts turbidity, they contributed respectively for 7% and 13%. The interaction X_1X_2 also had a significant impact on wort turbidity of unmalted *Madjeru* for which it contributed 23%. The interaction X_1X_3 had a significant impact on wort turbidity of malted *Madjeru* for which it contributed 24%. Optimization of the concerted actions of the three enzymes for turbidity of unmalted *Madjeru* gave a combination of (0 U; 298.25 BGU and 0 mg) for Hitempase 2XL, Bioglucanase TX and Brewers Protease respectively. This gave a minimal turbidity of 0.00 NTU. This combination was: 1387.50 U; 0 BGU and 32.23 mg for malted *Madjeru*, giving a minimal turbidity of 5.27 NTU.

Keywords: enzymes, turbidity, response surface methodology, optimization, *Madjeru*

IV.4.2) Comparison of the mashing and brewing potentials of crude extracts of *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*

Titre de la revue

ACADEMIC JOURNALS
expand your knowledge

Journal of Brewing and Distilling

OPEN ACCESS

Comité de lecture

ACADEMIC JOURNALS (/)
expand your knowledge

Login (http://ms.academicjournals.org)

JOURNAL OF
BREWING AND DISTILLING

Abbreviation: J. Brew. Distilling | Language: English | ISSN: 2141-2197 | DOI: 10.5897/JBD | Start Year: 2010 | Published Articles: 25

Editors - JBD

Prof. Yujie Feng
State Key Laboratory of Urban Water Resource and Environment
Harbin Institute of Technology (HIT)
China.

Dr. Marcus Vinicius Alves Finco
University of Hohenheim
Stuttgart,
Germany.

Editorial Board Members

Dr. Juan Carlos González-Hernández
Instituto Tecnológico de Morelia
Morelia,
Mexico.

Dr. Saeed Zaker Bostanabad
Islamic Azad University
Tehran,
Iran.

Editor, editorial board and other members do not receive any remuneration. These positions are voluntary

Table des matières

ACADEMIC JOURNALS (/)
expand your knowledge

Login (http://ms.academicjournals.org)

JOURNAL OF
BREWING AND DISTILLING

Abbreviation: J. Brew. Distilling | Language: English | ISSN: 2141-2197 | DOI: 10.5897/JBD | Start Year: 2010

JBD Articles

View: All

Sort by: Date

March 2017

Evaluation of copper content in beers obtained from retail in Sweden

A quantitative study of copper (Cu) content in 19 different beer brands produced in mainly European countries and consumed in Sweden were measured using atomic absorption spectrophotometer without sample digestion. Results showed that the Cu content in beers is below the permissible levels concentrations for potable drinking water recommended by World Health Organization. In addition, the studies indicated that there is...

Author(s): D. Osorio-Macías, J. Mauricio Peñarrieta and L. Nilsson

https://doi.org/10.5897/JBD2017.0049 (https://doi.org/10.5897/JBD2017.0049) | Article Number: F6C0BF963648

Abstract (/journal/JBD/article-abstract/F6C0BF963648)

April 2015

Application of high gravity fermentation worts to the brewing of industrial opaque beer

Fermentation of worts with high concentrations of fermentable sugars has become common practice in large clear beer breweries that use high gravity worts containing 16-18% (w/v) dissolved solids to obtain high alcohol contents. Normal and high gravity worts, ranging from 12 to 20% (w/v) initial dissolved solid contents were used in industrial opaque beer brewing and the biochemical characteristics of the brews were...

Author(s): Misihairabgwi, Jane M., Kudita, Ivy and Zvauya, Remigio

https://doi.org/10.5897/JBD2014. 0046 (https://doi.org/10.5897/JBD2014. 0046) | Article Number: 473938652215

Abstract (/journal/JBD/article-abstract/473938652215)

November 2014

234

Nitrogen compounds in brewing wort and beer: A review

ACADEMIC JOURNALS expand your knowledge Login (http://ms.academicjournals.org)

Malting barley is obtained from the treatment and processing of three raw materials (barley malt, hops and water). From it, brewing wort fermented by the action of yeasts is obtained. Wort composition depends on the quality and type of raw materials used, as well as the control of the various processing steps. Wort composition also depends on the concentration and profile of nitrogen compounds, such as proteins,...

Author(s): Thiago Rocha dos Santos Mathias, Pedro Paulo Moretzsohn de Mello and Eliana Flavia Camporese Sérvulo

https://doi.org/10.5897/JBD2014.0042 (https://doi.org/10.5897/JBD2014.0042) | Article Number: 0A7CB9248727

Abstract (/journal/JBD/article-abstract/0A7CB9248727)

July 2014

Solid wastes in brewing process: A review

A large amount of agro-industrial waste is produced annually around the world from the beneficiated agricultural products or in food industrialization. The disposal of these residues in the environment results in a lot of inconvenience to the ecosystem, due to its significant nutritional value and high concentration of organic compounds that confers a high biochemical oxygen demand to the waste's degradation. In...

Author(s): Thiago Rocha dos Santos Mathias, Pedro Paulo Moretzsohn de Mello and Eliana Flavia Camporese Sérvulo

https://doi.org/10.5897/JBD2014.0043 (https://doi.org/10.5897/JBD2014.0043) | Article Number: 0E6313746212

Abstract (/journal/JBD/article-abstract/0E6313746212)

September 2013

Role of magnesium ions on yeast performance during very high gravity fermentation

The advent of highly efficient, environmentally friendly and cost effective fermentation technology has given impetus to research in the field of optimizing nutritional parameters for optimum yeast fermentative performance. Very high gravity fermentation is a novel fermentation technology that provides an increased production capacity from same size fermentation facilities, with outstanding benefits that...

Author(s): Henry Okwudili Udeh and Tsietsie Ephraim Kgatla

https://doi.org/10.5897/JBD2013.0041 (https://doi.org/10.5897/JBD2013.0041) | Article Number: 3015B4A282

Abstract (/journal/JBD/article-abstract/3015B4A282)

September 2013

Comparison of the mashing and brewing potentials of crude extracts of Abrus precatorius, Burnatia enneandra and Cadaba farinosa

The mashing and brewing potentials of crude extracts of three plants commonly used in Northern Cameroon to make starch gruels sweet were assessed using sorghum cultivarSafrari as an adjunct. Alpha-amylase activities of the extracts fluctuated between 18 and 122 U/g, while the diastatic power and the β-carboxypeptidase activities ranged between 83 and 123 WK, and 16 and 63 mg FAN/min/µL,...

Author(s): Emmanuel J. Nso, Aseaku J. N., Zangué S. C. Desobgo, Ngulewu C., Aleambong D. K. and Taïra A.

https://doi.org/10.5897/JBD12.007 (https://doi.org/10.5897/JBD12.007) | Article Number: E23DA03287

Abstract (/journal/JBD/article-abstract/E23DA03287)

March 2013

Effect of pasteurization and season on milk composition and ripening of Ras cheese

235
ACADEMIC JOURNALS
Login (http://ms.academicjournals.org)

The objective of this study was to compare between the raw and pasteurized Ras cheese from cow's milk through the season. The chemical composition of cheese was also demonstrated as the ripening period progressed. High solids in winter milk and low solids in summer milk were observed and were attributed to the hot weather and the poorer quality pastures. Casein as a percentage of true protein and the...

Author(s): Hattem, H. E., Taleb, A. T., Manal A. N. and Hanaa S. S.

https://doi.org/10.5897/JBD11.010 (https://doi.org/10.5897/JBD11.010) | Article Number: FA69293272

Abstract (/journal/JBD/article-abstract/FA69293272)

January 2013

Consumer preferences and market potential for sorghum based clear beer in Tanzania

This paper assessed the influence of consumers on sorghum based clear beer (Eagle) value chain in Tanzania. The specific objectives were to assess consumers' preferences and market potential of Eagle beer in Tanzania. The study areas were Moshi Rural and Karatu Districts in Kilimanjaro and Arusha regions respectively in Northern Tanzania. In these regions, the Eagle beer was launched for the first time...

Author(s): J. R. Makindara, J. P. Hella, J. M. Erbaugh and D. W. Larson

https://doi.org/10.5897/JBD11.015 (https://doi.org/10.5897/JBD11.015) | Article Number: AD5438E258

Abstract (/journal/JBD/article-abstract/AD5438E258)

January 2013

Processing of "Amgba": A sorghum-maize based beer, brewed in Cameroon

Amgba is an African traditional maize sorghum based opaque beer mainly considered as food than beverage by Gbaya peoples in Adamaoua region of Cameroon. Despite Amgba's importance as food, physicochemical composition as well as its process production is still not well understood. To overcome these constraints, the process production of "Amgba" was carried out in order to identify critical...

Author(s): Djoulde Darman Roger, Lendzemo Venassius, Essia Ngang Jean Justin and Etoa François Xavier

https://doi.org/10.5897/JBD12.004 (https://doi.org/10.5897/JBD12.004) | Article Number: E8C862D261

Abstract (/journal/JBD/article-abstract/E8C862D261)

March 2012

An industrial perspective of factors affecting molasses fermentation by Saccharomyces cerevisiae

In this study, an effort has been made to address the key issue of how molasses quality and composition are key components for higher yields during ethanol fermentation. Moreover, it was also noted that the choice of a yeast strain and yeast preconditioning have a positive effect on alcohol yield during molasses fermentation. A considerably better alcohol yield (9%) was obtained with low residual...

Author(s): Thulasizwe T. Ngwenya, Pratyoosh Shukla, Nishana Baboolal, Kugen Permauland Suren Singh

https://doi.org/10.5897/JBD12.002 (https://doi.org/10.5897/JBD12.002) | Article Number: 5BBC7B2275

Abstract (/journal/JBD/article-abstract/5BBC7B2275)

March 2012

Improvement of ethanol production from sugarcane molasses through enhanced nutrient supplementation using Saccharomyces cerevisiae

236

ACADEMIC JOURNALS

Login (http://ms.academicjournals.org)

Saccharomyces cerevisiae as a yeast cream was utilized for alcoholic fermentation using sugar cane molasses. In the present study, fermentation was optimized for urea and yeast hydrolysate (YH) dosage and the combined effect was evaluated. Total sugars as inverts (TSAI) composition of molasses were determined by HPLC as 39% (m/v). Urea concentrations of 4, 2 and 3 gl-1 showed optimal ethanol...

Author(s): Zuko Nofemele, Pratyoosh Shukla, Arthur Trussler, Kugen Permaul, and Suren Singh

https://doi.org/10.5897/JBD12.003 (https://doi.org/10.5897/JBD12.003) | Article Number: 71B1982279

Abstract (/journal/JBD/article-abstract/71B1982279)

February 2012

Construction of bottom-fermenting yeasts that over express the ubiquitin ligase RSP5 gene and their effects on high-gravity fermentation

It has been reported that over expression of the ubiquitin ligase RSP5 gene conferred tolerance to various stresses in laboratory yeast Saccharomyces cereivisiae. We constructed strains of bottom-fermenting yeast, natural hybrid, in which the S. cerevisiae(SC)-RSP5 or Saccharomyces bayanus (SB)-RSP5 is highly expressed and used for high-gravity fermentation. The...

Author(s): Tomoo Ogata, Hiromi Yamagishi, Ken Ukibe and Hiroshi Takagi

https://doi.org/10.5897/JBD11.017 (https://doi.org/10.5897/JBD11.017) | Article Number: D79D90B260

Abstract (/journal/JBD/article-abstract/D79D90B260)

February 2012

Biodegradable polymer drilling mud prepared from guinea corn

A biodegradable polymer drilling mud was prepared using Guinea corn starch pre- gelatinized in the absence of a solvent. The filtration and rheological properties of the mud were studied at 25 to 200°C temperature range and 0.01 to 0.05 g/mL concentration of starch using filter loss and viscomertric methods, respectively. Experimental results showed that the new mud has better filtration control...

Author(s): C. O. Chike–Onyegbula, O. Ogbobe, S. C. Nwanonenyi

https://doi.org/10.5897/JBD11.018 (https://doi.org/10.5897/JBD11.018) | Article Number: D6F71E6265

Abstract (/journal/JBD/article-abstract/D6F71E6265)

December 2011

Sensory assessment of sorghum brew adjunct and barley brew lager beer

The type and strain of yeast used in fermentation has a great influence on the taste and character of beer produced. Apart from brewing, sorghum has been used extensively in food industries. The essence of this study is to investigate the behavior of yeast in a sorghum/barley brew and also to investigate the sensory acceptability of such a combination. The study showed that the assessors were unable to detect...

Author(s): Olu Malomo, Ogunmoyela O. A. B., Oluwajoba S. O., Adigun M. O. and Daniel 'Toyosi

https://doi.org/10.5897/JBD11.004 (https://doi.org/10.5897/JBD11.004) | Article Number: A166B64288

Abstract (/journal/JBD/article-abstract/A166B64288)

December 2011

Studies on wine production from coconut (Cocos nucifera)

237
ACADEMIC JOURNALS
Login (http://ms.academicjournals.org)

Wine was produced at 1:4 (must: sugar) from coconut (Cocos nucifera) using natural yeast (Recipe A), natural yeast augmented with granulated sugar (Recipe B), natural yeast augmented with Baker's yeast, granulated sugar (Recipe C), a control consisting of granulated sugar and Baker's yeast (Recipe D). On fermentation for 120 h, pH values were 4.68±0.191, 4±0.029, 4.08±0.023,...

Author(s): Idise, Okiemute Emmanuel

https://doi.org/10.5897/JBD11.013 (https://doi.org/10.5897/JBD11.013) | Article Number: E12C0CB290

Abstract (/journal/JBD/article-abstract/E12C0CB290)

November 2011

A study on the effect of thermal treatments on composition and some properties of camel milk

The present study was carried out to investigate the effect of different thermal treatments on the composition and chemical properties of camel milk. The rennet clotting time of camel milk was also investigated. Camel milk samples were thermal treated at 63, 80 and 90°C for 30 min and 72°C for 15 s, whereas raw milk sample was served as a control. We found that the fat content was not...

Author(s): Hattem H. E., Manal A. Naeim, Hanaa S. Sakr and Elham H. Abouel-Einin
Article Number: ACFA8E6276

Abstract (/journal/JBD/article-abstract/ACFA8E6276)

November 2011

Studies on wine production from pawpaw (Carica papaya)

Wine was produced from pawpaw (Carica papaya) at a ratio of 1:4 for pawpaw must: water in fermentation vessels A to D. Fermentation vessel A pawpaw must contained natural yeast and water; B contained natural yeast from pawpaw and sugar solution; C contained natural yeast, activated baker's yeast and sugar solution; and D (control) contained sugar solution and Baker's yeast. Pawpaw wines produced...

Author(s): Idise Okiemute Emmanuel and Ofiyai Odoyo
Article Number: 46AFE04280

Abstract (/journal/JBD/article-abstract/46AFE04280)

May 2011

Modeling the action of technical mashing enzymes on extracts and free-amino nitrogen yields of the Madjeru sorghum cultivar

The action of three technical mashing enzymes (hitempase 2XL, bioglucanase-TX and brewers protease) on yields of extract and free amino nitrogen (FAN) of the worts of mashes of unmalted and malted Madjeru sorghum was modeled and analyzed using the response surface methodology. The analysis showed that increasing amounts of hitempase 2XL considerably increased yields of extract during mashing of...

Author(s): Zangué S. C. Desobgo, Emmanuel J. Nso and Dzudie Tenin
Article Number: B65F82A266

Abstract (/journal/JBD/article-abstract/B65F82A266)

May 2011

Polyphenols and antioxidant properties in forced and naturally aged Brazilian beer

Beer is a beverage obtained through alcoholic fermentation of malt wort, usually made of barley, which could be added of other cereals, such as corn, rice or wheat. Its alcoholic content is between 3 and 8%. It can be considered a good source of polyphenols derived both from malt and hop. Due to its antioxidant capacity and low alcoholic content, its able to improve plasma antioxidant activity, reducing the...

Author(s): Priscila Becker Siqueira, Helena Maria André Bolini and Gabriela Alves Macedo
Article Number: 7C2356A271

ACADEMIC JOURNALS expand your knowledge
Login (http://ms.academicjournals.org)

Abstract (/journal/JBD/article-abstract/7C2356A271)

April 2011

Volatile components of aroma hops (Humulus lupulus L.) commonly used in beer brewing

The essential oils from seven different aroma (finishing) varieties of hops (Humulus lupulus L.), "Cascade", "Hallertauer", "Northern Brewer", "Saaz", "Sterling", "Vanguard", and "Willamette", were obtained by hydrodistillation and analyzed by gas chromatography – mass spectrometry. A total of 98 compounds were...

Author(s): Marcelina R. Nance and William N. Setzer
Article Number: 4027AE2252

Abstract (/journal/JBD/article-abstract/4027AE2252)

April 2011

Utilization of milk permeate in the manufacture of sports drinks

The purpose of this study was to milk permeate in the manufacture of sports drinks. The milk permeate contained 6.1% total solids, 4.2% lactose and 0.54% ash. The permeate was treated through several processes, heat fermentation and clarification. Strawberry and mango homogenates were prepared and stored at -20°C until use. Fruit beverages were prepared using the pretreated permeate and fruit homogenates...

Author(s): Hattem H. E, Elham H. Abouel-Einin and Mehanna N. M.
Article Number: 64C9EAE256

Abstract (/journal/JBD/article-abstract/64C9EAE256)

June 2010

Production of alcohol from cassava flour hydrolysate

Alcohol was produced from cassava flour hydrolysate (CFH) with standard glucose and sucrose solutions used as controls. The conversion efficiency of sugar to alcohol, rate of fermentation and types of alcohol produced were determined. The effects of yeast concentrations (5, 15 and 20%) and fermentation time (24, 48, 72, 96 and 120 h) on yield of alcohol from CFH were also studied. Results showed that the...

Author(s): F. C. K. Ocloo and G. S. Ayernor
Article Number: A4F7CE339944

Abstract (/journal/JBD/article-abstract/A4F7CE339944)

June 2010

Paraquat used as a catalyst to increase the percentage of alcohol distillated in illicit brewing industry of Sri Lanka

Illicit brew contaminated with Paraquat, bipridyl non -selective contact herbicide,resulting in an epidemic of paraquat poisoning was investigated in Sri Lanka. It was found that the brewers use to hang the paraquat bottle with the lid pierced over the distilling cocktail. Brewers believe that condensed particles act as a catalyst, increasing the concentration and quality of the distillate. Clinical data,...

Author(s): R. Shavindra Dias
Article Number: 7E5315439946

Abstract (/journal/JBD/article-abstract/7E5315439946)

ACADEMIC JOURNALS (/)
expand your knowledge
Login (http://ms.academicjournals.org)

March 2010

The environmental and economical advantages of agricultural wastes for sustainability development in Sudan

Sudan is enjoyed with abundant solar, wind, hydro and biomass resources. Like many tropical countries, Sudan has ample biomass resources that can be efficiently exploited in a manner that is both profitable and sustainable. Fuel-wood farming offers cost-effective and environmentally friendly energy solutions for Sudan, with the added benefit of providing sustainable livelihoods in rural areas. This article provides an...

Author(s): Abdeen Mustafa Omer
Article Number: 87D3690255

Abstract (/journal/JBD/article-abstract/87D3690255)

March 2010

Evaluation of acute and sub-acute toxicity of ethanol extracts of Cansjera rheedii J. Gmelin (Opiliaceae)

Acute and sub-acute toxicity of ethanol (95% v/v) extract of aerial parts of Cansjera rheedii J. Gmelin (Opiliaceae) was evaluated in Swiss mice and Wistar albino rats. The acute toxicity studies were conducted as per the OECD guidelines 420, where the limit test dose of 2000 mg/kg used. Observations were made and recorded systemically on 1, 2, 4 and 24 h after dose administration for skin changes, morbidity,...

Author(s): Varadarasou Mouttaya Mounnissamy, Subramanian Kavimani, Gnanapragasam Sankari, Sabarimuthu Darlin Quine and Kuppuswamy Subramani
Article Number: 7C41B56267

Abstract (/journal/JBD/article-abstract/7C41B56267)

Page 1 of 1, showing 25 records out of 25 total, starting on record 1, ending on 25

← →

Search

View all articles (/journal/JBD/articles) ›

Advertisement

Pages de l’article

academicJournals

Vol. 4(2), pp. 46-50, September 2013
DOI: 10.5897/JBD2012.007
ISSN 2141-2197 ©2013 Academic Journals
http://www.academicjournals.org/JBD

Journal of Brewing and Distilling

Full Length Research Paper

Comparison of the mashing and brewing potentials of crude extracts of *Abrus precatorius, Burnatia enneandra* and *Cadaba farinosa*

Emmanuel J. Nso*, Aseaku J. N., Zangué S. C. Desobgo, Ngulewu C., Aleambong D. K. and Taïra A.

Department of Process Engineering, National School of Agro - Industrial Sciences (ENSAI) Ngaoundere, Adamawa, Cameroon.

Accepted 10 June, 2013

The mashing and brewing potentials of crude extracts of three plants commonly used in Northern Cameroon to make starch gruels sweet were assessed using sorghum cultivar *Safrari* as an adjunct. Alpha-amylase activities of the extracts fluctuated between 18 and 122 U/g, while the diastatic power and the β-carboxypeptidase activities ranged between 83 and 123 WK, and 16 and 63 mg FAN/min/µL, respectively. A longer mashing time (180 min) was necessary to obtain higher yields of extracts. Extract obtained was 18.7 °P for malted *Safrari,* 14.6 °P for malted barley, and 9.5, 13.5 and 11.4 °P after mashing *Safrari* adjuncts with extracts from *Abrus precatorius, Burnatia enneandra* and *Cadaba farinose*, respectively. Similar levels of reducing sugars ranging between 60 and 65 g/L were obtained when mashing was carried out using *A. precatorius, B. enneandra* and crude extracts, but about 50 g/L were obtained for *C. farinosa.* Free amino nitrogen fluctuated between 56 and 72 mg/L for *C. farinose* and *B. enneandra*, respectively, but was as low as 17 mg/L for *A. precatorius.* Fermentability was low for the worts obtained after mashing *Safrari* adjuncts using the extracts of the three plants, as compared to the worts of malted sorghum cultivar *Safrari* and barley.

Key words: *Abrus precatorius, Burnatia enneandra*, *Cadaba farinosa,* α-amylase, extract, free amino nitrogen (FAN).

INTRODUCTION

The use of technical enzymes has tremendously facilitated and improved food processing for the past decades (Hudson, 1986; Delrue, 1987; Law, 1990). Mashing with high amounts of adjuncts or with poorly modified barley malts using exogenous enzymes in the brewing industry improves yields in extracts (MacFadden and Clayton, 1989; Dale et al., 1990; Bajomo and Young, 1992; Agu and Palmer, 1998; Goode et al., 2002; Goode and Arendt, 2003; Goode et al., 2003; Desobgo et al., 2010). Malted sorghum is known to have low levels of important mashing enzymes such as α-amylase and β-amylase, but mash easily when supplemented with adequate commercial enzymes (Arri, 1990; EtokApan and Palmer, 1990; Dufour and Melotte, 1992; Nso et al., 2003; Nso et al., 2006). These enzymes and others are extracted from microorganisms and plants and commercialized as technical enzymes.

In Northern Cameroon, sorghum, maize and rice based starch gruels are traditionally made sweet using crude extracts of the plants *Abrus precatorius, Burnatia enneandra* and *Cadaba farinosa* (Glew et al., 2010). In this paper, we assessed the mashing and brewing

*Corresponding author. E-mail: nso_emmanuel@yahoo.fr. Tel: + 237 79 82 88 00. Fax: + 237 22 25 25 99.

potentials of crude extracts of these plants using unmalted *Safrari* sorghum as an adjunct.

MATERIALS AND METHODS

Biological materials

Sorghum cultivar *Safrari* was obtained from the Institute of Agronomic Research and Development (IRAD) in Maroua, Cameroon. Barley malt was obtained from "Société Anonyme des Brasseries du Cameroun" (SABC) in Garoua, Cameroun. *B. enneandra* and *C. farinosa* were obtained from Yagoua and *A. precatorius* from Ngaoundere, Cameroun.

Obtaining crude enzyme extracts

A. precatorius and C. farinose extracts

The leaves and tender stems of these plants were harvested, chopped using a knife and air dried at 40°C for five days using a CKA 2000 AUF-type dryer Ngaoundere, Cameroun. The chips were ground into coarse particle sizes using a Fryma machine AG mill type ML-150 (CH-4310 Rheinfelden, Switzerland) and next into fine particle sizes (Ø≤1 mm) using a laboratory hammer mill of model-Polymix PX-MFC 90D apparatus type (VWR International S.A.S. Le Périgas 201, rue carnot, 94126 Fontenay-sous-Bois Cedex, France). Fifty milliliters of 0.2 M phosphate buffer (disodium-potassium di hydrogen phosphate)/pH 6 were added to 10 g of the powder and agitated after every 10 min for 1 h. The mix was then filtered using a Whatman paper No. 42. The filtrate was retained as the enzyme extract for liquefaction and saccharification of sorghum grits during mashing.

B. enneandra extract

B. enneandra nuts were washed clean repeatedly with tap water. The fibrous coating was scrapped off with a knife and the kernels obtained by cracking of the nuts. The kernels were then chopped into small chips. They were dried at 40°C for five days and enzyme extract was obtained as described above for *A. precatorius* and *C. farinosa*.

Determination of the α-amylase activity of the extracts

Alpha-amylase activity of the extracts was determined using the 3,5-dinitrosalicyclic acid (DNS) method of Fischer and Stein (1969).

Determination of the diastatic power of barley and *Safrari* malts, *A. precatorius*, *C. farinosa and B. enneandra* powders

Diastatic power was determined according to the method described by Analytica-EBC (2006).

Determination of carboxypeptidase activity

The carboxypeptidase activities of the plant extracts, barley and *Safrari* malts, were obtained by the method described by Okolo and Ezeogu (1995).

Mashing

Mashing unmalted Safrari grits using crude enzyme extracts

Two hundred milliliters of distilled water were put into a 600 mL beaker and 50 g of sorghum flour (Ø<1 mm) was added with continuous stirring until a homogenous mixture was obtained. This mixture was incubated at 45°C for 30 min in a water bath with intermittent stirring at intervals of 5 min. The temperature of the mash was then raised to boiling so as to gelatinize sorghum starch during 40 min with intermittent stirring at intervals of 5 min before cooling to 65°C. Fifty milliliters of crude enzyme extracts were added to the mash and allowed to incubate for 1 h 30 min with intermittent stirring at intervals of 10 min.

Mashing of Safrari malt grist

Mashing was carried out as described above but 250 mL of distilled water were used. A portion of the supernatant (50 mL) was removed after 30 min decantation of the mix at 45°C. Starches in the endosperms tissue of the sorghum grits was gelatinized as described above. Decanted enzymic supernatant fractions (50 mL) were added to appropriate gelatinized sorghum mashes after they were cooled to 65°C. Mashing time for this mash mixture was 1 h, 30 min. The mashes were stirred at intervals of 10 min.

Mashing of barley malt grits

Mashing was done as described for *Safrari* malt grits with omission of boiling mash. The mashes were filtered during 1 h using Whatman paper No 42.

Determination of reducing sugars

Reducing sugars were determined according to the DNS method of Bernfeld (1986).

Determination of free amino nitrogen

Free amino nitrogen (FAN) was determined as described by Analytica-EBC (2006).

Determination of attenuation limit

Apparent fermentability of wort was determined according to the method described by Analytica-EBC (2006).

RESULTS AND DISCUSSION

The enzymatic brewing potential (α-amylase, diastatic power and β-carboxypeptidase) of malted cereals for mashing is an important criterion for accepting such raw material for beer brewing (Briggs et al., 2004). This enzymatic brewing potential of crude extracts of the plants *A. precatorius, B. enneandra* and *C. farinosa*, as well as the malted sorghum cultivar *Safrari* and barley, as reference malt, are compared in Table 1. Alpha-amylase

Table 1. Alpha-amylase and β-carboxypeptidase activities, and diastatic power of crude extracts of *A. precatorius, B. enneandra* and *C. farinosa* and malts.

Property	Extract type				
	A. precatorius	***B. enneandra***	***C. farinose***	**Malted *Safrari***	**Malted barley**
α-Amylase activity(U/g)	34.04±0.00	122.37±0.02	18.27±0.01	181.16±0.48	350,88±0.26
DP (WK)	83.43±0.10	122.47±0.25	109.52±0.33	273.32±0.18	483.84±0.13
β-Carboxy-peptidase (mg FAN/min/µL)	67.62±0.06	16.84±0.02	20.68±0.03	72.53±0.22	58.34±0.04

Table 2. Effect of duration of mashing unmalted *Safrari* grits using the crude enzyme extracts of *A. precatorius, B. enneandra* and *C. farinosa* on the wort extracts.

Sample type	Extract (°P)	
	Mashing time (min)	
	90	**180**
Unmalted *Safrari/A. precatorius*	7.8 ± 0.11	9.5 ± 0.05
Unmalted *Safrari/B. enneandra*	8.8 ± 0.13	13.5 ± 0.21
Unmalted *Safrari/C. farinosa*	8.0 ± 0.30	11.4 ± 0.15
Malted *Safrari*	16.6 ± 0.11	18.7 ± 0.11
Malted Barley	13 ± 0.09	14.6 ± 0.04

Table 3. Reducing sugars, FAN and fermentability after mashing *Safrari* and barley malts, and unmalted *Safrari* using crude extracts of*A. precatorius, B. enneandra* and *C. farinosa.*

Wort characteristics	Wort type				
	***Safrari* malt**	**Barley malt**	**Unmalted *Safrari/A. precatorius***	**Unmalted *Safrari/B. enneandra***	**Unmalted *Safrari/C. farinosa***
Reducing sugars (g/L)	34.29 ± 0.18	83.40 ± 0.09	64.31 ± 0.03	60.34 ± 0.15	49.56 ± 0.33
FAN (mg/L)	139.14 ± 0.01	173.27 ± 0.13	17.18 ± 0.02	71.60 ± 0.01	55.85 ± 0.03
Fermentability (%)	58.2	58.2	41.6	45.8	37.5

activity of the plant extracts was highest for *B. enneandra,* followed by *A. precatorius* and then *C. farinosa*. The importance of this activity is in the ratio of 100:28:15%, respectively. This activity was however highest for barley malt extract, about two times that of malted *Safrari* extract, and three times that of *B. enneandra* extract. Similarly, diastatic power of the extracts was in the ratio of 100:89:68% for *B. enneandra*, *C. farinosa* and *A. precatorius*, respectively. It was however highest for barley extract, about two times that of malted *Safrari* extract and four times that of *B. enneandra.* The ratio for β-carboxypeptidase activity is, 100:30:25% for *A. precatorius, C. farinosa and B. enneandra*, respectively. The activity of this enzyme for *A. precatorius* extract is comparable to that of malted *Safrari* and barley malt. Though the enzymatic potential of these crude extracts are lower than that for malted barley and *Safrari*, longer mashing periods or highly concentrated purified extracts will help obtain acceptable mashing performances.

The importance of time (90 and 180 min) on yields of extracts when mashing unmalted *Safrari* grits using the crude enzyme extracts of *A. precatorius, B. enneandra* and *C. farinose* was also compared. The results obtained (Table 2) show that yields of extracts were higher after mashing for 180 min as compared to mashing for 90 min. The greatest impact of mashing time on yields of extracts was obtained for unmalted *Safrari/B. enneandra* sample type, a difference of about 5 °P. A difference of about 2 °P was obtained for unmalted *Safrari/A. precatorius, Safrari* and barley malts was obtained and about 3 °P for unmalted*Safrari/C. farinosa* sample type. A mashing time of 180 min was therefore generally considered appropriate if higher yields of extract are to be obtained particularly when mashing with *B. enneandra* extracts.

Sugars and free amino nitrogen (FAN) are decisive in the fermentability of worts during beer brewing (Hough et al., 1982; Briggs et al., 2004; Edney et al., 2007). Three major brewing properties of wort compared were: the reducing sugars, FAN and fermentability (Table 3).

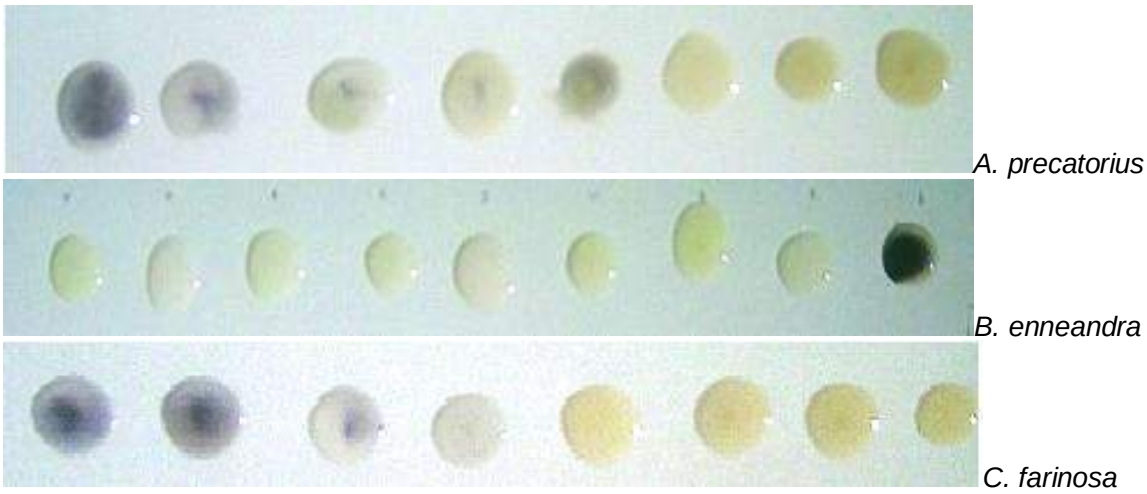


Figure 1. Iodine test during mashing of unmalted *Safrari* sorghum using crude extracts of *A. precatorius, B. enneandra* and *C. farinosa.*

Reducing sugars are about the same level after mashing unmalted *Safrari* with *A. precatorius* and *B. enneandra,* but slightly lower with *C. farinosa.* The level was two times on the average as low after mashing *Safrari* malt, as compared to those obtained for mashing unmalted *Safrari* using *A. precatorius* and *B. enneandra* extracts, but about three times as high after mashing barley malt. FAN was highest after mashing unmalted *Safrari* with *B. enneandra,* followed by *C. farinose* and then *A. precatorius* extracts and this is in the ratio of 100:78:24%. The free amino nitrogen content of malted barley wort was about 120% that of malted *Safrari* worts. The fermentability levels of *Safrari* and barley worts were similar but were much higher than those of the extracts and adjuncts. Worts obtained after mashing unmalted *Safrari* using the crude enzyme extracts of *A. precatorius, B. enneandra* and *C. farinose* showed fermentabilities fluctuating between 37 and 46%, with *C. farinosa* giving the lowest results and *B. enneandra* the highest. The fermentation performance of the yeast strain used in this study was however lower than expected (Briggs et al., 2004). The results obtained after carrying out the iodine test during mashing are shown in Figure 1.

Conclusion

The crude extracts of *A. precatorius, B. enneandra, and C. farinose* used in northern Cameroon to make sweet starch gruel for local consumption do have amylase and proteolytic activities. These extracts can be used for mashing and brewing of sorghum and other cereals. Further fractionation and purification of the crude extracts in order to concentrate their various enzyme components, would be of great use not only to the people of this part of Cameroon but also for industrial purposes.

REFERENCES

Agu RC, Palmer GH (1998). Effect of mashing with commercial enzymes on the properties of sorghum worts. World J. Microbiol. Biotechnol. 14:43-48.

Analytica-EBC (2006). European Brewery Convention. Fachverlag Hans Carl: Nürnberg, Germany.

Arri BK (1990). Problems associated with the use of sorghum for lager beer production. Industrial utilization of sorghum: Symposium on the Current Status and Potential of Industrial Uses of Sorghum. ICRISAT: Kano, Nigeria.

Bajomo MF, Young TW (1992). Development of profile for the use of microbial enzymes in brewing with raw sorghum (80%) and malted barley of sorghum malt (20%). J. Inst. Brew. 98:515-523.

Bernfeld P (1986).Amylases, alpha and beta. This week's citation classic n° 40. Tufts University School of Medicine. Boston, MA. Meth. In Enzymol. 1:149-158.

Briggs DE, Boulton CA, Brookes PA, Stevens R (2004). Brewing science and practice. Cambridge: Woodhead Publishing Limited and CRC Press LLC.

Dale CJ, Young TW, Omole T (1990). Small scale mashing experiments with grist containing high proportions of raw sorghum. J. Inst. Brew. 96:403-409.

Delrue RM (1987). A review of glucose and fructose syrups. In: A. Turner, Ed., Food Technology, International Europe. Sterling Publications International. London: 171-174.

Desobgo ZSC, Nso EJ, Tenin D, Kayem GJ (2010).Modelling and optimizing of mashing enzymes - effect on yield of filtrate of unmalted sorghum by use of response surface methodology. J. Inst. Brew. 116 (1):62-69.

Dufour JP, Melotte L (1992). Sorghum malts for the production of a lager beer. J. Am. Soc. Brew. Chem. 50 (3):110-119.

Edney MJ, Eglinton JK, Collins HM, Barr AR, Legge WG, Rossnagel BG (2007). Importance of Endosperm Modification for Malt Wort Fermentability. J. Inst. Brew. 113(2):228-238.

EtokApan OU, Palmer GH (1990). Comparative studies of the development of endosperm-degrading enzymes in malting sorghum and barley. World J. Microbiol. Biotechnol. 6:408-417.

Fisher EH, Stein EA (1969). Enzymes 2nd Ed. Vol 4, Academic Press, New York: 343.

Glew RH, Kramer JKG, Hernandez M, Pastuszyn A, Ernst J, Ngouya DN, VanderJagt DJ (2010). The amino acid, mineral and fatty acid content of three species of human plant foods in Cameroon. J. Phytochem. 62(4):21-30.

Goode LD, Arendt EK (2003). Pilot scale production of lager beer from

grist containing 50% unmalted sorghum. J. Inst. Brew. 109(3):208-217.
Goode LD, Halbert C, Arendt EK (2002). Mashing studies with unmalted sorghum and malted barley. J. Inst. Brew. 108(4):465-473.
Goode LD, Halbert C, Arendt EK (2003). Optimisation of mashing conditions when mashing with unmalted sorghum and commercial enzymes. J. Am. Soc. Brew. Chem. 61(2):69-78.
Hough JS, Briggs DE, Stevens R, Young TW (1982). Malting and brewing science. University Press ed. London: Chapman and Hall.
Hudson J (1986). What's new in brewing technology? Food Manuf. 60:64-65.
Law BA (1990). Tailoring enzymes for food users. In: A. Turner, Ed., Food Technology International Europe. Sterling Publications International, London. 161-165.
MacFadden DP, Clayton M (1989). Brewing with sorghum-use of exogenous enzymes. Brewing and Beverage Industry International. 1:71-81.
Nso EJ, Ajebesone PE, Mbofung CM, Palmer GH (2003). Properties of three sorghum cultivars used in the production of Bili-Bili beverage in Northern Cameroon. J. Inst. Brew. 109(3):245-450.
Nso EJ, Nanadum M, Palmer GH (2006). The effect of formaldehyde on enzyme development in sorghum malts. Tech. Q. Master Brew. Assoc. Am. 43(3):177-182.
Okolo BN, Ezeogu LI (1995). Effects of air rest period on the mobilization of sorghum reserve proteins. J. Inst. Brew.101:463-468.

Résumé de l’article

Comparison of the mashing and brewing potentials of crude extracts of *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*

Emmanuel J. Nso*, Aseaku J. N., **Zangué S. C. Desobgo**, Ngulewu C., Aleambong D. K. and Taïra A.

Abstract

The mashing and brewing potentials of crude extracts of three plants commonly used in Northern Cameroon to make starch gruels sweet were assessed using sorghum cultivar *Safrari* as an adjunct. Alpha-amylase activities of the extracts fluctuated between 18 and 122 U/g, while the diastatic power and the β-carboxypeptidase activities ranged between 83 and 123 WK, and 16 and 63 mg FAN/min/µL, respectively. A longer mashing time (180 min) was necessary to obtain higher yields of extracts. Extract obtained was 18.7 °P for malted *Safrari*, 14.6 °P for malted barley, and 9.5, 13.5 and 11.4 °P after mashing *Safrari* adjuncts with extracts from *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*, respectively. Similar levels of reducing sugars ranging between 60 and 65 g/L were obtained when mashing was carried out using A. *precatorius*, B. *enneandra* and crude extracts, but about 50 g/L were obtained for C. *farinosa*. Free amino nitrogen fluctuated between 56 and 72 mg/L for C. *farinosa* and B. *enneandra*, respectively, but was as low as 17 mg/L for A. *precatorius*. Fermentability was low for the worts obtained after mashing *Safrari* adjuncts using the extracts of the three plants, as compared to the worts of malted sorghum cultivar *Safrari* and barley.

Keywords: *Abrus precatorius*, *Burnatia enneandra*, *Cadaba farinosa*, α-amylase, extract, free amino nitrogen (FAN)

IV.4.3) Dimethyl Sulfide Stripping Behavior During Wort Boiling Using Response Surface Methodology

Titre de la revue

American Society of Brewing Chemists
FREE ACCESS

Comité de lecture

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, pleas
contact our customer service department to purchase a subscription.

Journal

Journal of the American Society of Brewing Chemists ›
The Science of Beer

This journal

Editorial board

Editor-in-Chief
Inge Russell

Editorial Board
G. Aerts
R. Agu
P. Aldred
M. Andersen
P. Aron
C. Boulton
S. Britton
D. Cook
C. Curtin
S. Deckers
J. De Clippeleer
S. Duke
A. Egi
R. Foster
L. Garbe
C. Henson

A. Hill
J. Hort
N. Kageyama
M. Kanauchi
S. Lawrence
Q. Li
B. Lodolo
A. Macintosh
D. Maskell
C. Powell
G. Sanchez
D. Sedin
S. Serna-Saldivar
T. Shellhammer
J. Sheppard
A. Speers
D. Stewart
E. Storgards
L. Van Nedervelde
K. Verstrepen
D. Vollmer
G. Walker
D. Wang
H. Wedler
X. Yin
M. Zarnkow
B. Ziola

Publisher
Amy L. Hope

Director of Publications
Greg Grahek

Technical Editor

Carol Duling

Circulation Coordinator

Dawn Wuest

Table des matières

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, please contact our customer service department to purchase a subscription.

Journal of the American Society of Brewing Chemists

The Science of Beer

2017 Impact Factor
0.880

Publish open access in this journal

Advanced search

Submit an article New content alerts RSS Citation search

Current issue Browse list of issues

Official Journal of the American Society of Brewing Chemists

This journal

Kirkendall et al.
Published online: 11 Jun 2018

Investigations into the Transfer Rate of Volatile Compounds in y F ing tanol-Water Partition Coefficient Model

Control of Fermentation By-Products and Aroma Features of Beer Pr ed with Sc Ale Yeast by Variation of Fermentation Temperature and Wort Aeration Rate

Analysis of Physicochemical Indices, Volatile Flavor Components, and Microbial Community of a Light-Flavor *Daqu*

See all volumes and issues

Volume 73, 2015 | Vol 72, 2014 | Vol 71

Issue 4 | Issue 3 | Issue 2 | Issue 1

Biographical Review

Review

Seduced by Yeast

Graham G. Stewart

Pages: 1-21

Published online: 05 Feb 2018

4 Views | 0 CrossRef citations | 0 Altmetric

Original Articles

Article

Use of Exogenous Enzymes and Process Management to Improve the Shelf Life of Traditional Opaque Beer

Sorelle D. Nsogning, Martin Zarnkow, Thomas Becker, Alexander Merz & Sven Schönenberg

Pages: 22-28

Published online: 05 Feb 2018

2 Views | 0 CrossRef citations | 0 Altmetric

Article

Identification of Malting Quality QTLs in Advanced Generation Breeding Germplasm

Duke Pauli, Gina Brown-Guedira & Thomas K. Blake

Pages: 29-40

Published online: 05 Feb 2018

3 Views | 0 CrossRef citations | 0 Altmetric

Article

Pilot Plant Production of Low-Alcohol Beer by Osmotic Distillation ›

Giovanni De Francesco, Valeria Sileoni, Ombretta Marconi & Giuseppe Perretti

Pages: 41-48

Published online: 05 Feb 2018

5 Views | 0 CrossRef citations | 0 Altmetric

Article

Measuring the Emotional Response to Beer and the Relative Impact of Sensory and Packaging Cues ›

C. Chaya, J. Pacoud, M. Ng, A. Fenton & J. Hort

Pages: 49-60

Published online: 05 Feb 2018

11 Views | 0 CrossRef citations | 14 Altmetric

Article

Polyfunctional Thiols in Fresh and Aged Belgian Special Beers: Fate of Hop *S*-Cysteine Conjugates ›

Thi Thu Hang Tran, Marie-Lucie Kankolongo Cibaka & Sonia Collin

Pages: 61-70

Published online: 05 Feb 2018

6 Views | 1 CrossRef citations | 0 Altmetric

Article

HPLC Bottom-Up MS-Based Proteomics for Mapping of Specific Proteins in Several European Spring Barley Varieties ›

Dana Flodrová, Dagmar Benkovská, Markéta Laštovičková & Janette Bobálová

Pages: 71-77

Published online: 05 Feb 2018

2 Views | 0 CrossRef citations | 0 Altmetric

Article

Simultaneous Determination of Maltooligosaccharides in Beer Using HPLC-ELSD and Their Influence on Beer Foam Stability ›

Xi Chen, Jinjing Wang & Qi Li

Pages: 78-83

Published online: 05 Feb 2018

2 Views | 0 CrossRef citations | 0 Altmetric

Article

Dimethyl Sulfide Stripping Behavior during Wort Boiling Using Response Surface Methodology ›

Zangué S. C. Desobgo, R. A. Stafford & D. J. A. Metcalfe

Pages: 84-89

Published online: 05 Feb 2018

7 Views | 4 CrossRef citations | 0 Altmetric

Article

An Improved Model for Prediction of Wort Fermentation Progress and Total Diacetyl Profile ›

Kristoffer Krogerus, Brian Gibson & Eemeli Hytönen

Pages: 90-99

Published online: 05 Feb 2018

10 Views | 0 CrossRef citations | 0 Altmetric

Article

Exploring the Binding Behavior of Beer Staling Aldehydes in Model Systems ›

Jeroen J. Baert, Jessika De Clippeleer, Luc De Cooman & Guido Aerts

Pages: 100-108

Published online: 05 Feb 2018

3 Views | 2 CrossRef citations | 0 Altmetric

Acknowledgements

Acknowledgment of *ASBC Journal* Referees for 2014 ›

Page: 109

Published online: 05 Feb 2018

0 Views | 0 CrossRef citations | 0 Altmetric

Explore

Most read articles Most cited articles Open access articles

Pages de l’article

Dimethyl Sulfide Stripping Behavior During Wort Boiling Using Response Surface Methodology

Zangué S. C. Desobgo,[1] *Department of Biotechnology and Food Technology of the Faculty of Science, and Faculty of Engineering and Built Environment of the University of Johannesburg;* **R. A. Stafford,** *Faculty of Engineering and Built Environment, University of Johannesburg;* **and D. J. A. Metcalfe,** *Faculty of Science, Department of Biotechnology and Food Technology, University of Johannesburg*

ABSTRACT

J. Am. Soc. Brew. Chem. 73(1):84-89, 2015

The action of two wort variables (power input and boiling time) on the residual dimethyl sulfide (DMS) of two boiled wort substitutes (water/DMS and water/sugar/DMS) was modeled and analyzed using response surface methodology. The analysis showed that both power input and boiling time had significant impact on residual DMS during wort boiling, with power input contributions of 12.4 and 11.9% for water/DMS and water/sugar/DMS, respectively, and boiling time contributions of 45.6 and 48.8% for water/DMS and water/sugar/DMS, respectively. The interaction also had a significant impact on residual DMS for the water/DMS wort substitute, with a contribution of 2.8%. The volatilization coefficient (k_2) obtained at each power input were not statistically significantly different for the two wort substitutes but exhibited exponential growth evolution: from 0.0202 to 0.0436 min^{-1} and from 0.0143 to 0.0360 min^{-1} for water/DMS and water/sugar/DMS wort substitutes, respectively. To achieve an energy target of 50 ppb by minimizing the energy consumed at the end of boiling, the following conditions were adopted: for water/DMS, boiling at 500 W for 123 min (3.66 MJ); for water/sugar/DMS, boiling at 500 W for 174 min (5.19 MJ).

Keywords: Boiling time, Dimethyl sulfide, Power input, Response surface methodology, Wort boiling

DMS is a sulfur compound that is recognized as the source of off-flavor. It is volatile and results from the conversion of a precursor (*S*-methyl methionine, SMM) in malt during boiling and, to a lesser extent, during fermentation of beer. It could contribute in several ways positively or negatively to the flavors of many food products and fermented beverages (1,4,10,18,23). It is known as a significant component of beer flavor, and several studies have been done in order to identify, quantify, and understand its formation and removal from wort and beer (8,11,16,26). Many detection techniques have been developed for that purpose (4,7,9,10,14,18). For a better understanding of DMS, some kinetic models have been developed in order to predict its formation via SMM and its removal during wort boiling and fermentation (12,29). The modeling approach in the literature was predominantly empirical and focused on boiling time. The aim of this study was to investigate the behavior shown in the stripping of DMS using a response surface methodology (RSM) approach. Power input and boiling time were used as covariables. Two wort substitutes (water/DMS and water/sugar/DMS) were considered to study the impact of the main wort component (sugar) on DMS stripping.

[1] Corresponding author. Phone: +237 77909391; E-mail: desobgo@yahoo.fr

http://dx.doi.org/10.1094/ASBCJ-2015-0103-01

© 2015 American Society of Brewing Chemists, Inc.

EXPERIMENTAL

Chemicals

The chemicals used in this study were DMS solution (99% purity) and sucrose (≥99.5% purity) from Sigma Aldrich and dichloromethane (DCM) solution (≥99.8% for HPLC) from Chromasolv.

Sample Preparation

Two wort substitutes were considered: distilled water and distilled water and sugar (12°B), both doped with DMS to an initial concentration of 650 ppb (w/v). A HANNA HI 96801 refractometer, 0 to 85% Brix (from HANNA Instruments Inc., Woonsocket, RI) was used to measure sugar concentration.

The wort-boiling unit consisted of a voltage regulator (phases, 1; input, 220 V, 50 to 60 Hz; output, 0 to 250 V; capacity, 2,000 VA; max., 8 amp; model TDGC2-2kVA from AC-DC Dynamics, Johannesburg, South Africa), which was connected to a Lutron DW-6060 watt meter. The watt meter was connected to the boiling kettle. A thermometer from Therma 3 Thermometer (manufactured in the United Kingdom by ETI Ltd.) was used to determine the wort temperature during the boiling process.

To execute the boiling experiments, a high-power input (2,000 W) was used to shorten the preheating time and bring the wort substitutes (10 L) to boiling temperature (95°C). After reaching the boiling point, the power input was reduced to the desired power using the voltage regulator, and the power input value was obtained via the watt meter according to the Doehlert experimental design (Table I). Timekeeping was then implemented immediately according to the experimental design (all the boiling experiments were done in triplicate). When boiling was complete, 100 mL of each manipulation was collected with a 250-mL Schott Duran glass (with screw top) and cooled in cold water. After cooling, 20 mL of DCM was added, and the residual DMS extraction was done at 450 rpm using a centrifuge (HT Infors AG Rittergasse CH-4103, Bottmingen, Switzerland) for 1 h. At the end of the extraction process, the organic phase was introduced into vials and crimped for GC analysis. The standard curve was prepared using a DMS concentration from 0 to 700 ppb.

Gas Chromatography Analysis of DMS

Analysis of DMS by gas chromatography (GC) was performed using a Shimadzu GC-2010 Plus capillary gas chromatograph autosampler equipped with a flame ionization detector (FID). The column used was a Restek RTX-5 (30 m × 0.32 mm × 0.25 µm). The chromatograph was set for a split ratio of 5. The injection volume was 1 µL. A volumetric flow rate of 3 mL/min with helium as the carrier gas was used with a constant column head pressure of 83 kPa. The oven temperature program started with an initial setting of 35°C for 3.5 min, followed by an immediate ramp of 40°C/min to 280°C followed by a hold of 3 min. This led to a total program time of 12.63 min. The FID burner temperature

was 300°C with a hydrogen flow rate of 30 mL/min and an airflow rate of 300 mL/min.

Experimental Design, Modeling, and Validation of the Model

RSM with the Doehlert design (25) was used for the experiments in order to model and optimize the DMS removal during boiling of wort substitutes. The independent factors were the power input (x_1) and the boiling time (x_2). The intervals of these factors were X_1, 500 to 1,500 W, and X_2, 0 to 60 min, while the response was the residual DMS in the experimental wort after boiling. The two-factor Doehlert design gave a total of eight experiments, as shown in Table I.

From the coded factors, mathematical equations were used to convert them into real values for experiments. Those equations were as follows:

$$X_i = X_{0i} + x_i \times \Delta X_i \quad (1)$$

$$N = k^2 + k + k_0 \quad (2)$$

where X_i is a real variable; X_{0i} is the center of the variable; x_i is a coded variable given by the Doehlert table; ΔX_i is the increment; k is number of variables; k_0 is the number of center points, and N is the number of experiments.

Mathematical models describing the relationships among the process-dependent responses and the independent factors in a second-order equation were developed (17). Design-based experimental data were matched according to the following second-order polynomial equation.

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum \sum_{i<j}^{k} \beta_{ii} x_i x_j \quad (3)$$

where Y is the response, x_i and x_j are the factors, β_0 is the constant, β_i is the coefficient of the linear terms, β_{ii} is the coefficient of the quadratic terms, and β_{ij} is the coefficient of the interaction terms.

The coefficients of the models were obtained using Minitab version 16 software (Minitab, Ltd., Coventry, U.K.). This software was also used to execute a statistical analysis (ANOVA) on the models, and the curves were plotted using Sigmaplot version 12.5 (Systat Software, Inc., San Jose, CA).

The validation of the models was obtained by calculating the absolute average deviation (AAD), the bias factor (B_f), and the accuracy factor (A_f) (2,34), which were obtained using equations 4, 5, and 6 below.

$$AAD = \frac{\left[\sum_{i=1}^{N}\left(\frac{\left|Y_{i,\exp} - Y_{i,cal}\right|}{Y_{i,\exp}}\right)\right]}{N} \quad (4)$$

$$B_f = 10^{\frac{1}{N}\sum_{i=1}^{N}\log\left(\frac{Y_{i,cal}}{Y_{i,\exp}}\right)} \quad (5)$$

$$A_{f1} = 10^{\frac{1}{N}\sum_{i=1}^{N}\left|\log\left(\frac{Y_{i,cal}}{Y_{i,\exp}}\right)\right|} \quad (6)$$

where $Y_{i,exp}$ and $Y_{i,cal}$ are experimental and calculated responses, respectively, and N is the number of experiments used in the calculation.

Estimation of DMS Volatilization Rate Coefficient k_2 and Statistical Comparison

A simulation was done using the models at fixed values of power input and the DMS concentration equation, which was as follows (29):

$$[D]_L = \frac{k_1}{k_2 - k_1}[S]_0\{\exp(-k_1 t) - \exp(-k_2 t)\} + [D]_{L0}\exp(-k_2 t) \quad (7)$$

where k_1 is the reaction rate coefficient from SMM to DMS; k_2 is the volatilization rate coefficient of DMS; t is boiling time; $[D]_L$ is concentration of DMS in the liquid phase; $[S]$ is concentration of SMM in the liquid phase, and the subscript "0" indicates the initial time.

Since $[S]_0 = 0$ because of the absence of SMM in the substitute worts, the DMS vaporization equation could be written as:

$$[D]_L = [D]_{L0}\exp(-k_2 t) \quad (8)$$

In order to compare the influence of wort boiling on the two wort substitutes, the data of the two models were compared statistically using the *t*-test (comparison of means), the *F*-test (comparison of standard deviations), the *W*-test (comparison of medians), and the Kolmogorov–Smirnov test (comparison of the distributions of the two samples). This was done using the software Statgraphics Centurion XVI (build 16.1.11 StatPoint Technologies, Inc., Warrenton, VA, U.S.A.).

TABLE I
Matrixes of Doehlert and Validation Coefficients (R^2, AAD, B_f, A_f)[a]

Coded values		Real values		Water/DMS	Water/sugar/DMS
x_1	x_2	X_1 (W)	X_2 (min)	DMS (ppb)	DMS (ppb)
0	0	1,000	30	258.00 ± 3.11	289.66 ± 2.57
0	0	1,000	30	256.14 ± 2.95	287.47 ± 3.76
1	0	1,500	30	172.66 ± 5.31	193.32 ± 7.77
0.5	0.866	1,250	60	74.85 ± 5.07	92.52 ± 4.29
–0.5	0.866	750	60	185.61 ± 6.72	224.28 ± 4.31
–1	0	500	30	303.20 ± 11.15	352.20 ± 10.15
–0.5	–0.866	750	0	615.00 ± 13.81	589.00 ± 12.43
0.5	–0.866	1,250	0	588.00 ± 7.33	618.00 ± 8.61
			R^2	0.999	0.997
			AAD	0.006	0.032
			B_f	1.001	0.994
			A_f	1.006	1.033

[a] DMS =dimethyl sulfide; x_1 = power input; x_2 = boiling time; AAD = absolute average deviation, B = bias factor, A = accuracy factor.

Optimization of the Models

The optimization, which consisted of the minimization of energy consumption, was done by evaluating the minimum energy consumed by the boiling process. The target of 50 ppb (22) was set.

Energy Estimation

The calculation of the energy depends on the power of the device and its usage time. Thus the energy consumed during the boiling of the wort is estimated by the formula:

$$E = P_w \times t \tag{9}$$

where E is the energy consumed (J); P_w is the power input, and t is the boiling time.

RESULTS AND DISCUSSION

Mathematical Statistical Model for Residual DMS of Wort Substitutes

Modeling to estimate the residual DMS during boiling of wort substitutes (water/DMS and water/sugar/DMS) was done using the RSM with data reported in Table I. The mathematical statistical models obtained using ANOVA (Table II and Table III) for that purpose were as follows:

$$y_{water/DMS}(x_1, x_2) = 257.07 - 66.47x_1 - 272.10x_2 - 48.36x_1x_2 - 19.14x_1^2 + 151.45x_2^2 \tag{10}$$

$$y_{water/sugar/DMS}(x_1, x_2) = 288.57 - 70.09x_1 - 256.99x_2 - 92.82x_1x_2 - 15.81x_1^2 + 128.47x_2^2 \tag{11}$$

where $y_{water/DMS}(x_1,x_2)$ is the mathematical model for residual DMS in wort substitute water/DMS; $y_{water/sugar/DMS}(x_1,x_2)$ is the mathematical model for residual DMS in wort substitute water/sugar/DMS; x_1 is the power input (W); and x_2 is boiling time (min).

The models were found to be multivariable polynomial with correlation coefficients (R^2) of 0.999 and 0.997, respectively, for $y_{water/DMS}(x_1,x_2)$ and $y_{water/sugar/DMS}(x_1,x_2)$.

According to the literature for evaluation of real performance of predictive models in complex systems (2,34), the AAD, B_f, and A_{f1} were also calculated. These parameters were measures of the relative average deviation of predicted and observed responses. A bias factor and accuracy factor of 1 and AAD of 0 indicated perfect agreements between observed and predicted responses.

The correlation coefficient associated with AAD, B_f, and A_{f1} permitted validation of the models, as shown in Table I and according to the literature (2,34).

The factors of the models were linear or first degree (x_1 and x_2), quadratic (x_1^2 and x_2^2), and of the interaction form (x_1x_2). They were statistically considered significant or not if the probability (P) was ≤0.05 or ≥0.05, respectively (Table II). After validation of the model, a simulation was done to view the impact of a single factor when the other one was fixed.

The models showed a negative coefficient for the power input (x_1). Increasing power input contributed significantly (Table II) to linearly reducing the residual DMS in water/DMS (wort 1, P = 0.000) and water/sugar/DMS (wort 2, P = 0.017). A simulation of power input impact is shown in Figure 1A and B for water/DMS and water/sugar/DMS, respectively. The boiling time was fixed at 0 min and 60 min. At t = 0 min, the ranges of residual DMS were 611 to 562 and 582 to 602 ppb for water/DMS and water/sugar/DMS wort substitutes, respectively. These differences (8 and 3.2%, respectively, for water/DMS and water/sugar/DMS) could be due to the residual values obtained after the preheating stage since there was no boiling stage. After "wort" boiling (t = 60 min), the greatest DMS removal was obtained for 1,500 W since the removed amounts were 555 and 600 ppb for water/DMS and water/sugar/DMS, respectively. For a power input of 500 W, after 1 h of boiling, ~387 and ~284 ppb were removed for water/DMS and water/sugar/DMS, respectively. In fact, a high evaporation rate (due to high power input) resulted in greater DMS removal and lower residual DMS in the two wort substitutes. This was similar to the literature observation (31). In the quadratic form (x_1^2), which was considered an excess of power input, the reduction of DMS was significant for water/DMS (wort 1) at P = 0.013 (Table II).

Concerning the boiling time (x_2), the models showed a negative coefficient, which confirmed that the boiling time had a signifi-

TABLE II
Analysis of Variance for the Model Resulting from Boiling Water/DMS (Wort 1) and Water/Sugar/DMS (Wort 2)[a]

	Sum of Squares			Mean Square		*F* ratio		*P* value		Contribution (%)	
Source	Wort 1	Wort 2	Df	Wort 1	Wort 2	Wort 1	Wort 2	Wort 1	Wort 2	Wort 1	Wort 2
A: x_1	13,256.1	14,736.4	1	13,256.1	14,736.4	2,544.88	55.89	0.0004	0.0174	12.4	11.9
B: x_2	222,095.0	198,114.0	1	222,095.0	198,114.0	42,637.41	751.42	0.0000	0.0013	45.6	48.8
AA	366.34	249.798	1	366.34	249.798	70.33	0.95	0.0139	0.4330	2.8	3.4
AB	1,753.93	6,460.94	1	1,753.93	6,460.94	336.72	24.51	0.0030	0.0385	16.5	8.7
BB	22,934.1	16,499.0	1	22,934.1	16,499.0	4,402.83	62.58	0.0002	0.0156	22.8	27.2
Total error	10.4179	527.307	2	5.20893	263.654						
Total (corr.)	265,503	240,204	7								

[a] DMS = dimethyl sulfide.

TABLE III
Evolution of Volatilization Rate Coefficient k_2 at Different Power Inputs for Substitute Worts Water/DMS (Wort 1) and Water/Sugar/DMS (Wort 2)[a]

	Power (W)									
	500		750		1,000		1,250		1,500	
Model terms	Wort 1	Wort 2	Wort 1	Wort 2	Wort 1	Wort 2	Wort 1	Wort 2	Wort 1	Wort 2
R^2	0.979	0.942	0.991	0.982	0.997	0.997	0.996	0.996	0.981	0.981
$[D]_{L0}$	593	582	605	598	610	607	609	608	602	600
k_2 (min^{-1})	0.0202	0.0143	0.0236	0.0182	0.0281	0.0233	0.0345	0.0314	0.0436	0.0360

[a] DMS = dimethyl sulfide, $[D]_L$ = concentration of DMS in the liquid phase, and the subscript "0" indicates the initial time.

cant impact (P = 0.000 for water/DMS and P = 0.001 for water/sugar/DMS, Table II) on the reduction of residual DMS in wort substitutes. The simulation in Figure 2A and B showed that at fixed power inputs 500, 750, 1,000, and 1,250 W, the residual DMS decreased with boiling time for both wort substitutes. This trend was similar to findings in the literature (3,6,13,33,35,40,41) and was justified by the fact that, during wort boiling, undesirable volatile compounds (i.e., DMS) were driven off with the steam produced during boiling (5,8,15,19,21,24,27,28,36,39). In the quadratic form (x_2^2), the impact of boiling time was significant for both substitute worts (P = 0.000, and 0.015 for worts 1 and 2, respectively) (Table II).

The interaction power input/boiling time (x_1x_2) had a significant (P = 0.003 for water/DMS and P = 0.038 for water/sugar/DMS, Table II) synergistic impact on the DMS removal.

DMS Volatilization Rate Coefficient k_2 and Statistical Comparison

The polynomial models for each substitute wort were used at fixed power input and correlated with the exponential equation of DMS volatilization in order to estimate k_2. As shown in Table III, the higher the power input, the higher the value of k_2; the values were similar to values in the literature (29). This suggested that RSM could be used to evaluate k_2 since, following the Taylor and MacLaurin series, an exponential equation could be transformed into a polynomial equation (20,32,37,38). Figure 3 shows the exponential growth of k_2 with the heat supply rate (values shown in Table IV). This exponential growth observed was similar to that

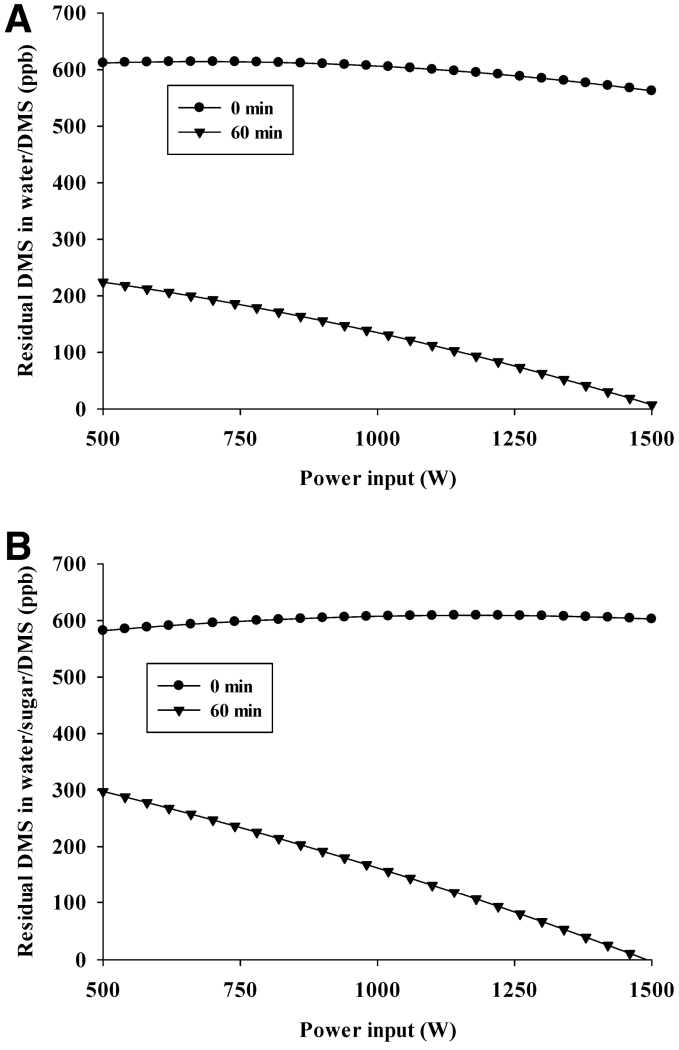


Fig. 1. Evolution of residual dimethyl sulfide (DMS) at fixed boiling times as a function of power input in **A**, water/DMS; and **B**, water/sugar/DMS (12°B).

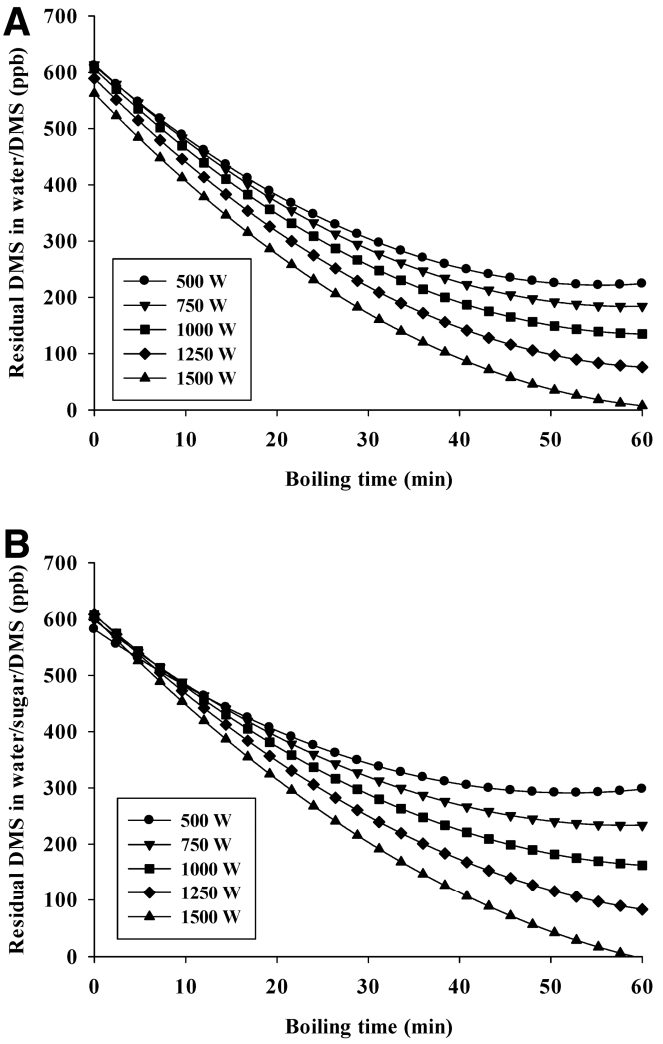


Fig. 2. Evolution of residual DMS at fixed power input as a function of boiling time in **A**, water/DMS; and **B**, water/sugar/DMS (12°B).

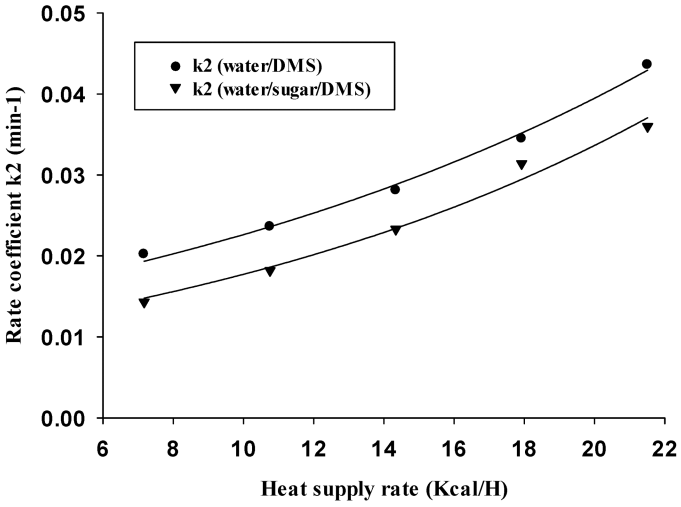


Fig. 3. Evolution of DMS volatilization coefficient k_2.

obtained in a literature patent (30). In fact, the k_2 values obtained by Mitani et al (30) in 1998, when using a 6-m^3 kettle wort boiling, was higher than the one found in the current study. This could be explained by the fact that the heat rate supply (H) was more than thousand times higher (120 to 280 Mcal/hr compared to 7 to 22 kcal/hr).

A statistical analysis using the t test, F test, W test, and Kolmogorov–Smirnov test, was done and demonstrated no significant difference between the residual values of DMS in the two wort substitutes (Table V). In addition, there was no significant difference between the values of rate coefficient k_2 of the two wort substitutes (Table VI) in spite of the fact that visually they seemed to be different.

Optimization

Since the RSM method was efficient only inside the studied domain, the exponential decay equations for residual DMS obtained for substitute wort boiling were used. The aim was to determine conditions to minimize boiling energy in order to obtain a target value of 50 ppb since the recommended value was between 40 and 60 ppb (22). A simulation was done using the initial DMS concentration of 600 ppb when the boiling point is reached.

To obtain the target of 50 ppb to minimize energy consumption during wort boiling, the power input and each boiling time were determined. For that purpose, the wort should be boiled for about 57 to 122 min for water/DMS (wort 1) and 69 to 173 min for water/sugar/DMS (wort 2), as shown in Table VI. The estimated energy was from 3.66 to 5.40 MJ and from 5.19 to 6.42 MJ for water/DMS and water/sugar/DMS, respectively (Table VI). The smallest amount of energy consumed was obtained at 500 W for both wort substitutes.

TABLE IV
Equations of k_2 Evolution Versus Heat Rate Supply of the Two Wort Substitutes[a]

Terms	Water/DMS	Water/Sugar/DMS
Equation	$0.013 \times e^{0.0556 \times H}$	$0.0093 \times e^{0.0641 \times H}$
R^2	0.993	0.983

[a] DMS = dimethyl sulfide, H = heat rate supply (kcal/hr).

TABLE V
Statistical Comparison Between the Residual DMS of Water/DMS and Water/Sugar/DMS[a]

t test		*F* test		*W* test		Kolmogorov–Smirnov Test	
t	*P*	*F*	*P*	*W*	*P*	DN	*P*
–0.25385	0.803	1.10532	0.898	38	0.563	0.25	0.963

[a] DMS = dimethyl sulfide, W = Shapiro–Wilk statistics, DN = Kolmogorov–Smirnov statistics.

CONCLUSION

The effects of power input and boiling time on the removal of DMS during wort boiling were studied for two wort substitutes (water/DMS and water/sugar/DMS). The two variables had significant effects on DMS, with the boiling time considered to have higher impact than the power input. The study showed that the DMS volatilization coefficient rate (k_2) progressed exponentially (showed exponential growth) with the increase of the heat rate supply and that there was no significant statistical difference between the residual DMS when the two worts substitutes were boiled. Minimization of the energy consumed when boiling was achieved at the lowest power input.

ACKNOWLEDGMENTS

We acknowledge the University of Johannesburg via the Faculty of Science (Department of Biotechnology and Food Technology), the Faculty of Engineering and Built Environment (School of Mining, Metallurgy and Chemical Engineering—Brewing and Beverage Engineering Initiative), and Reinout Meijboom and Nathan Charles Antonels of the University of Johannesburg, Department of Chemistry for support of this study.

LITERATURE CITED

1. Arfi, K., Spinnler, H. E., Tache, R., and Bonnarme, P. Production of volatile compounds by cheese-ripening yeasts: Requirement for a methanethiol donor for S-methyl thioacetate synthesis by *Kluyveromyces lactis*. *Appl. Microbiol. Biotechnol.* 58:503-510, 2002.
2. Baranyi, J., Pin, C., and Ross, T. Validating and comparing predictive models. *Int. J. Food Microbiol.* 48:159-166, 1999.
3. Barnes, Z. C. Brewing process control. In: *Handbook of Brewing*. F. G. Priest and G. G. Stewart, eds. Taylor and Francis, Boca Raton, FL, 2006.
4. Berger, C., Martin, N., Collin, S., Gijs, L., Khan, J. A., Piraprez, G., Spinnler, H. E., and Vulfson, E. N. Combinatorial approach to flavor analysis. 2. Olfactory investigation of a library of S-methyl thioesters and sensory evalutaion of selected components. *J. Agric. Food Chem.* 47:3274-3279, 1999.
5. Briggs, D. E., Boulton, C. A., Brookes, P. A., and Stevens, R. *Brewing Science and Practice.* Woodhead Publishing Ltd., Cambridge, 2004.
6. Buckee, G. K., Malcolm, P. T., and Peppard, T. L. Evolution of volatile compounds during wort-boiling. *J. Inst. Brew.* 88:175-181, 1982.
7. Burmeister, M. S., Drummond, C. J., Pfisterer, E. A., Hysert, D. W., Sin, Y. O., Sime, K. J., and Hawthorne, D. B. Measurement of volatile sulfur compounds in beer using gas chromatography with a sulfur chemiluminescence detector. *J. Am. Soc. Brew. Chem.* 50:53-58, 1992.
8. Clarke, B. J., Burmeister, M. S., Krynicki, L., Pfisterer, E. A., Sime, K. J., and Hawthorne, D. B. Sulfur compounds in brewing. In: *Proc. Eur. Brew. Conv. Congr.*, Lisbon, Pp. 217-224, 1991.
9. De-Schutter, D. P., Saison, D., Delvaux, F., Derdelinckx, G., Rock, J.-M., Neven, H., and Delvaux, F. R. Optimization of wort volatile analysis by headspace solid-phase microextraction in combination with gas chromatography and mass spectrometry. *J. Chromatogr. A* 1179:75-80, 2008.

TABLE VI
Energy (E) Spent During Boiling of Water/DMS (Wort 1) and Water/Sugar/DMS (Wort 2)[a]

	k_2			*t* (min)			*E* (MJ)	
Target (ppb)	Wort 1	Wort 2	$[D]_L$	Wort 1	Wort 2	*P* (W)	Wort 1	Wort 2
50	0.0202	0.0143	593	122	173	500	3.66	5.19
50	0.0236	0.0182	605	106	137	750	4.77	6.17
50	0.0281	0.0233	610	89	107	1,000	5.34	6.42
50	0.0345	0.0314	609	72	80	1,250	5.40	6.00
50	0.0436	0.036	602	57	69	1,500	5.13	6.21

[a] DMS = dimethyl sulfide, k_2 = rate coefficient, t = time, $[D]_L$ = concentration of DMS in the liquid phase, P = power.

10. Dercksen, A., Laurens, J., Torline, P., Axcell, B. C., and Rohwer, E. Quantitative analysis of volatile sulfur compounds in beer using a membrane extraction interface. *J. Am. Soc. Brew. Chem.* 54:228-233, 1996.
11. Dercksen, A. W., Meijering, I., and Axcell, B. Rapid quantification of flavor-active sulfur compounds in beer. *J. Am. Soc. Brew. Chem.* 50:93-101, 1992.
12. Dickenson, C. J. The relationship of dimethyl sulphide levels in malt, wort and beer. *J. Inst. Brew.* 85:235-239, 1978.
13. Esslinger, H. M., and Narziss, L. Beer. In: *Ullmann's Encyclopedia of Industrial Chemistry.* Wiley-VCH Verlag GmbH & Co., Weinheim, Germany, 5:177-221, 2012.
14. Firor, R. L., and Quimby, B. D. A comparison of sulfur selective detectors for low level analysis in gaseous streams. In: *Application Note.* Agilent Technologies, Wilmington, DE, Pp. 1-8, 2001.
15. Fix, G. Sulfur flavors in beer. *Zymurgy* 15:40-44, 1992.
16. Gibson, R. M., Large, P. J., and Bamforth, C. W. The influence of assimilable nitrogen compounds in wort on the ability of yeast to reduce dimethyl sulfoxide. *J. Inst. Brew.* 91:401-405, 1985.
17. Giovanni, M. Response surface methodology and product optimization. *J. Food Technol.* 37:41-45, 1983.
18. Hill, P. G., and Smith, R. M. Determination of sulphur compounds in beer using headspace solid-phase microextraction and gas chromatographic analysis with pulsed flame photometric detection. *J. Chromatogr. A* 872:203-213, 2000.
19. Hough, J. S., Briggs, D. E., Stevens, R., and Young, T. W. *Malting and Brewing Science*. Chapman and Hall, London, 1982.
20. Kline, M. *Mathematical Thought from Ancient to Modern Times.* Oxford University Press, New York, 1990.
21. Krottenthaler, M., Rübsam, H., and Becker, T. Optimizing brewhouse technology with reference to dimethylsulfide. *Brauwelt Int.* 28:138-145, 2010.
22. Kunze, W. *Technology Brewing and Malting*. VLB, Berlin, Germany, 2004.
23. Leppänen, O. A., Denslow, J., and Ronkainen, P. P. Determination of thioacetates and some other volatile sulfur compounds in alcoholic beverages. *J. Agric. Food Chem.* 28:359-362, 1980.
24. Lewis, M. J., and Bamforth, C. W. *Essays in Brewing Science*. Springer, New York, 2006.
25. Mathieu, D., Feneuille, D., and Phan-Tan-Luu, R. Méthodologie de la recherche expérimentale: Etude des surfaces de réponse. In: *Laboratoire de Prospective Reactionnelle et d'Analyse de l'Information*. IUT de l'Université d''Aix-Marseille, Marseille, 1977.
26. Matsui, S., Yabuuchi, S., and Amaha, M. Production of S-methyl thioacetate from methyl mercaptan by brewer's yeast. *Agric. Biol. Chem.* 45:771-772, 1981.
27. Meilgaard, M. Effects on flavour of innovations in brewery equipment and processing: A review. *J. Inst. Brew.* 107:271-286, 2001.
28. Miracle, R. E., Ebeler, S. E., and Bamforth, C. W. The measurement of sulfur-containing aroma compounds in samples from production-scale brewery operations. *J. Am. Soc. Brew. Chem.* 63:129-134, 2005.
29. Mitani, Y., Suzuki, H., Abe, T., Nomura, M., and Shinotsuka, K. Performance of wort boiling with inert gas sparging for the energy reduction. In: *Proc. Eur. Brew. Conv. Congr.*, Cannes, France, Pp. 619-626, 1999.
30. Mitani, Y., Suzuki, H., Ohshima, T., Kobayashi, M., Kurihara, T., Akiyama, H., and Ishida, F. Method of boiling wort and wort boiler used therefor. European patent number EP 0875560 A1, 1998.
31. O'Rourke, T. The function of wort boiling. *Brew. Int.* 17-19, 2002.
32. Odibat, Z. M., and Shawagfeh, N. T. Generalized Taylor's formula. *Appl. Math. Comput.* 186:286-293, 2007.
33. Poreda, A., Czarnik, A., Zdaniewicz, M., Jakubowski, M., and Antkiewicz, P. Corn grist adjunct—Application and influence on the brewing process and beer quality. *J. Inst. Brew.* 120:77-81, 2014.
34. Ross, T. Indices for performance evaluation of predictive models in food microbiology. *J. Appl. Bacteriol.* 81:501-508, 1996.
35. Schulbach, K. F., Rouseff, R. L., and Sims, C. A. Changes in volatile sulfur compounds in strawberry puree during heating. *J. Food Sci.* 69:FCT268-FCT272, 2004.
36. Seldeslachts, D., Van-Den-Eynde, E., and Degelin, L. Wort stripping. In: *Proc. Congr. Eur. Brew. Conv.*, Maastricht, 2:323-332, 1997.
37. Struik, D. J. *A Source Book in Mathematics 1200–1800*. Harvard University Press, Cambridge, MA, 1969.
38. Taylor, B. *Direct and Reverse Methods of Incrementation*. Harvard University Press, London, 1715.
39. Walker, M. D. Formation and fate of sulphur volatiles in brewing. In: *Proc. Congr. Eur. Brew. Conv.*, Lisbon, Pp. 521-528, 1991.
40. White, F. H., and Wainwright, T. The measurement of dimethyl sulphide precursor in malts, adjuncts, worts and beers. *J. Inst. Brew.* 82:46-48, 1976.
41. Wilson, R. J. H., and Booer, C. D. Control of the dimethyl sulphide content of beer by regulation of the copper boil. *J. Inst. Brew.* 85:144-148, 1978.

Résumé de l’article

Dimethyl Sulfide Stripping Behavior During Wort Boiling Using Response Surface Methodology

Z. S. C. Desobgo*, R. A. Stafford, and D. J. A. Metcalfe

Abstract

The action of two wort variables (power input and boiling time) on the residual dimethyl sulphide (DMS) of two boiled wort substitutes (water/DMS and water/sugar/DMS) was modeled and analyzed using response surface methodology. The analysis showed that both power input and boiling time had significant impact on residual DMS during wort boiling, with power input contributions of 12.4 and 11.9% for water/DMS and water/sugar/DMS, respectively, and boiling time contributions of 45.6 and 48.8% for water/DMS and water/sugar/DMS, respectively. The interaction also had a significant impact on residual DMS for the water/DMS wort substitute, with a contribution of 2.8%. The volatilization coefficient (k2) obtained at each power input were not statistically significantly different for the two wort substitutes but exhibited exponential growth evolution: from 0.0202 to 0.0436 min^{-1} and from 0.0143 to 0.0360 min^{-1} for water/DMS and water/sugar/DMS wort substitutes, respectively. To achieve an energy target of 50 ppb by minimizing the energy consumed at the end of boiling, the following conditions were adopted: for water/DMS, boiling at 500 W for 123 min (3.66 MJ); for water/sugar/DMS, boiling at 500 W for 174 min (5.19 MJ).

Keywords: Boiling time, Dimethyl sulfide, Power input, Response surface methodology, Wort boiling

IV.4.4) Partial purification of α-amylase from *Burnatia enneandra* Micheli. Part 1: Extraction using statistical model

Titre de la revue

International Journal of Research in
Biotechnology and Biochemistry
Available online at
www.urpjournals.com

Comité de lecture

EDITORIAL/ ADVISORY BOARD

Prof. Jesus Simal-Gandara
SCI FAC. OURENSE CAMPUS
E32004, OURENSE.SPAIN
Email: JSIMAL@UVIGO.ES

Dr. Mortaza Iranifam
Asst. Proff. In Analytical Chemistry,
University of Maragheh
Amir Kabir Highway, Mother Sq, Maragheh,
East Azerbaijan, Iran, 55181-83111
Email: Mortezairanifam@yahoo.com
Mortezairanifam@maragheh.ac.ir.

Dr. Ola Mostafa Abdallah
4675eket ec waili-Hadaek el Koba
Cairo, Egypt
Email: Olamody@yahoo.com

Prof. Dr. Mohammed Rageeb Mohammed Usman
Assistant Professor
Department of Pharmacognosy
Smt. S. S. Patil College of Pharmacy,
Chopda, Maharashtra, India
Email: rageeb_shaikh@rediffmail.com

Dr. Jiang Qian
Department of Medicine, Duke University Medical Center
P.O. Box 3821, Durham, NC
Phone: 919-684-4751, Email: qjohn@receptor-biol.duke.ed

Dr. Subha Ganguly
All India Coordinated Research Project on Post Harvest Technology (ICAR)
Department of Fish Processing Technology,
Faculty of Fishery Sciences
West Bengal University of Animal and Fishery Sciences
Chakgaria, Kolkata 700 094 (WB).
Email: ganguly38@gmail.com

Dr. Sreenivasa Rao Ramisetty
10 Liberty Lane,
Apt # 56
South Portland, ME,
Tel No: 860-759-4124
ramisettypu@yahoo.com

Dr. Justin D.Fair
Dept. of Chemistry, Indiana Unv. Of Pennsylvania,
975, Oakland AVE., Rm.143 Weyandt Hall
Indiana, USA, Postal code: 15701,
Email: j.fair@iup.edu.

Prof. Yongchun Zhu
253 Huanghe Street Huanggu District
Shenyang Normal, University College of Chemistry and Life Sciences. Liaoning, China
Postal code: 110034
Email: yongchunzhu@126.com

Dr. Tan Guan Huat
Dept of Chem, University of Malaya
Kuala Lumpur, Malaysia
Postal code: 50603.
Email: ghtan@um.edu.my

Dr. Tarek S. Belal
Pharmaceutical Analytical Chemistry Department,
Faculty of Pharmacy,
Alexandria University, Egypt
Email: tbelaleg@yahoo.com

Dr. Moinuddin Sarker
1376 Chopsey Hill Road, Bridgeport,
CT-06606, USA
Email: msarker@naturalstateresearch.com

Dr. Amita Mahajan
Rayat and Bahra Institute of Engg. and Technology,
Sahauran, Kharar
Dist. Mohali, Punjab
Email: amitaanil44@yahoo.com,
deanrbiebt@rayatbahra.com

Dr. Bensafi Abd-El-Hamid
Department of Chemistry
Faculty of Sciences
Abou Bekr Belkaid University of Tlemcen
P.O.Box 119, Chetouane
13000 Tlemcen
Algeria, Email: aeh.bensafi@gmail.com

Copyright © 2010 Universal Research Publications
Powered by Genesis Infoways
Terms and Conditions

Table des matières

------ Internationaly indexed journals

2011, Volume 1, Issue 1

1. Editorial

2. Screening of supplementary nitrogen source for fungal L-asparaginase production from soya bean meal flour using latin square design

G.Basker and S. Ranganathan

3. Microbial diversity and phytochemical profile of Solanum nigrum L from two different sites of Kannyakumari district, Tamil Nadu, India

S. K. Sundar and V. Meera Sabari

4. Micro RNA- Biogenesis, Mechanism of Action and Applications-A Review

Subhabrata Ghosh

5. RESPONSES OF SOME WHEAT GENOTYPES TO CALLUS REGENERATION UNDER IN VITRO SALT STRESS

Ayoli K.1, El Yacoubi H., Kouakou T.H., Atmane R.

2012, Volume 2, Issue 1

1.Homology modeling of an unique extracelluar glutaminase free L-asparaginase from novel marine Actinomycetes

[1]Senthil Kumar.M*, [2]Selvam.K and [3]Singaravel.R

2012, Volume 2, Issue 2

1.Protective effect of eugenol against alcohol-induced biochemical changes in rats

Anbu S and Anuradha CV*

2012, Volume 2, Issue 4

1.Screening and characterization of antifungal Cumin

Nisha Kumari* and R K Deshwal

2013, Volume 3, Issue 1

1.Identification and Screening of Bioactive Compounds Inbarleriaprionitis Linn Rhizome Exhibitingantibacterial Activity

Nidhi, Uttam Kumar*, Sumit kumar

2.Production of Protease From Bacillus Subtilis And Its Application In Leather Making Process

Sathiya G

3.Studies on the Nutritional Supplementation of Vitamin C Treated MR2 Mulberry Leaves Fed by V Instar Larvae of Silkworm, *Bombyx mori* (L.) (Lepidoptera: Bombycidae) in Relation to Feed Efficacy and Growth Rate

Dr. D. Balasundaram*, P. Ganesh Prabu, Selvisabhanayakam, V. Mathivanan and V. Ramesh

4.Simple, Rapid Method for Direct Isolation of Metagenomic DNA From Pichavaram Mangrove Sediment

Rajesh Singh. J*, Sivasubramani. K And Jayalakhsmi. S

5.Screening of Aspergillus species from Tamarind fruit for lectins: Inhibitor factor for Methicillin resistant Staphylococcus aureus

Santhiya.m1, Dr.Jansi.m2

2013, Volume 3, Issue 2

1.Thais bufo (Lamarck), A Neogastropod-Fit for Human Consumption

Sini Margret. M and Jansi. M

2013, Volume 3, Issue 3

1.Effect of Benzyl Amino Purine (BAP) concentration on *in vitro* shoot proliferation of Banana (*Musa spp*.)

Devendrakumar. D, M.Anbazhagan and R.Rajendran

2013, Volume 3, Issue 4

1.Efficient concentration of clarified Tiny shrimp hepatopancreatic tissue homogenate during the recovery of crude alkaline phosphatase by ammonium sulfate

Krishna Prasad Nooralabettu

2014, Volume 4, Issue 1

1.Feed utilization, Growth parameters and Coloration of Different Feeds in Gold Fish, *Carassius auratus*

Vasudhevan*, Asokan.K, Rinna Hamlin. S and Rama Devi. P

2.To Study The Antagonistic Organisms And New Chemicals Against The Bacterial Blight Phathogen (*Xanthomonasoryzaepv.Oryzae*) Of Rice.

Ramalingam Parthasarathy, Jayaraman Indira, Appu Manikandan, ArumugamKarthikeyan*

3.Bioremedial Potential of Microbial Culture; Isolated From the Contaminated Soil with Crude Oil

Shrikant Kol *, Rishabh D Saket *, U.K. Chauhan #

4.STUDIES ON INVITRO ANTIBACTERIAL AND ANTIFUNGAL PROPERTY OF senna auriculata

*S.Narendhiran, J. Arun, G. Alagu Lakshmi, L. Saravanan, V. Dineshkumar, K. Sylvia Grace, E. Sutha, R. priyanka, J. Hemamalini, D. Goverthana priya, R. Priyanka, K. Praveenkumar, R. Akhil, R. Tamilselvan, J. Akshaya, M. Sathiyapriya

5.Effect of hormones on direct shoot regeneration in leaf explants of tomato

Byale Gundamma Kalyani and Srinath Rao*

2014, Volume 4, Issue 2

1.Molecular Farming: A biotechnological approach in agriculture for production of useful metabolites

* Parmeshwar Ku. Sahu, Tarun S. Patel, Pooja Sahu, Satyapal Singh, Praveen Tirkey and Dr. Deepak Sharma

2.*In silico* development of DNA signatures of *Aspergillus* species for rapid diagnostics

Rahul Prakash* and S. N. Jha

3.Genetic transformation of Rhodobacter capsulatus KU002 using a heat shock protein (hsp) gene for salt and temperature tolerance

Ramchander Merugu*, Swetha Garimella, N. Ramasamy , S. Girisham and S. M. Reddy

4.Effect of Cultural Conditions on Hydrogen Production by Phototrophic Bacteria Isolated From Water Logged Soils in Rourkela, India

Manisha D.R, M.P.Pratap Rudra, Ramchander Merugu

2015, Volume 5, Issue 1

1.Reactive Oxygen and Nitrogen Speceis Scavenging *Activity of Aplotaxis Auriculata Root* ﷺ *An In Vitro* Study

Abdul Aseeb CP and V. Mariappan

2.Applications of Extracellular Microbial Lipase- A Review

Subhajit Ray

3.Partial purification of a-amylase from Burnatia enneandra Micheli. Part 1: Extraction using statistical model

Taira A., Desobgo Z. S. C.*, Nso J. E.

2016, Volume 6, Issue 1

1.A comparative study on antioxidant activities of three cultivars of Cucumis sativas (Linn)

Latha Kumaraswamy

2.Effect of Depo-medroxyprogesterone acetate (DMPA) on Lipid Metabolism

Muluken Fekadie*1, Daniel Seifu2, Solomon Kumpi3 and Addis Kokeb4

3.Hypoglycemic and Antioxidant Effects of gold nanoparticals in alloxan-Induced Diabetes Rats

Hasan F.Al-Azzawie, Laith A.Yaaqoob

4.Applications of Biotechnologically derived Vaccines to Animal health

Rajashekar B, Srinivas M and Shivajyothi J

Home About us Submission Contact us
Copyright © 2010 Universal Research Publications
Powered by Genesis Infoways
Powered by Genesis Infoways
Terms and Conditions

Pages de l’article

Available online at http://www.urpjournals.com

International Journal of Research in Biotechnology and Biochemistry

Universal Research Publications. All rights reserved

ISSN: 2277-3827

Original article

Partial purification of α-amylase from *Burnatia enneandra* Micheli. Part 1: Extraction using statistical model

Taira A.[1], Desobgo Z. S. C.[2,3*], Nso J. E.[1]

[1]Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI) of the University of Ngaoundere, P.O. Box 455 ENSAI, Ngaoundere, Cameroon

[2]Department of Food Processing and Quality Control of University Institute of Technology (UIT) of the University of Ngaoundere, Cameroon

[3]Department of Biotechnology and Food Technology of the University of Johannesburg, South Africa

E-mail: desobgo.zangue@gmail.com

Received 13 September 2015; accepted 31 December 2015

Abstract

The impact of pH, stirring speed and centrifugation time was tested on α-amylase specific activity of *Burnatia enneandra* tubers from Cameroon. The response surface methodology using Doehlert experimental design as instrument, was employed to establish, validate and optimize the mathematical model conducive to understand the influence of extraction factors (pH, stirring speed and centrifugation time) either singular or in interactions. It was exhibited that pH as singular factor and, in its first degree (X_1) provided 12 % of the specific activity of α-amylase although, stirring speed (X_2) and centrifugation time (X_3) provided 3 % and 10 % respectively. It was also observed that, the raise of pH reduced specific activity of α-amylase while, an increase of centrifugation time increased the specific activity of α-amylase. The combined effort (interaction) of pH / centrifugation time and stirring speed / centrifugation time was significant with respective contribution of 25 % and 9 % respectively. For optimization, a theoretical triplet (pH, 4.02; stirring speed, 147.3 rpm and centrifugation time, 10 min) was exhibited and, gave 49.33±1.9 U/mg as maximal α-amylase specific activity from *Burnatia enneandra*.

© 2015 Universal Research Publications. All rights reserved

Keywords: *Burnatia enneandra* tubers, extraction, Doehlert experimental design, Modelling, Optimization.

1. Introduction

Burnatia enneandra Micheli is an herbaceous plant of the Sudano-Sahelian region, belonging to the family of *Alismataceae*. In Cameroon this plant grows mainly in swampy areas of the north and the far north. Common names of this plant is known among Tupuri as "*tigna'ri"* [1, 2] and among Fulani as "*Anjakooje"* [3]. These *Burnatia enneandra* Micheli tubers dried and crushed are used to "sweeten" the slurry during the grazing due to the remoteness of grazing areas. Others ate the tubers after blown. Finally, the white latex in it is commonly used to treat injuries and some intestinal parasites of children [1]. With the traditional use of this tuber, scientific works have been done [1, 2]. This work has shown that these tubers had a very low simple sugar content, this assumes that the *Burnatia enneandra* tuber is not sweet itself and the fact of sweeten porridge would not be due to its high simple sugar content but rather due to substances with amylolytic potential [2]. This suggests the presence in the tuber of amylolytic enzymes. Other preliminary works related to the brewing area has focused on the characterization of worts obtained by saccharification of sorghum mash by extracts of *Burnatia enneandra* Micheli tuber. These studies showed that the enzyme extracts obtained from these tubers were capable of hydrolyzing sorghum starch [4].

The general objective is set to extract the α-amylase from the crude extract of *Burnatia enneandra* Micheli tuber. More specifically it will be to model the extraction process of α-amylase from the tuber and, optimize extraction conditions.

Abbreviations

ANOVA	Analysis of variance
AAD	Average absolute deviation

A_f	Accuracy factor
B_f	Bias factor
k	Number of variables
k_0	Number of center points
N	Number of experiments
P	Probability level
R^2	Coefficient of determination
Res	Residue
RSM	Response surface methodology
x_i	Coded variables given by the Doehlert table
X_i	Real variables
X_{0i}	Centre of variable
ΔX_i	Increment
Y	Response
$Y_{SpecAct}$	Mathematical model for α-amylase specific activity of crude extract of *Burnatia enneandra*
Y_{ical}	Theoretical response
$Y_{i\exp}$	Experimental response

Greek symbols

β_{ij}	Coefficient of the interactions terms
β_{ii}	Coefficient of the quadratic terms
β_i	Coefficient of the linear terms
β_0	Constant

2. Materials and methods

2.1. Material

Plant material utilised for this study consisted mainly of *Burnatia enneandra* Micheli tubers. These tubers were harvested in the region of the far north precisely Datcheka (located at about 70 Km of Yagoua, Cameroon). Once harvested they were sorted and the film or the protective cover was removed. Bare tubers were then cleaned in tap water, and cut into thin slices (about 2 to 3 mm) and finally dried (in drier CKA AUF-2000) at 45 °C for 5 days. The dried discs were ground and the obtained powder was sieved to select only a smaller particle size (Ø ≤ 250 µm).

2.2 Chemicals

All chemicals used mainly consists of analytical grade reagents provided by Sigma-Aldrich. It mainly: Sodium phosphate, soda pellets, potassium iodide, concentrated sulphuric acid, bovine serum albumin (BSA), soluble starch and the Folin-Ciocalteu reagent, polyethylene glycol molecular mass 6000 (PEG-6000) and ammonium sulfate.

2.3 Experimental design, modelling and validation of the model

Doehlert experimental design [5-7] was implemented to make experiments in favour of building and optimizing statistical model for α-amylase extraction and partial purification from *Burnatia enneandra* Micheli. The independent factors were obtained from preliminary studies, while the response was the specific activity.

Matrix from the coded variables were transformed into real values for experiments, using the formulas below:

$$X_i = X_{0i} + x_i \Delta X_i \quad (1)$$

$$N = k^2 + k + k_0 \quad (2)$$

Where: X_i, real variables; X_{0i}, centre of variable; x_i, coded factors (variables) given by Doehlert matrix; ΔX_i, increment; k, number of variables; k_0, number of centre points and N, number of experiments.

Mathematical models of second-order equation were developed [8]. Design-based experimental data were builtusing to the second-order polynomial model as follows:

$$Y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ij} x_i x_j + \sum \beta_{ii} x_i^2 + \sum \beta_{ij\ldots z} x_i x_j \ldots x_z + e \quad (3)$$

With: Y, is the response. It is measured during the experiment and is obtained with a given accuracy; x_i and x_j, represent the level assigned to the factor i and j respectively by the experimenter to perform a test. This value is well known. It is even assumed that this level is determined without error (classical hypothesis of regression); β_0, β_i,, β_{ii}, β_{ij} ,are the coefficients of the adopted mathematical model. They are not known and must be calculated from the results of experiments.

Statistical models and analysis of variance (ANOVA) were obtained using Minitab version 16 (Minitab, Ltd. Coventry, UK). Sigma plot version 12.5 (Systat Software, Inc. Wbcuped, GmbH, Germany) was used to plot the curves.

Models validation was achieved by calculating some validation parameters as mentioned in the literature [9-11]. The formulas were as follows:

$$AAD = \frac{\left[\sum_{i=1}^{N}\left(\frac{\left|Y_{i\exp} - Y_{ical}\right|}{Y_{i\exp}}\right)\right]}{N} \quad (4)$$

$$B_f = 10^{\frac{1}{N}\sum_{i=1}^{N}\log\left(\frac{Y_{ical}}{Y_{i\exp}}\right)} \quad (5)$$

$$A_{f1} = 10^{\frac{1}{N}\sum_{i=1}^{N}\left|\log\left(\frac{Y_{ical}}{Y_{i\exp}}\right)\right|} \quad (6)$$

With: $Y_{i,exp}$ and $Y_{i,cal}$; respectively data-based (experimental) and mathematical responses; N, trials number; AAD, absolute average deviation; B_f, bias factor; A_f, accuracy factor.

Linear, interaction and quadratic contributions of each variable were calculated as follows [11]:

Linear,
$$Contribution(\%) = \frac{|\beta_i|}{\sum_{i=1}^{k}|\beta_i| + \sum_{i=1}^{k}|\beta_{ii}| + \sum\sum_{i<j}^{k}|\beta_{ij}|} \quad (7)$$

Quadratic,
$$Contribution(\%) = \frac{|\beta_{ii}|}{\sum_{i=1}^{k}|\beta_i| + \sum_{i=1}^{k}|\beta_{ii}| + \sum\sum_{i<j}^{k}|\beta_{ij}|} \quad (8)$$

Interaction,
$$Contribution(\%) = \frac{|\beta_{ij}|}{\sum_{i=1}^{k}|\beta_i| + \sum_{i=1}^{k}|\beta_{ii}| + \sum\sum_{i<j}^{k}|\beta_{ij}|} \quad (9)$$

Optimization was the last stage of the study and, was performed using Mathcad software v15.0 (build 15.0.0.436 Parametric Technology Corporation, USA). The conditions to maximize the specific activity of α – amylase during extraction was fixed. A test was done at that theoretical

optimum to confirm it.

2.4 Factors ranges and responses.

Preliminary studies permitted to identify three main factors that could have greater influence on α-amylase extraction. These factors and their ranges were as follows: pH, 4 to 7, because as found in the literature, that amylases catalyse better within this range [12]; Stirring speed, 100 to 250 rpm, to minimize enzyme denaturation, and centrifugation time, 10 to 30 min at 6500 × g. Doehlert experimental design was used to carry out extraction.

2.5 Extraction of enzymes of *Burnatia enneandra* tubers

A 20 g of the sieved powder of *Burnatia enneandra* tubers was weighed using analytical balance (KERN EMB 200-3, Sysmatec Oberdorfstrasse). To that mass was added 200 mL of phosphate buffer (200 mM) at pH between 4 to 7. The mixture was stirred for one hour at precise speed according to experimental design (100 to 250 rpm) using laboratory overhead stirrer (model: AM120Z-P, Meditry Instrument Co. Ltd), and then permitted to settle down for 15 min. The supernatant was recovered and introduced into a 45 mL centrifuge tubes and, centrifuged at 6500 × g for 10 to 30 minutes at 4 °C using refrigerated Heraeus centrifuge. The collected supernatant was then filtered and the filtrate obtained was the enzyme extract containing the enzyme to be purified.

2.6 Protein quantitation

The protein amount was obtained using Lowry's method [13-15]. A volume of sample or standard (0.1 mL) and NaOH (0.1 mL, 2 N) was mixed. The mixture was boiled at 100 °C for 10 min in a boiling water bath and, was chilled to 25 °C. A was prepared by associating, 100:1:1 stock solutions (2% (w/v) Na_2CO_3; 1% (w/v) $CuSO_4$ $5H_2O$; 2% (w/v) sodium potassium tartrate). After that, 1mL of that complex-forming reagent was added to the mixture. The solution was left for 10 min at 25 °C. Folin reagent (0.1 mL) was then added, and the mixture leftfor 30-60 min at 25 °C. The absorbance was read at 750 nm for protein concentration less than 500 µg/mL, or at 550 nm for protein concentration at interval between 100 and 2000 µg/mL. Standard curve was performed for protein concentrations (P) determination in the samples.

2.7 Measurement of enzyme activity

α-amylase activity was carried using Fuwa's colorimetric method [16, 17] with some modifications. A diluted enzyme (50 µL) in phosphate buffer pH 7 (50 mM) was mixed with soluble-starch (100 µL, 1.1%) and, the mixture was incubated for 10 min at 50 °C. After that incubation, the reaction was interrupted by incorporating 250 µL of stopping solution (made of 5: 1 ratio of 0.5 N acetic acid and 0.5 N HCl). A volume (100 µL) of the previous reaction was mixed with 1 mL iodine (0.01% I_2 dissolved in 0.1% KI) reagent. The colour reduction was obtained by measuring at 660 nm against the reference (control), which was prepared using the same method but, by adding the stopping solution before the enzyme. One α-amylase activity unit was considered as the measure of enzyme whichreducedby 0.1 in 10 min, the absorbance of 660 nm.

$$A_T = \frac{d \times (DO_B - DO_S)}{DO_B} \times 100 \qquad (10)$$

The specific activity (A_S) in U/mg was obtained using the formula:

$$A_S = \frac{A_T}{P} \qquad (11)$$

With: A_T, Total activity (U); d, dilution factor; DO_B, optical density of the blank; DO_S, sample optical density; P, protein quantity (mg).

3 Results and discussion

Modelling the impact of pH, agitation speed and centrifugation time, on α-amylase extraction from *Burnatia enneandra* Micheli was carried out using Doehlert experimental design with specific activity as response (Table 1). The mathematical model obtained was as follows:

$$\begin{aligned} Y_{SpecAct}(x_1,x_2,x_3) &= 36.378 - 10.757x_1 - 2.825x_2 \\ &+ 8.470x_3 - 2.069x_1x_2 + 22.258x_1x_3 + 7.580x_2x_3 \\ &- 14.304x_1^2 - 10.892x_2^2 + 8.891x_3^2 \end{aligned} \qquad (12)$$

With $Y_{SpecAct}(x_1, x_2, x_3)$ representing the mathematical model for α-amylase specific activity of crude extract; x_1, pH; x_2, Stirring speed and x_3, centrifugation time.

The mathematical model was polynomial and validated according to the method described by [9] as shown in Table 2. The factors of the models were of first degree (x_1, x_2 and x_3), of second degree (x_1^2, x_2^2 and x_3^2), and of interaction (x_1x_2, x_1x_3 and x_2x_3) form. They were statistically significant or not if the probability (P) was ≤0.05 or ≥0.05, respectively.

3.1. Effect of pH

The pH effect on α-amylase specific activity of the crude extract is shown in Fig. 1a. Specific α-amylase activity decreased significantly from 47.84 U/mg at pH 4 to 0 U/mg

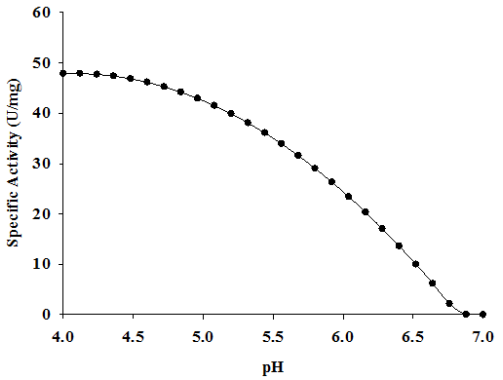


Fig. 1a Effect of pH as the singular factor on the specific activity of α-amylase from *Burnatia enneandra* (fixing stirring speed at 100 rpm and centrifugation time at 10 min)

At pH 7, with a probability P = 0.000, its contribution was 12 % (Table 3). It was observed when fixing stirring speed at 100 rpm and centrifugation time at 10 min. It was also obtained that, the quadratic effect of pH (x_1^2) contributed for 16 % with a significant probability of 0.000 (Table 3). This optimal pH of 4 is in accordance with the α-amylase pH of malt [18] and, could be explained by the

Table 1: Doehlert experimental design: coded variables, real variables and response

N°	Factors						Protein (µg)	Total activity (U/mL)	Response		
	Coded variables			Real variables					Specific activity (U/mg)		
	x_1	x_2	x_3	X_1	X_2	X_3			Exp	Cal	Res
1	0	0	0	5.5	175	20	1340.90±5.70	48.60±0.46	36.25±1.24	36.37	-0.12
2	1	0	0	7	175	20	1497.72±3.00	15.20±0.63	10.15±0.99	11.31	-1.16
3	-1	0	0	4	175	20	429.54±3.21	14.60±0.52	34.00±1.88	32.83	1.17
4	0.5	0.866	0	6.25	250	20	952.27±3.20	18.90±1.86	19.85±1.23	15.91	3.94
5	-0.5	-0.866	0	4.75	100	20	663.63±19.24	21.21±2.57	31.95±2.81	31.56	0.39
6	0.5	-0.866	0	6.25	100	20	1090.9±7.90	26.52±0.27	24.30±1.90	22.59	1.71
7	-0.5	0.866	0	4.75	250	20	447.72±3.22	13.73±1.10	30.60±1.40	28.46	2.14
8	0.5	0.289	0.816	6.25	200	30	1570.45±3.23	68.72±1.05	43.75±1.28	49.09	-5.34
9	-0.5	-0.289	-0.816	4.75	150	10	852.27±3.26	38.52±2.25	45.20±1.92	47.66	-2.46
10	0.5	-0.289	-0.816	6.25	150	10	1204.54±11.01	25.34±0.52	20.92±1.51	19.34	1.58
11	0	0.577	-0.816	5.5	225	10	618.18±6.44	16.50±2.99	26.69±1.21	26.56	0.13
12	-0.5	0.286	0.816	4.75	200	30	831.81±4.80	32.80±0.94	39.43±1.34	42.29	-2.86
13	0	-0.577	0.816	5.5	125	30	750.00±6.42	32.63±0.96	43.47±1.43	43.64	-0.17
14	0	0	0	5.5	175	20	1343.18±3.21	48.81±0.60	36.33±2.25	36.37	-0.04
15	0	0	0	5.5	175	20	1338.63±3.22	48.71±0.35	36.38±1.31	36.37	0.01
16	0	0	0	5.5	175	20	1340.90±6.20	49.00±0.50	36.54±2.42	36.37	0.17
17	0	0	0	5.5	175	20	1341.00±6.42	48.80±0.63	36.39±1.70	36.37	0.02

Table 2: Model validation

Models	R^2	AAD	B_f	A_f
$Y_{SpecAct}(x_1, x_2, x_3)$	0.990	0.041	0.987	1.043

Table 3: Estimated coefficients impact and contributions to enzyme specific activity

Effects	Specific activity		
	Coefficients	Probability	Contribution (%)
Constant	36.378	0.000	
x_1	-10.757	0.000	12
x_2	-2.825	0.009	3
x_3	8.470	0.000	10
x_1^2	-14.304	0.000	16
x_2^2	-10.892	0.000	13
x_3^2	8.891	0.001	10
x_1x_2	-2.069	0.292	2
x_2x_3	7.580	0.000	9
x_1x_3	22.258	0.019	25

fact that, the side chains of amino acids in the active site of the enzyme could act as weak acids and bases according to the ionization state. They could play an essential role in the interactions that maintain the structure of proteins. Eliminating a proton from an enzyme could discard an ionic interaction, crucial for stabilizing the active conformation of the enzyme [19]. That decrease could also probably due to synchronous denaturation in the structure of the enzyme protein induced by pH variation [20].

3.2 Effect of Stirring speed

The effect of stirring speed on the specific activity of α-amylase crude extract is shown in Fig. 1b. Specific α-amylase activity was 47.84 U/mg at 100 rpm then increased non-significantly to 51.10 U/mg at 147.40 rpm. After that a significant decrease (P = 0.009, Table 3) was observed till 35.82 U/mg at 250 rpm. Its contribution was 3% (Table 3). This was observed when fixing pH at 4 and centrifugation time at 10 min. The quadratic effect of stirring speed (x_2^2) contributed for 13% and was significant (P = 0.000, Table 3). The decrease could be explained by the fact that, the higher the stirring speed, the higher the destruction of hydrogen bonds and some London forces, inducing protein denaturation. When a protein is denatured, its secondary and tertiary conformations are modified but, the peptide bonds of the primary structure between the amino acids are

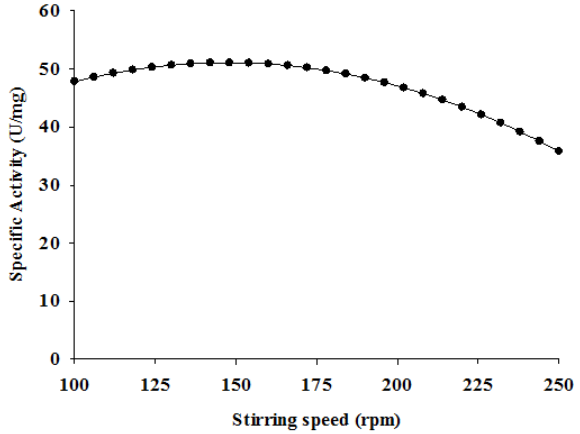


Fig. 1b Effect of stirring speed as the singular factor on the specific activity of α-amylase from *Burnatia enneandra* (fixing pH at 4 and centrifugation time at 10 min)

maintained intact. Seeing that all structural levels of the protein dictate its function, the protein can no longer achieve its role once it has been deteriorated. An enzyme depletes its catalytic activity when it is denaturized [21, 22].

3.3 Effect of centrifugation time

The effect of centrifugation time on the specific activity of α-amylase crude extract is shown in Fig.1c. α-amylase specific activity started with 35.38 U/mg after 10 min of centrifugation (at 6500 × g) then decreased non-significantly to 34.36 U/mg at 14.16 min. After that it increased significantly (P = 0.000, Table 3) to 49.21 U/mg at after 30 min of centrifugation. Its contribution was 10 % (Table 3). It was observed when fixing pH at 5.5 and stirring speed at 175 rpm. The quadratic effect of centrifugation time (x_3^2) had a significant probability of 0.001 with a contribution of 10 % (Table 3). This could be explain by the fact that, at the beginning (10 min to 15 min), the liquid phase was still charged with suspension and the consequence was a lower specific activity. When increasing the centrifugation time, the liquid phase became much free of suspended materials [23] and therefore inducing higher specific activity.

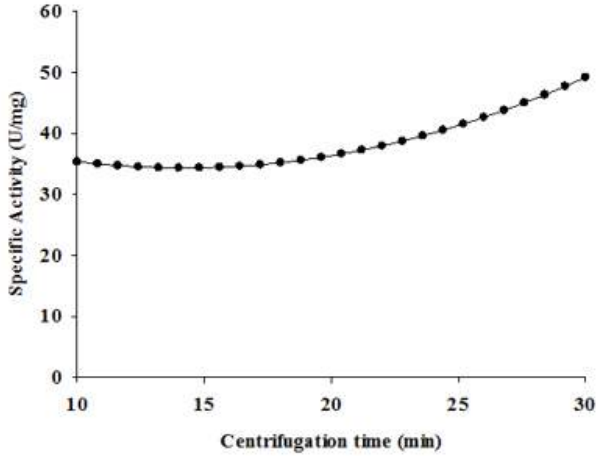


Fig. 1c Effect of centrifugation time as the singular factor on the specific activity of α-amylase from *Burnatia enneandra* (fixing pH at 5.5 and stirring speed at 175 rpm)

3.4 Effect of interaction pH/centrifugation time

The pH / Centrifugation time interaction had significant (P =0.000, Table 3) impact on α-amylase specific activity. This was obtained when fixing the stirring speed at 100 rpm. Its contribution was 25 % (Table 3). In fact, when decreasing the pH from 7 to 5.5, whatever the centrifugation time, it was observed an increase of specific activity. While, when decreasing the pH from 5.5 to 4, an increase of specific activity was observed when decreasing centrifugation time (Fig. 2a). Fractional precipitation was achieved by varying the pH of the medium. At the isoelectric point, the charge of the protein was not clear. This imposed a reduced solubility because it was unable to interact with the environment and precipitated [24]. The centrifugation time permitted to settle them down with also secondary metabolite and, at the same time increased the purity of amylase [23]. This confirm that amylase is stable at acidic pH [25-27].

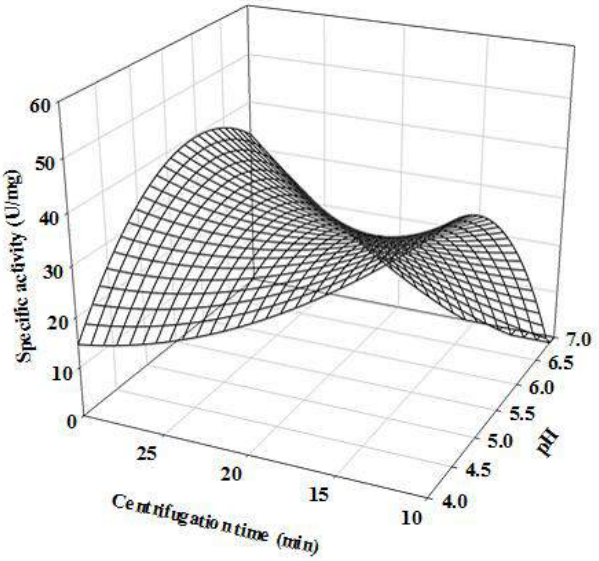


Fig. 2a Effect of interaction pH/centrifugation time on the specific activity of α-amylase from *Burnatia enneandra* (fixing the stirring speed at 100 rpm)

3.5 Effect of interaction stirring speed / centrifugation time

The effect of Stirring speed / Centrifugation time interaction had significant (P = 0.019, Table 3) impact on α-amylase specific activity. Its contribution was 9 % (Table 3). It was observed that, whatever the stirring speed, when decreasing the centrifugation time, the α-amylase specific activity increased significantly. It was also observed that, when increasing the stirring speed, the enzyme activity increased to reach a maximum and decrease afterward (Fig. 2b). Since in plant tissues cell are covered with strong cell walls, the increase of stirring speed (mechanical agitation) permitted the disruption of the cell walls [28] and at the same time the release of enzyme in the medium. The higher the enzyme concentration resulting from that disruption induced higher activity. Also when the stirring was executed, the better homogenization level in the liquid phase was obtained when increasing rates [29] thus, increasing amylase extraction and activity. At higher

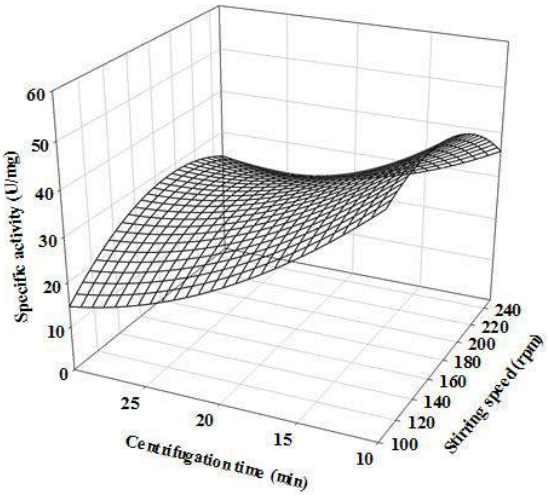


Fig. 2b Effect of interaction stirring speed/centrifugation time on the specific activity of α-amylase from *Burnatia enneandra* (fixing the pH at 4)

stirring speed, extracted enzymes undergone deactivation which explained the decrease of enzyme activity. This was also observed in the literature [30, 31].

3.6 Optimization

The result obtained for the action of extraction parameters (pH, stirring speed and centrifugation time) on α-amylase specific activity on the basis of the model, was optimized to determine the best condition for α-amylase extraction, in order to go to the next step which is partial purification. After using Mathcad 15.0, theoretical optimum was obtained and was as follows: pH, 4.02; stirring speed, 147.3 rpm and centrifugation time, 10 min. These values permitted to obtain a theoretical α-amylase specific activity at 51.11 U/mg. That combination (pH, 4.02; stirring speed, 147.3 rpm and centrifugation time, 10 min) was tested in the laboratory to verify the theoretical result and, 49.33±1.9 U/mg was obtained.

4 Conclusion

The impact of extraction parameters (pH, stirring speed and centrifugation time) on the specific activity of α-amylase from *Burnatia enneandra* Micheli were studied. The pH was the singular parameter which was influencing more the specific activity of α-amylase, followed by the centrifugation time. Concerning interactions, the pH / Centrifugation time was very important, meaning there was a high synergetic action between the two factors, compare to stirring speed / centrifugation time while, pH / stirring speed interaction was not significant. The theoretical optimization showed interesting results which was confirmed by the laboratory test. This could permit to use the same modelling approach to purify the α-amylase from *Burnatia enneandra* in order to valorise that herbaceous plant.

Acknowledgements

The authors gratefully acknowledge the Department of Process Engineering and Food Science and Nutrition of the National School of Agro- Industrial Sciences (ENSAI) and, The University of Ngaoundere (Cameroon) for providing necessary facilities for the successful completion of this research work.

References

1. N. Djidimbele, Characterisation fonctionnelle d'une plante à activité edulcorante: *Burnatia enneandra* (tinga'ari), Science Alimentaires et Nutrition, University of Ngaoundere, Ngaoundere, 2002.
2. H.R. Glew, J.K.G. Kramer, M. Hernandez, A. Pastuszyn, J. Ernst, N.N. Djomdi, D.J. VanderJagt, The amino acid, mineral and fatty acid content of three species of human plant foods in Cameroun, Food, 4 (2010) 1-6.
3. H. Tourneux, D. Yaya, Dictionnaire peul de l'agriculture et de la nature (Diamaré, Cameroun), suivi d'un index français-fulfulde, Karthala / CTA / CIRAD ed., Paris / Wageningen / Montpellier, 1998.
4. E.J. Nso, J.N. Aseaku, Z.S.C. Desobgo, C. Ngulewu, D.K. Aleambong, A. Taïra, Comparison of the mashing and brewing potentials of crude extracts of *Abrus precatorius*, *Burnatia enneandra* and *Cadaba farinosa*, Journal of Brewing and Distilling, 4 (2013) 46-50.
5. D. Mathieu, D. Feneuille, R. Phan-Tan-Luu, Méthodologie de la recherche expérimentale: Etude des surfaces de réponse, Laboratoire de Prospective Reactionnelle et d'Analyse de l'Information, IUT de l'Université d'Aix-Marseille, Marseille, 1977.
6. J. Goupy, L. Creighton, Introduction aux plans d'expériences, 3 ed., Dunod, Paris, 2006.
7. J. Goupy, Plans d'expériences pour surfaces de réponse, Dunod1999.
8. M. Giovanni, Response surface methodology and product optimization, Food Technology, 37 (1983) 41-45.
9. T. Ross, Indices for performance evaluation of predictive models in food microbiology, Journal of Applied Bacteriology, 81 (1996) 501-508.
10. J. Baranyi, C. Pin, T. Ross, Validating and comparing predictive models, International Journal of Food Microbiology, 48 (1999) 159-166.
11. A.A.J.F. Ekorong, G. Zomegni, Z.S.C. Desobgo, R. Ndjouenkeu, Optimization of drying parameters for mango seed kernels using central composite design, Bioresources and Bioprocessing, 2 (2015) 1-9.
12. H.D. Tindall, Monitoring of tree growths in the arid regions, J. Plant Physiol., 9 (1996) 711-811.
13. O.H. Lowry, N.J. Rosebrough, A.L. Farr, R.J. Randall, Protein measurement with the folin phenol reagent, J. Biol. Chem., 193 (1951) 265-275.
14. P. Gerhardt, R.G.E. Murray, W.A. Wood, N.R. Krieg, Methods for general and molecular bacteriology, ASM, Washington DC, 1994.
15. B. Frolund, R. Palmgren, K. Keiding, P.H. Nielsen, Extraction of extracellular polymers from activated sludge using a cation exchange resin, Water Res., 30 (1996) 1749-1758.
16. H. Fuwa, A new method for microdetermination of amylase activity by the use of amylose as the substrate, Journal of Biochemistry, 41 (1954) 583-603.
17. K. Arpana, K.S. Vinay, F. Jörg, P. Tino, M.K. Arvind, α-amylases from germinating soybean (Glycine max) seeds- Purification and characterization and sequential

similarity of conserved and catalytic amino acid residues, Phytochemistry, 71 (2010) 1657-1666.
18. E.H. Clyde, The optimum pH for diastase of malt activity, The Ohio Journal of Science, 59 (1959) 257-262.
19. D.L. Nelson, M.M. Cox, Lehninger principles of biochemistry, W. H. Freeman2008.
20. C.A. Afiukwa, U.A. Ibiam, C.O. Edeogu, F.N. Nweke, U.E. Chukwu, Determination of amylase activity of crude extract from partially germinated mango seeds (Mangifera oraphila), African Journal of Biotechnology, 8 (2009) 3294-3296.
21. M. Vert, Y. Doi, K.-H. Hellwich, M. Hess, P. Hodge, P. Kubisa, M. Rinaudo, F. Schué, Terminology for biorelated polymers and applications (IUPAC Recommendations 2012), Pure Appl. Chem., 84 (2012) 377-410.
22. A. Mehrnoush, Y. Mohd, Abdul, Manap, Z. Norkhanani, Optimization of processing parameters for extraction of amylase enzyme from Dragon (*Hylocereus polyrhizus*) peel using response surface methodology, The Scientific World Journal, 2014 (2014) 1-12.
23. P. Bonner, L. R. , Protein purification, Taylor & Francis Group, 270 Madison Avenue New York, NY 10016, 2007.
24. H. Bisswanger, Practical enzymology, 2 ed., Wiley-Blackwell, Strauss GmbH, Morlenbach, Federal Republic of Germany, 2011.
25. T. Dutta, Kr., M. Jana, P. Pahari, R., T. Bhattacharya, The effect of temperature, pH, and salt on amylase in *Heliodiaptomus viduus* (Gurney) (Crustacea: Copepoda: Calanoida), Turk. J. Zool., 30 (2006) 187-195.
26. Y. Minoda, K. Yamada, Acid-stable alpha-amylase of black *Aspergilli*. Part I. Detection and purification of acid-stable dextrinizing amylase, Agr. Biol. Chem., 27 (1963) 806-811.
27. E.M. Doyle, C.T. Kelly, W.M. Fogarty, The high maltose producing alpha-amylase of *Penicillium expansum*, Applied Microbiology and Biotechnology, 30 (1989) 492-496.
28. K.H. Van-Het-Hof, B.C.J. De-Boer, L.B.M. Tijburg, B.R.H.M. Lucius, I. Zijp, C.E. West, J.G.A.J. Hautvast, J.A. Weststrate, Carotenoid bioavailability in humans from tomatoes processed in different ways determined from the carotenoid response in the triglyceride- rich lipoprotein fraction of plasma after a single consumption and in plasma after four days of consumption., J. Nutr., 130 (2000) 1189-1196.
29. A. Dıaz, B. , I. Caro, I. De-Ory, A. Blandino, Evaluation of the conditions for the extraction of hydrolitic enzymes obtained by solid state fermentation from grape pomace, Enzyme and Microbial Technology, 41 (2007) 302-306.
30. H. Ingesson, G. Zacchi, B. Yang, A.R. Esteghlalian, J.N. Saddler, The effect of shaking regime on the rate and extent of enzymatic hydrolysis of cellulose, J. Biotechnol., 88 (2001) 177-182.
31. J.D. Wright, Ethanol from biomass by enzymatic hydrolysis, Chem. Eng. Prog., 89 (1988) 62-74.

Source of support: Nil; Conflict of interest: None declared

Résumé de l’article

Partial purification of α-amylase from *Burnatia enneandra* Micheli. Part 1: Extraction using statistical model

Taira A., **Desobgo Z. S. C.***, Nso J. E.

Abstract

The impact of pH, stirring speed and centrifugation time was tested on α-amylase specific activity of *Burnatia enneandra* tubers from Cameroon. The response surface methodology using Doehlert experimental design as instrument, was employed to establish, validate and optimize the mathematical model conducive to understand the influence of extraction factors (pH, stirring speed and centrifugation time) either singular or in interactions. It was exhibited that pH as singular factor and, in its first degree (X_1) provided 12 % of the specific activity of α-amylase although, stirring speed (X_2) and centrifugation time (X_3) provided 3 % and 10 % respectively. It was also observed that, the raise of pH reduced specific activity of α-amylase while, an increase of centrifugation time increased the specific activity of α-amylase. The combined effort (interaction) of pH / centrifugation time and stirring speed / centrifugation time was significant with respective contribution of 25 % and 9 % respectively. For optimization, a theoretical triplet (pH, 4.02; stirring speed, 147.3 rpm and centrifugation time, 10 min) was exhibited and, gave 49.33±1.9 U/mg as maximal α-amylase specific activity from *Burnatia enneandra*.

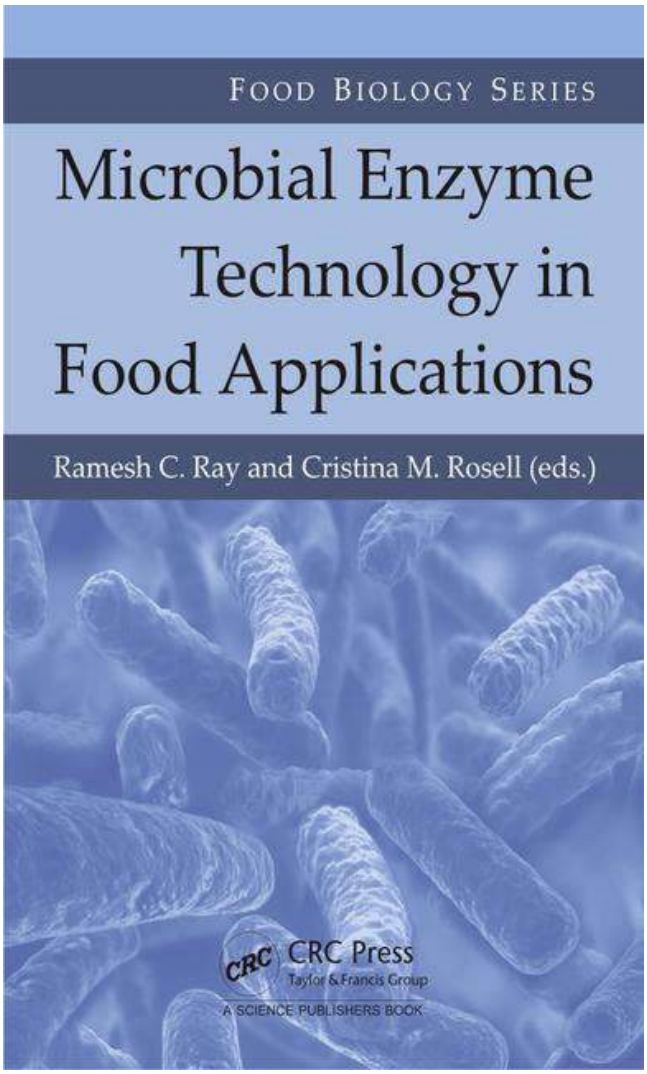
Keywords: *Burnatia enneandra* tubers, extraction, Doehlert experimental design, Modelling, Optimization.

IV.4.5) Chapter 25: Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview

Titre du livre

CRC Press Taylor & Francis Group

Search or Browse by Subject



Microbial Enzyme Technology in Food Applications

Ramesh C. Ray, Cristina M. Rosell

November 28, 2016 by CRC Press
Reference - 520 Pages - 11 Color & 55 B/W Illustrations
ISBN 9781498749831 - CAT# K27165
Series: Food Biology Series

For Librarians Available on CRCnetBASE >>

Select Format:

Hardback

Quantity:

1

GBP £127.00

Add to Cart

Add to Wish List

Comité de lecture

CRC Press
Taylor & Francis Group

Contact Us Menu

Editorial Contacts

Our editorial staff is fully equipped to handle a wide variety of inquiries.

Please contact an editor if you are interested in publishing a book with CRC Press, copublishing, sponsoring or contributing to a series or book, or have ideas for one. (links are to direct e-mail address).

Business & Management

Kristine Mednansky

Disciplines: Healthcare Administration, including Lean & Quality Management; Patient Safety; Financial Management; Strategy & Leadership; and Information Management

Tel: (630) 482-9886

Michael Sinocchi

Disciplines: Lean Manufacturing & Lean Service; Quality & Six Sigma; Product Development; and Supply Chain Management; Green Manufacturing & Sustainability; Lean & Quality Improvement

Tel: (212) 216-7867

Biological Science

Randy Brehm

Disciplines: Agriculture, Crop Science, Forestry, Horticulture, Plant Sciences, Soil Sciences, Wildlife Science

Tel: (561) 361-6088

Chuck Crumly

Disciplines: Cell, Developmental, and Molecular Biology; Microbiology; Virology; Systematics; and Evolution

Tel: 510-710-2712

Alice Oven - Senior Editor

Disciplines: Disciplines: Botany; Ecology; Zoology; Evolutionary Biology; Animal Science;

Veterinary Science; Laboratory Animal Science; and Marine Science
Tel: +44 (20) 755 19992

Renu Upadhyay

Disciplines: All Areas
Tel: +91 11 4315 5159

Chemistry

Fiona Macdonald/Publisher - Senior Publisher

Disciplines: Chemical Information; Handbook of Chemistry & Physics
Tel: (561) 998-2564

Barbara (Glunn) Knott

Disciplines: Analytical Chemistry; Industrial and Applied Chemistry; Materials Chemistry and Physical Chemistry
Tel: (207) 672-3857

Hilary LaFoe

Disciplines: Organic and Inorganic Chemistry, Environmental Chemistry, Green Chemistry, Pharmaceutical Science, Sustainable Science & Drug Discovery
Tel: +44 (0)7717 800251

Renu Upadhyay
Disciplines: All Areas
Tel: +91 11 4315 5159

Computer Science

Rick Adams

Disciplines: Computer Science, Gaming, and Graphics
Tel: (614) 446-2151

Randi Cohen

Disciplines: Computer Science
Tel: (757) 240-7501

Sean Connelly

Disciplines: Game Development, Animation, Web Design/Development
Tel: (781) 313-8822

Engineering

Cindy Carelli

Disciplines: Manufacturing Engineering & Quality; Reliability Engineering; Industrial Engineering; Ergonomics & Human Factors; Operations Research; Industrial Hygiene; and Occupational Health & Safety
Tel: (352) 536-9510

Marc Gutierrez

Discipline: Biomedical Engineering and Biotechnology, Electrical Engineering and Optical Sciences
Tel: (561) 998-2528

Nora Konopka - Editorial Director

Disciplines: Electrical Engineering; Computer Engineering; and Nanotechnology
Tel: (561) 998-2531

Kyra Lindholm

Disciplines: Mechanical, Aerospace/Aviation, and Nuclear Engineering
Tel: (561) 430-4848

Ed Needle

Disciplines: Construction and Real Estate
Tel: +44 (20) 701 76142

Jonathan Plant

Disciplines: Mechanical, Aerospace, and Nuclear Engineering
Tel: (781) 635-5004

Allison Shatkin

Disciplines: Chemical Engineering; Materials Science and Engineering; Plastics & Polymer Engineering; Petroleum Engineering
Tel: (561) 843-8407

Gagandeep Singh

Disciplines: Engineering
Tel: +91 11 431 555 180

Environmental Science

Nora Konopka/Publisher

Tel: (561) 998-2531

Léon Bijnsdorp

Disciplines: Conference Proceedings in Engineering, Earth Sciences, & Water Sciences
Tel: +31-71-524-3089

Janjaap Blom/Publisher

Disciplines: Geotechnical Engineering; Earth Sciences; Water Sciences; & Energy
Tel: +31-71-524-3080

Alistair Bright

Disciplines: Geotechnical Engineering; (Renewable) Energy
Tel: +31 71 524 3088

Joe Clements

Disciplines: Civil Engineering; Environmental Engineering; Water Engineering & Science; Clean Tech & Renewable Energy
Tel: (561) 361-6016

Tony Moore

Disciplines: Civil Engineering; Environmental Engineering; Water Engineering & Science
Tel: +44 (20) 701 76672

Irma Shagla Britton

Disciplines: Earth Sciences and Environmental Sciences, GIS, and Remote Sensing

& Cartography
Tel: (561) 361-6067

Forensics and Homeland Security

Mark Listewnik

Disciplines: Forensics Science
Tel: (508) 614-1467

NOTE: In 2016, the CRC Press Criminal Justice books were unified with the Routledge imprint. You can find Editorial Contacts for criminal justice and criminology at: https://www.routledge.com/contacts/editorial

Food Science

Steve Zollo

Disciplines: Food Science & Culinary Arts
Tel: (561) 998-2547

Information Technology (IT)

Rich O'Hanley - Senior Publisher

Disciplines: Communications Engineering & Networking; Information Security; Physical Security; and Applied Manufacturing
Tel: (917) 351-7146

He Ruijun

Disciplines: Communications & Networking; Information Security; Physical Security; Applied Manufacturing Software Engineering; Systems Development; Database; and IT
Tel: +86 10 5845 2830

John Wyzalek

Disciplines: Project Management; Information Technology; Software Engineering; Data Analytics and Big Data
Tel: (917) 351-7149

Mathematics
Sunil Nair - Editorial Director

Disciplines: Mathematics, Financial Mathematics, Computational Biology, Imaging Sciences, and Visualization
Tel: +44-20-7017-6346

Bob Ross

Discipline: Mathematics
Tel: (781) 535-9277

Callum Fraser

Discipline: Mathematics: includes Financial Mathematics, Recreational Mathematics, Discrete Mathematics, Applied Mathematics, Pure Mathematics, and more
Tel: +44 20 701 74000

Aastha Sharma
Discipline: Mathematics, Statistics, Physics and Computer Science (South Asia)
Tel: (91) 11 43155175

Medicine

Joanna Koster
Senior Publisher Disciplines: Undergraduate Textbooks and Revision Guides; Non-Clinical Medicine including skills and training, medical education, healthcare systems and services; Anatomy & Physiology; Emergency Medicine; General Practice; General/Internal Medicine; Medical Genetics; Medical Imaging; Occupational & Environmental Medicine;
Tel: +44 (20) 337 73780

Miranda Bromage

Disciplines: Surgery and Surgical Specialties, ENT, Orthopedics & Trauma, Urology, Forensic Medicine, Neurology, Pathology
Tel: +44 (20) 755 19463

Robert Peden

Disciplines: Dermatology & Cosmetic Science, Cosmetic Dentistry, Gynecology & Obstetrics, Reproductive Medicine, Women's Health, Fetal Medicine, Pediatrics & Neonatology, Oncology & Palliative Medicine
Tel: +44 (20) 701 76674

Shivangi Pramanik

Disciplines: Cardiology, Endocrinology & Diabetes, Microbiology & Infectious Disease, Pulmonary Medicine, Public Health & Preventative Medicine, publishing for the Indian subcontinent
Tel: +91 11 4315 5210

Nutrition

Randy Brehm

Disciplines: Clinical Nutrition; Nutrition Science; and Sports Nutrition
Tel: (561) 361-6088

Physics

Francesca McGowan (covered by Rebecca Davies)

Discipline: Physics, including Astronomy, Condensed Matter, Geophysics, High Energy, Medical Physics, Biophysics, Nuclear, Particle, Plasma and Sensors

Rebecca Davies

Discipline: Physics, including Astronomy and Astrophysics, Popular Science, Condensed Matter, Geophysics, High Energy, Medical Physics and Biomedical Engineering, Biophysics, Nuclear, Particle, Plasma and Sensors

Statistics

Rob Calver

Discipline: Statistics
Tel: +44-20-7017-6334

David Grubbs

Discipline: Statistics
Tel: (561) 998-2524

John Kimmel

Discipline: Statistics
Tel: (949) 391-8329

CRC Press Editorial Staff

Table des matières

FREE Standard Shipping!

Additional Book Information

Table of Contents

HISTORY

Microbial Enzymes in Food Applications: History of Progress

Swati S. Mishra, Ramesh C. Ray, Cristina M. Rosell and Debabrata Panda

CHARACTERIZATION PRODUCTION AND APPLICATIONS OF MICROBIAL ENZYMES

Insight of The A-Amylase Family of Enzymes: Endo- and Exo-Acting A, 1-4 Hydrolyses

Mario M. Martínez and Manuel Gómez

Starch-active debranching and α-glucanotransferase enzymes

Mario M. Martínez and Manuel Gómez

Glucose Isomerising Enzymes

Savitha S. Desai, Dhanashree B. Gachhi and Basavaraj S. Hungund

Sucrose Transforming Enzymes: Hydrolysis & Isomerization

Harish B.S. and Kiran Babu Uppuluri

Sucrose Transforming Enzymes: Hydrolysis & Isomerization

Harish B.S. and Kiran Babu Uppuluri

β- Galactosidases for Lactose Hydrolysis and Galactooligosaccharide Synthesis

Francisco J. Plou, Julio Polaina and Julia Sanz-Aparicio

Pectinases and their Biotechnological Applications

Anuja Vohra and Reena Gupta

Proteases

Olga Luisa Tavano

Microbial Transglutaminase and Applications in Food Industry

Marek Kieliszek and Stanisław Błażejak

Microbial Milk Coagulants

Ekaterini Moschopoulou

Lipase: Properties, functions and food application

Maria Antonia Pedrine Colabone Celligoi, Cristiani Baldo, Thiago Andrade Marques Marcelo Rodrigues de Melo, Fabiana Guillen Moreira Gasparin and Márcio de Barros

Catalases: Types, structure, applications and future outlook

Balwinder Singh Sooch, Baljinder Singh Kauldhar, Munish Puri

Microbial Laccases as Potential Eco-friendly Biocatalysts for the Food Processing Industries

Susana Rodríguez-Couto

MICROBIAL ENZYMES IN FOOD FERMENTATION

Role of intrinsic and supplemented enzymes in brewing and beer properties

Sergio O. Serna-Saldivar and *Monica Rubio-Flores*

Enzymes in Baking

Angela Dura and Cristina M. Rosell

Enzymes in Winemaking

José Manuel Rodriguez-Nogales, Encarnación Fernández-Fernández and *Josefina Vila-Crespo*

Microbial Linamarase in Cassava Fermentation

Sudhanshu S. Behera and *Ramesh C. Ray*

Dairy Processing

Ashok Kumar Mohanty and *Pradip Behare*

ADVANCEMENT IN MICROBIAL ENZYME TECHNOLOGY

Recombinant Enzymes in the Meat Industry and the Regulations of Recombinant Enzymes in Food Processing

Kelly Dong, Yapa A. Himeshi Samarasinghe, Wenjing Hua, Leah Kocherry and *Jianping Xu*

Recombinant Enzymes Used in Fruit and Vegetable Juice Industry

Yapa A. Himeshi Samarasinghe, Wenjing Hua, Kelly Dong, Leah Kocherry and Jianping Xu

Marine Microbial Enzymes in Food Application

Arunachalam Cinnathambi and *Chandrasekaran Muthusamy*

Extremophiles as potential resource for food processing enzymes

Archana Sharma and *T. Satyanarayana*

Production of Microbial Enzymes by Solid-State Fermentation for Food Applications

Quentin Carboué, Marie-Stéphane Tranier, Isabelle Perraud-Gaime and Sevastianos Roussos

Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview

Steve C. Z. Desobgo, Swati S. Mishra, Sunil K. Behera and *Sandeep K. Panda*

Biotechnology of Microbial Xylanase: Overview

Hooi Ling Ho

Encapsulation Technology of Enzymes and Applications in Food Processing

Steva Lević[1], Verica Đorđević, Zorica Knežević-Jugović, Ana Kalušević, Nikola Milašinović, Branko Bugarsk[2] and Viktor Nedović

Share this Title

Pages du chapitre

Microbial Enzyme Technology in Food Applications
R.C. Ray and Christina M. Rossell (eds.)
ISBN 978-1-4987-4983-1

Not for Circulation

25

Scaling-up and Modelling Applications of Solid-state Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries

An Overview

Steve C.Z. Desobgo,[1,4,*] *Swati S. Mishra,*[2] *Sunil K. Behera*[3] and *Sandeep K. Panda*[4]

1. Introduction

Solid-state fermentation (SSF) is regarded as one of the most acceptable and convenient technologies for production of microbial enzymes. SSF is understood as the cultivation of microorganisms on solid, moist substrates in the absence of free aqueous phase, at average water activity significantly below 1 (Pandey, 2003). SSF is advantageous over submerged fermentation for the production of enzymes in numerous aspects, especially, fungal enzyme production is preferred in SSF as fungi show higher germination rates, spore formation and hyphae penetration in moist solid substrates (Holker and Lenz, 2005). Keeping in view the market size of the enzymes (£ 2100 million in 2010) and compound annual growth rate (CAGR) of 6 per cent forecast over the next five years, researchers and industrialists are showing tremendous interest in the techno-economic

For affiliaton see at the end of the chapter.
For Nomenclature see at the end of the chapter.

feasibility of production of different microbial enzymes (Saxena, 2015). Microbial enzymes are very commonly applied in modern times for the production of different food products. The most important microbial enzymes used in food industries are α-amylase, gluco-amylase, lipase, protease, invertase and pectinase, etc. Several studies in the last decade have developed technologies for overproduction of these enzymes. Researchers have also focused on economical production of the enzymes from cheaper substrates to reduce the cost of the final product (Panda and Ray, 2015). Genetically-engineered strains have been proved to be useful for enhanced production of the enzymes (Panda et al., 2016).

Although several review articles have covered the history and microbiological production of different enzymes related to food processing on the laboratory scale, hardly any article covers the exact scenario in the scaling-up process. The current article covers the developments in modelling, scaling-up equipments and production of commercially important enzymes related to food industries in different types of bioreactors with selected examples.

2. Scale up and Enzymes

The production of bulk chemicals and enzymes has secured an advantage with SSF (Soccol et al., 1994). Several researchers have demonstrated the bulk production of enzymes using SSF. Pectolytic enzymes were produced in large scale by solid-state fermentation using *Aspergillus carbanerius* strain on wheat bran medium. Fermentation for 21 hours with the tray temperature of 30ºC gave maximum production of enzymes. Further, steaming of wheat bran at 15 Pa for 45 min. enhanced the enzyme production (Ghildyal et al., 1981). Roussos et al. (1993) described a novel, large-scale solid-state fermenter designated as *Zymotis*, which aids the upscaling studies at 4–12 kg substrate dry matter (SDM) or 15–55 kg moist solid medium capacity, depending on the initial moisture content of the medium. Sugarcane bagasse and wheat bran [80:20 (w/w)] were used in fermentation for production of cellulase. The fermentation was conducted for 64 hours at 28ºC and the medium was aerated at the rate of 300:l humidified air/h/compartment during the first 12 hours, and further the aeration rate was doubled for rest of the fermentation time. The study was carried out to compare the production of cellulolytic enzymes by *Trichoderma harzianum* in *Zymotis* and a medium-sized laboratory column fermenter. It was observed that the enzyme titres were marginally higher in *Zymotis* at all the substrates when compared with parallel fermentation in the laboratory-scale column fermenter. The improved performance of the *Zymotis* is attributed to better control of cultural parameters in it.

3. Scale-up Approaches and Models

In the natural environment, SSFs occur everywhere—in cultivated grounds, the compost or the ensilage, but the term ‘fermentation’ is not naturally associated with what occurs in these mediums. This term is used with more elaborate processes developed in laboratory and implemented in bioreactors.

The scale-up of a bioprocess is a critical stage which guarantees the economic viability of the bio-product concerned. It consists in increasing the size of the bioreactor in order to reach sufficient productivity, and this, while maintaining as much as possible the outputs obtained at the time of tests in laboratory or on a pilot scale. For most biotechnological products (like enzymes production), a viable process is reached only for volumes of bioreactor of a few hundreds of thousands of liters (Lonsane et al., 1992). Technically, the definition of the scale-up understands several aspects (Trilli, 1986; Glenn and Rogers, 1989; Kossen and Oosterhuis, 1985; Oosterhuis et al., 1985). It would not only be about the increase in the size of the bioreactor, but should take into account the costs, the outputs and the simplicity of the device (Oosterhuis et al., 1985). In the case of microbial fermentation for the production of enzymes, a broad multidisciplinary field is shared (Banks, 1984) and the scale up then becomes an important link for the bioprocess transfer from the laboratory scale to the industrial scale for commercial needs.

The scale up is carried out in several stages (Banks, 1984; Trilli, 1986): from Erlenmeyer flask to the laboratory bioreactor, from laboratory bioreactor to the pilot bioreactor and from pilot bioreactor to the industrial bioreactor. It is impossible to preserve all the parameters identical or proportional to the scaling. Each transfer to a greater scale is complex because various parameters, such as the scale of sterilization, aeration and agitation are modified when one increases volume, the diameter and the height of the bioreactor (Lonsane et al., 1992; Mitchell et al., 2006). Similar physicochemical conditions must be maintained in the environment of each cell in spite of the increase in the volume of culture. With each stage of the scale up, various parameters are analyzed and modified because the physicochemical and enzymatic reactions occurring inside the bioreactor vary according to the volume of the bioreactor used. Moreover, during the scaling, it is essential to take into account the investment costs of equipment (bioreactor, techniques of extraction and purification) and of operation (culture medium and energy); to carry out an automation of equipment if possible; to reduce the production of waste; to obtain products corresponding to desired quality (Mitchell et al., 2006).

The representation of the working system in terms of mathematical expression is what constitutes the modelling in SSF. The application of mathematical modelling techniques to describe the biological and transport phenomena within the system made significant improvements in understanding how to design, operate and scale-up SSF bioreactors. Various features of the conceptually divided microscale and macroscale phenomena that occur within SSF bioreactors are described by equations of the mathematical models of bioreactor (Mitchell et al., 2000). The prediction models for the scale up is taking into account the growth kinetic, rotating-drum, traditional and *Zymotis* packed-bed, intermittently-mixed forcefully-aerated and well-mixed bioreactors. The aspects globally developed are growth kinetic, energy and water balance. Some assumptions are made to handle the models.

3.1 Growth kinetic models

The growth kinetic models are one of the first important models concerning the scale up and especially on modelling and controlling. It can be used to handle the conditions

in the reactor. These conditions take into consideration the parameters involved during biomass growth. Table 1 presents a non-exhaustive number of models used for growth modelling. In a study conducted by Rodriguez-Fernandez et al. (2011), the behavior of

Table 1. Describing equations for microbial kinetics.

Model	Equations	
Arrhenius	$\mu_{\max}(T) = k_g^0 \exp\left(\frac{-E_g}{RT}\right) - k_g \exp\left(\frac{-E_d}{RT}\right)$	[5]
Bovill et al.	$\frac{dX}{dt} = \mu X\left(1-\frac{X}{X_m}\right)\left(\frac{Q}{1+Q}\right)$ (Bovill et al., 2000)	[6]
Esener	$\mu_{\max}(T) = \frac{A\exp\left(-\frac{\Delta H_1}{RT}\right)}{1+k\exp\left(-\frac{\Delta H_2}{RT}\right)}$ (Saucedo-Castaneda et al., 1990)	[7]
Fanaei and Vaziri	$\mu = \left(\frac{\mu_s + (T_{\max} - T_{opt})}{T_{\max} - T_{opt}}\right)\left(\frac{\mu_{opt}(T_{\max} - T)}{\mu_s + (T_{\max} - T)}\right)$ (Fanaei and Vaziri, 2009)	[8]
Okazaki et al.	$X = \frac{X_m}{1+\left[\left(\frac{X_m}{X_0}\right)-1\right]e^{-\mu t}}$ (Okazaki et al., 1980)	[9]
Saucedo-Castaneda	$\mu = \frac{2.964\times10^{11}\exp\left(-\frac{70225}{RT}\right)}{1+1.3\times\exp\left(-\frac{283356}{RT}\right)}$ $X_m = -127.08 + 7.95(T-273) - 0.016(T-273)^2$ $+4.03\times10^{-3}(T-273)^3 + 4.73\times10^{-5}(T-273)^4$ (Saucedo-Castaneda et al., 1990)	[10] [11]
Ratkowsky et al.	$\mu_{\max}(T) = c_0(T-T_{\min})\left[1-\exp(c_1(T-T_{\max}))\right]^2$ (Ratkowsky et al., 1983; Weber et al., 2002)	[12]
Exponential	$\frac{dX}{dt} = \mu X$ (Mitchell et al., 2004; Sosa et al., 2012)	[13]
Linear	$\frac{dX}{dt} = K$ (Mitchell et al., 2004; Sosa et al., 2012)	[14]
Logistic	$\frac{dX}{dt} = \mu X\left(1-\frac{X}{X_m}\right)$ (Mitchell et al., 2004; Sosa et al., 2012)	[15]

Table 1. contd....

Table 1. contd....

Model	Equations	
Polynomials	$\mu_{max}(T) = -s_0 + s_1T - s_2T^2 + s_3T^3 - s_4T^4 + s_5T^5$ $\mu_{max}(T) = -b_0 + b_1T - b_2T^2$ $X_m(T) = -e_0 + e_1T - e_2T^2 + e_3T^3 - e_4T^4$ (Mitchell et al., 2004; Sosa et al., 2012)	[16] [17] [18]
Two phase	$\frac{dX}{dt} = \mu X,\ t \le t_a$ $\frac{dX}{dt} = \left[\mu L e^{-k(t-t_a)}\right] X,\ t \ge t_a$ (Mitchell et al., 2004; Sosa et al., 2012)	[19] [20]

kinetic parameters in production of pectinase and xylanase by solid-state fermentation was observed. *Aspergillus niger* F3 was applied for production of pectinase and xylanase in a 2 kg bioreactor and citrus peel was used as a substrate. It was revealed that pectinase production was highest at 72 hours whereas the xylanase production increased after 72 hours, which is because of the reduction of pectin in the medium and forcing the microorganism to use xylan as the carbon source. The best air flow intensity noted for the microorganism growth and optimum production of pectinase (265 U/g) and xylanase (65 U/g) was 1 V kg M (volumetric air flow per kilogram of medium). This is because of the sufficient amount of O_2 incorporated into the medium. The following equation (1) was applied to obtain the values for metabolic O_2 balance:

$$\frac{dO_2}{dt} = \frac{1}{Y_{x/o}}\frac{dx}{dt} + mX \quad [1]$$

where *dX/dt* is the biomass production rate; *X*, biomass synthesised during the time interval; *Yx/o*, yield based on O_2 consumption for biomass synthesis; dO_2, differential O_2 consumed during the differential time interval; *m*, maintenance coefficient; *dt*, differential time interval.

Along with the growth of microorganisms and consumption of substrates, researchers also studied the modelling of product formation, such as enzymes and bio-ethanol. One of the general modelling used for the formation of products in biological processes is to assume the growth and non-growth-associated components. Therefore, the general equation (2) for a product (*P*) is:

$$\frac{dp}{dt} = Y_{PX}\frac{dX}{dt} + m_P X \quad [2]$$

where Y_{PX} is the stoichiometric coefficient and m_P is the maintenance coefficient.

Mass balances are also used to develop the product formation models. Hashemi et al. (2011) proposed equation (3) to model different phases of bacterial growth curve and the production of α-amylase in the SSF process using wheat bran as substrate and *Bacillus* sp. as inoculum.

$$\frac{dW}{dt} = \frac{dS}{dt} + \frac{dB}{dt} + \frac{dP}{dt} \quad [3]$$

In the study it was assumed that the changes in total dry fermenting medium weight (W) correspond to substrate consumption rate (dS/dt), biomass growth rate (dB/dt) and product formation rate (dP/dt).

Experimental data generated from a series of batch fermentations were applied to validate the proposed models. Prediction of the production of α-amylase during the fermentation process was attempted by using equation (4) which makes a correlation between P (enzyme production) and t (time) based on the variation in the fermented medium weight. According to the equation, α and β coefficients are estimated experimentally to predict the product kinetics derived from $\frac{dW}{dt}$ data:

$$P = (\alpha - \frac{\gamma}{\delta}) \int_0^t B dt + \frac{\beta}{\delta} \int_0^t \frac{dW}{dt} dt \quad [4]$$

3.2 Rotating-drum bioreactors models for scale-up and applications

The rotating-drum bioreactors comprise a horizontally rotating drum, that may or may not have a paddle mixer and rotates slowly for proper mixing of fermentation substrate. For scaling-up purposes, many assumptions need to be made concerning the rotating-drum bioreactors (Fig. 1). The most important ones can be summarized as follows: the bioreactor is cylindrical (with a length L and diameter D) and partially filled; since the solid materials are degraded during fermentation, it will be considered that only the density of the bed is affected; the dry gas remains constant in the headspace; the gas flow rates remain the same between the inlet and the outlet of the bioreactor; the solid particles and gas phase are in equilibrium (moisture and thermal) and the diffusion from the axe is negligible (Mitchell et al., 2002).

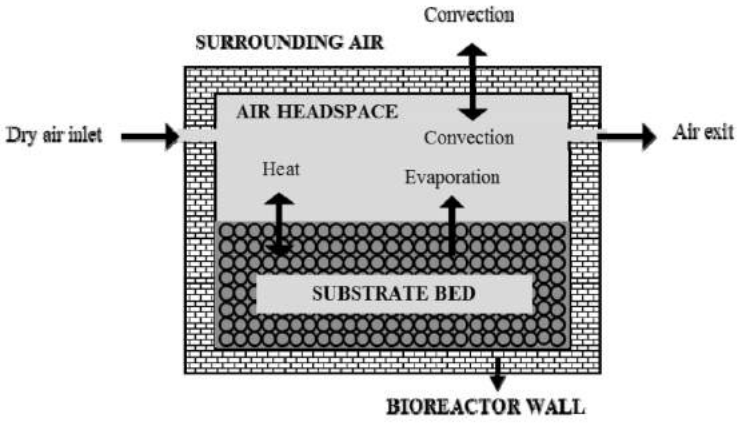


Figure 1. Rotating-drum bioreactor.

The models used for the rotating drum bioreactors scale-up take into consideration mass and heat transfer balances. The mass transfer (for water and air) occurring over the bed and headspace must be considered.

3.2.1 Microbial growth

Initially, at $t = 0$, $X = X_0$, and the microbial growth kinetic which is a logistic equation can be expressed as follows (Mitchell et al., 2002; Wang et al., 2010):

$$\frac{dX}{dt} = \mu X\left(1 - \frac{X}{X_m}\right) \quad [21]$$

where: X, is the biomass concentration, μ, the specific growth rate; X_m, maximal concentration of biomass and X_0, is the initial biomass concentration.

3.2.2 Applications

The theoretical aspects of the rotating-drum bioreactors were applied for different enzymes production. Several successful stories have been reported for upscaling of enzyme production using rotating-drum bioreactors. In the early 19th century manufacture of amylase by *Aspergillus oryzae* on wheat bran, in rotating-drum bioreactors was scaled up to industrial level (Takamine, 1914). It reported the use of fuzzy logic control for amylase and protease enzymes production by *A. oryzae*. That fuzzy logic control system as a scale-up aspect exhibited the highest enzyme activity (Sukumprasertsri et al., 2013). While using the same microorganism, the scale up on a pilot-scale was realized and concerned the oxygen uptake and agitation. Achievement in terms of O_2 utilization was better at 9 rpm than at 2 rpm. This was apparently as a result of the effect of the rotational speed on the performance of the stirring inside the bed (Stuart, 1996). A comparative study was attempted by Alam et al. (2009) for the production of cellulase enzyme in both Erlenmeyer flask (500 mL) and a horizontal rotating-drum bioreactor (50 L) by using empty fruit bunches as substrate. It was observed that the highest cellulase activity on the fourth day of fermentation in the 500 mL flask was 8.2 filter paper activity (FPA)/gram dry solids (gds) of empty fruit bunches, while the same was 10.1 FPA/gds for rotating-drum bioreactor on the second day of fermentation.

3.3 Traditional and Zymotis packed-bed bioreactors models

The scale up purpose for this bioreactor assumes that the traditional packed-bed bioreactor is a cylindrical unit which is aerated with humid air from the bottom (Fig. 2). The humid packed-bed (substrate) is then inoculated and introduced in the unit and that time is considered as zero with no agitation (static bed) (Mitchell et al., 1999; Mitchell et al., 2003). In the *Zymotis* packed-bed bioreactor (Fig. 3) which was modelled by Mitchell and Von-Mein (2000), the heat transfer is realized in two directions (the horizontal direction is normal to air flow direction and the direction

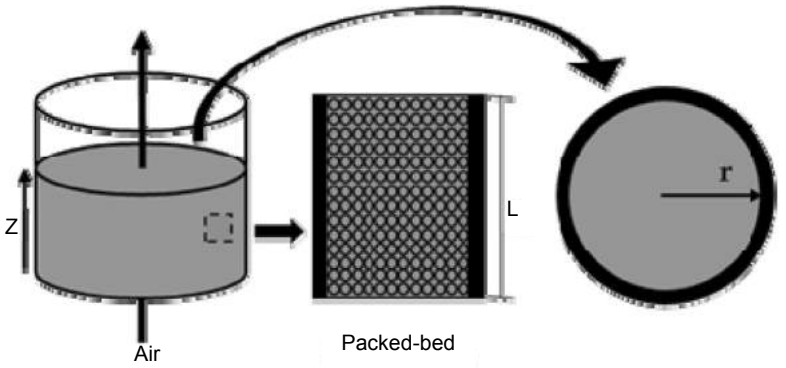


Figure 2. Traditional packed-bed bioreactor.

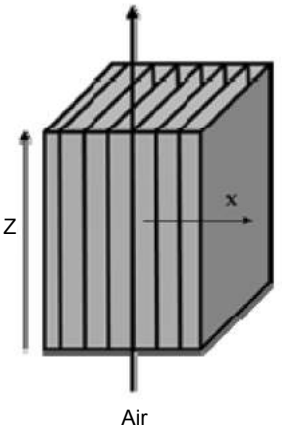


Figure 3. *Zymotis* packed-bed bioreactor.

which is co-linear to air flow exhibiting the removal of evaporative and convective heat). The front-to-back gradients are considered negligible (Mitchell et al., 2003).

3.3.1 Microbial growth

The logistic equation is used to express the kinetic growth of the biomass for both packed-bed and is as follows (Mitchell et al., 1999):

$$\frac{dX}{dt} = \mu X\left(1 - \frac{X}{X_m}\right) \qquad [22]$$

The packed-bed bioreactor presents a limitation on the height of the bed which can reduce significantly the performance. That bed height limit is not constant and varies with the microbe growth rate and superficial air velocity (Mitchell et al., 1999).

3.3.2 Applications

Successful upscaling applications for enzyme production were carried out using packed-bed bioreactor. The production of pectinase was scaled up from 12 g to 30 kg of dry substrate; the best outcome was achieved with a 40-cm high bed having 27 kg of wheat bran and 3 kg of sugarcane bagasse (Pitol et al., 2016). The manufacture of lipase from *Penicillium simplicissimum* was performed also in packed-bed bench-scale bioreactors and the scale up regarding the yield of the enzyme was profitably completed by adjusting the temperature and air circulation rate in the bioreactor, utilizing bagasse and sugarcane molasses (6.25 per cent). The highest lipase activity reached 26.4 U/g at 27°C and a flow rate of 0.8 L/min (Cavalcanti et al., 2005). Also, a model has been established with *N*-tanks in the series approach as a scale up for a packed-bed bioreactor, using solid-state fermentation. The model investigated the production of protease enzyme applying *A. niger* and was confirmed across experimental research accessible in literature (Sahir et al., 2007). Similarly, scale up was realized in a laboratory packed-bed bioreactor to obtain α-amylase from *Bacillus* sp. KR-8104 using SSF by prospecting the control of temperature. Wheat bran (WB) was used as substrate. The coexisting impacts of aeration rate, initial humidity of substrate and temperature incubation on α-amylase manufacture were checked out. The optimum circumstances in which the maximum α-amylase production was attained were 37°C, 72 per cent (w/w) initial substrate humidity and 0.15 L/min aeration. The typical enzyme activity reached under best conditions was 473.8 U/g dry substrate (Derakhti et al., 2012). In another study, α-amylase production by *Bacillus amyloliquefaciens* was executed in 300 mL and 3 L packed-bed bioreactors working volume. The observations pointed out high rates of aeration demand to boost enzyme yield. That yield exhibited a linear relationship with air flow rate. The highest activity of 41.4 U/(mL·h) was attained in 14 hours of fermentation in 300-mL and a similar activity of 40 U/(mL·h) was reached after 12 hours in 3 L (Gangadharan et al., 2011).

3.4 Intermittently-mixed forcefully-aerated bioreactor

The bioreactor is advantageous over the packed-bed bioreactors as it is relatively simple to add water uniformly to the substrate (Mitchell et al., 2006). In this type of bioreactor (Fig. 4), two types of behaviors are to be considered—the static and mixing systems (Durand and Chereau, 1988; Xue et al., 1992; Chamielec et al., 1994; Agosin et al., 1997; Bandelier et al., 1997). The packed-bed system is assumed to be the one observed during the static phase. Other assumptions are: the heat transfer from the wall is negligible so that the heat and mass transfer are in one direction (axial); the solid and air are not in thermal and moisture equilibrium. No degradation of microorganism growth is included in the model (Mitchell et al., 2003; Von-Meien and Mitchell, 2002; Mitchell et al., 2006).

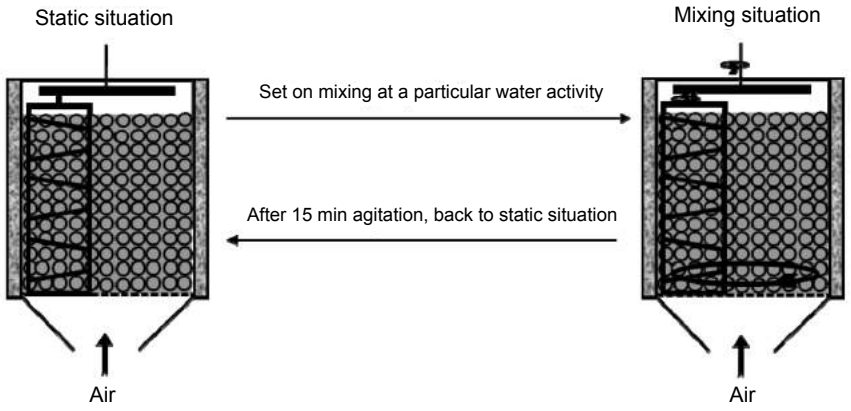


Figure 4. Intermittently-mixed forcefully-aerated bioreactor.

The calculation of changes in the solid and liquid phase takes into consideration the driving forces, when the mass and heat transfer balanced equation is presented. Since the temperature and the water activity affect the microbial growth, the models are used to calculate the water activity of the solid, using its water content and temperature.

3.4.1 Microbial growth

The microbial growth is written as (Mitchell et al., 2003; Von-Meien and Mitchell, 2002; Mitchell et al., 2006):

$$\frac{\partial X}{\partial t} = \mu X\left(1 - \frac{X}{X_m}\right) \qquad [23]$$

The consumption of solid during microbial fermentation can be expressed as follows (Von-Meien and Mitchell, 2002; Mitchell et al., 2006):

$$\frac{\partial M_s}{\partial t} = \left[1 - \frac{1}{Y_s}\right]\frac{\partial\left(XM_s\right)}{\partial t} \qquad [24]$$

3.4.2 Applications

An intermittent spouting with air-bed bioreactor was developed to produce enzymes from rice substrate using *A. oryzae*. The enzyme production was realized in a large scale. The scaling up was to overcome problems like mass transfer, heat transfer and solid handling. High levels of α-amylase, β-amylase and glucoamylase were obtained. It was noticed that an increase of spouting frequency decreased enzyme production (Silva and Yang, 1998). The production of β-mannanase from palm kernel cake was scaled up in a laboratory glass-column bioreactor (consisting of a jacketed vessel with a height of 50 cm, an inner diameter of 16 cm and loaded with 100 g of palm kernel cake) in terms of maximizing the yield. The optimal conditions from the model stated that for the highest level of β-mannanase, the incubation temperature must be 32°C,

initial humidity 59 per cent and aeration 0.5 L/min. This allowed β-mannanase activity of 2231.26 U/g (Abdeshahian et al., 2010).

3.5 Well-mixed bioreactor

In a well-mixed bioreactor, no concentration gradients are observed either in gas or in liquid phase. The assumptions made for the well-mixed bioreactor are: it is cylindrical, with water-jacketed on its sides (Fig. 5); the microbial growth is considered as a logistic equation, with specific growth rate constant affected by the water activity and the temperature of the particles; the gas and air phases are considered as different subsystems (Mitchell and Krieger, 2006).

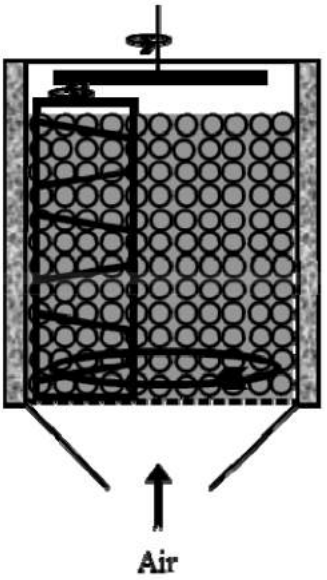


Figure 5. Well-mixed bioreactor.

The microbial growth, solid consumption, water and energy balances are treated here and the equations are written (Mitchell and Krieger, 2006; Von-Meien and Mitchell, 2002; dos-Santos et al., 2004; Marques et al., 2006):

3.5.1 Microbial growth

The logistic equation used for this bioreactor is:

$$\frac{dX}{dt} = \mu X\left(1 - \frac{X}{X_m}\right) \qquad [25]$$

The specific growth rate (fractional) can be influenced by water activity and is obtained by using the following equation:

$$\mu_{aw} = 1.0538 \exp\left(-131.6a_w^3 + 94.996a_w^2 + 214.219a_w - 177.668\right) \quad [26]$$

where: μ_{aw} is fraction of water activity dependence specific growth rate; a_w, water activity.

3.5.2 Applications

Like the other type of bioreactors, the well-mixed bioreactor was used and scaled up for the production of food enzymes. It was a low-cost process developed for apple pomace utilisation in order to obtain pectinolytic enzyme. That enzymes from *A. niger* as well as pectinesterase and polygalacturonase were studied. The scale-up process was from the laboratory tray bioreactor to a 15 L horizontal stirred bioreactor. Process specifications, such as inoculation, mixing, aeration, temperature and humidity on pectolytic enzymes production, were investigated. The highest quantities of 15 $g.kg^{-1}$ of substrate of polygalacturonase, 200 $mg.kg^{-1}$ pectinesterase at activity up to 900 AJDA U ml-1 of enzyme mixture was attained on an average (Berovic and Ostroversnik, 1997). Also, investigations were conducted on the manufacture of protease by slightly halophilic *Bacillus* sp. on agro-industrial waste. The optimal pH (7.0), temperature (30°C) and agitation rate (50 rpm) were found to be the best conditions for protease production during the scale-up fermentation (Prasad et al., 2014). Multiple isolates of *A. niger* were also screened from polluted oil soil samples and isolated for lipase production, using tributyrin medium. The lipase production was successfully scaled up on a 5 L pilot scale stirred fermenter, preserving expansion parameters at pH (7), temperature (28°C), stirring (120 rpm), airflow rate (30 L/hr), O_2 concentration (50 per cent) and pressure (0.05 MPa) (Rai et al., 2014). A model for a well-mixed bioreactor was also executed to investigate the problems that could occur on a large scale. It was suggested that, using high flow rate, up to 85 per cent of the enzyme obtained from the microorganism could be denatured by the end of fermentation, exhibiting the problems of large-scale well-mixed bioreactor (dos-Santos et al., 2004).

4. Limitations

Scale up, product purification and biomass estimation are major challenges that need to be established before SSF can become industrially viable. The reason for scale up is difficult because of transportation limitations within a large reactor. Other major problems encountered are control over different parameters, such as pH, temperature, aeration, oxygen transfer and moisture. Also the used microorganisms are limited as they grow in reduced levels of humidity. Lack of experimental data hampers parameter identification and thus a broader use of mathematical modelling is essential.

5. Conclusion and Future Perspectives

The current article critically discusses the upscaling, modelling, microbiology and biochemical aspects of solid-state fermentation for obtaining enzymes related to the food industry. In addition microbial enzymes are used for treatment in the food industry. Although much work has been done on solid-fermentation bioreactors, the important aspect is to explore the production of enzymes in these industries. Work on different kinetics in bioreactors needs to be investigated. Also, optimization of enzyme production can be one of the primary axes as the ability to obtain high yields within short intervals during fermentation in solid media has been recognized. There is another important research on enzymatic degradation of the substrates. Therefore, optimization of the physical parameters in bioreactors and appropriate kinetics are crucial. The continuous cultivation of microorganisms (using genetically modified strains) and high density culture of cells in order to produce food enzymes needs to be investigated as well as the scale-up bioreactor. More research is needed on physical techniques and computational approaches to allow better model validation and ensure progress in rational bioengineering of SSF.

Nomenclature

A	Area of heat transfer coefficient bioreactor wall	m^2
a_w	Water activity	
b_0, b_1, b_2	Constants	
M_s	Dry mass of substrate bed	kg
m_W	Water production maintenance coefficient	
S_0, S_1, S_2, S_3, S_4, S_5,	Constants	
t	Time	s
t_c	Contact time between substrate particles and wall	s
T_a	Air phase temperature	^oC
$T_{\max}$	Maximal temperature for growth	^oC
$T_{\min}$	Minimal temperature for growth	^oC
T_{opt}	Optimal growth temperature	^oC
X	Biomass concentration	$kg\ biomass/kg\ substrate$
X_0	Initial biomass concentration	$kg\ biomass/kg\ substrate$
X_{m}	Maximal concentration of biomass	
Y_{X}	Heat yield metabolic coefficient	$J/kg\ biomass$
μ	Specific growth rate	s^{-1}

contd....

contd....

μ_{aw}	Fraction of water activity dependence specific growth rate	s^{-1}
μ_{opt}	Optimal specific growth rate	s^{-1}
μ_T	Fraction of temperature dependence specific growth rate	s^{-1}
ρ_a	Air density	kg/m^3

References

Abdeshahian, P., Samat, N., Hamid, A.A. and Yusoff, W.M. 2010. Utilization of palm kernel cake for production of beta-mannanase by *Aspergillus niger* FTCC 5003 in solid substrate fermentation using an aerated column bioreactor. Journal of Industrial Microbiology and Biotechnology, 37(1): 103–109.

Agosin, E., Perez-Correa, R., Fernandez, M., Solar, I. and Chiang, L. 1997. An Aseptic Pilot Bioreactor for Solid Substrate Cultivation Processes. Dordrecht: Kluwer Academic Publishers, pp. 233.

Alam, M.Z., Mamun, A.A., Qudsieh, I.Y., Muyibi, S.A., Salleh, H.M. and Omar, N.M. 2009. Solid state bioconversion of oil palm empty fruit bunches for cellulase enzyme production using a rotary drum bioreactor. Biochemical Engineering Journal, 46(1): 61–64.

Bandelier, S., Renaud, R. and Durand, A. 1997. Production of gibberellic acid by fed-batch solid state fermentation in an aseptic pilot-scale reactor. Process Biochemistry, 32: 141–145.

Banks, G.T. 1984. Scale up of fermentation processes. pp. 170–266. *In*: A. Wiseman (ed.). Topics in Enzyme and Fermentation Biotechnology. Chichester: Ellis Horwood Limited.

Berovic, M. and Ostroversnik, H. 1997. Production of *Aspergillus niger* pectolytic enzymes by solid state bioprocessing of apple pomace. Journal of Biotechnology, 53(1): 47–53.

Bovill, R., Rew, J., Cook, N., D'Agostino, N., Wilkinson, N. and Baranyi, J. 2000. Predictions of growth for *Listeria* monocytogenes and *Salmonella* during fluctuation temperature. International Journal of Food Microbiology, 59(3): 157–165.

Cavalcanti, E.d'A.C., GutarraI, M.L.E., FreireI, D.M.G., dos Reis Castilho II, L. and Sant'Anna Júnior II, G.L. 2005. Lipase production by solid-state fermentation in fixed-bed bioreactors. Brazilian Archives of Biology and Technology, 48: 79–84.

Chamielec, Y., Renaud, R., Maratray, J., Almanza, S., Diezand, M. and Durand, A. 1994. Pilot-scale reactor for aseptic solid-state cultivation. Biotechnology Techniques, 8: 245–248.

Derakhti, S., Shojaosadati, S.A., Hashemi, M. and Khajeh, K. 2012. Process parameters study of α-amylase production in a packed-bed bioreactor under solid-state fermentation with possibility of temperature monitoring. Preparative Biochemistry and Biotechnology, 42(3): 203–216.

dos-Santos, M.M., da-Rosa, A.S., Dal'Boit, S., Mitchell, D.A. and Krieger, N. 2004. Thermal denaturation: Is solid-state fermentation really a good technology for the production of enzymes? Bioresource Technology, 93: 261–268.

Durand, A. and Chereau, D. 1988. A new pilot reactor for solid-state fermentation: Application to the protein enrichment of sugar beet pulp. Biotechnology and Bioengineering, 31: 476–486.

Fanaei, M.A. and Vaziri, B.M. 2009. Modelling of temperature gradients in packed-bed solid-state bioreactors. Chemical Engineering and Processing, 48(1): 446–451.

Gangadharan, D., Nampoothiri, M. and Pandey, A. 2011. Alpha-amylase produced by *B. amyloliquefaciens.* Food Technology and Biotechnology, 49(3): 336–340.

Ghildyal, N.P., Ramakrishna, S.V., Nirmala Devi, P., Lonsane, B.K. and Asthana, H.N. 1981. Large-scale production of pectolytic enzyme by solid state fermentation. Journal of Food Science and Technology, 18(6): 248–251.

Glenn, D.R. and Rogers, P.L. 1989. Industrialization of indigenous food processes: Technological aspects. *In*: K.H. Steinkraus (ed.). Industrialization of Indigenous Fermented Foods. New York: Marcel Dekker, Inc.

Holker, U. and Lenz, J. 2005. Solid-state fermentation: Are there any biotechnological advantages? Current Opinion in Microbiology, 8: 301–306.

Hashemi, M., Mousavi, S.M., Razavi, S.H. and Shojaosadati, S.A. 2011. Mathematical modelling of biomass and α-amylase production kinetics by *Bacillus* sp. in solid-state fermentation based on solid dry weight variation. Biochemical Engineering Journal, 53: 159–164.

Kossen, N.W.F. and Oosterhuis, N.M.G. 1985. Modelling and scaling up of bioreactors. pp. 572–605. *In*: H.-J. Rehm and G. Reed (eds.). Biotechnology. Weinheim: VCH.

Lonsane, B.K., Saucedo-Castaneda, G., Raimbault, M., Roussos, S., Viniegra-González, G., Ghildyal, N.P., Ramakrishna, M. and Krishnaiah, M.M. 1992. Scale-up strategies for solid-state fermentation systems. Process Biochemistry, 27: 259–270.

Marques, C.B., Barga, M.C., Balmant, W., Luz-Jr, L.F., Krieger, N. and Mitchell, D.A. 2006. A model of the effect of the microbial biomass on the isotherm of the fermenting solids in solid-state fermentation. Food Technology and Biotechnology, 44(4): 457–463.

Mitchell, D.A., Berovic, M. and Krieger, N. 2006. Solid-state Bioreactors. Germany: Springer-Verlag Berlin Heidelberg.

Mitchell, D.A. and Krieger, N. 2006. A model of a well-mixed SSF bioreactor. pp. 295–314. *In*: D.A. Mitchell, N. Krieger and M. Berovic (eds.). Solid-State Fermentation Bioreactors: Fundamentals of Design and Operation. Germany: Springer-Verlag Berlin, Heidelberg.

Mitchell, D.A., Pandey, A., Sangsurasak, P. and Krieger, N. 1999. Scale-up strategies for packed-bed bioreactors for solid-state fermentation. Process Biochemistry, 35: 167–178.

Mitchell, D.A., Krieger, N., Stuart, D.M. and Pandey, A. 2000. New developments in solid-state fermentation. II. Rational approaches to the design, operation and scale-up of bioreactors. Process Biochemistry, 35: 1211–1225.

Mitchell, D.A., Tongta, A., Stuart, D.M. and Krieger, N. 2002. The potential for establishment of axial temperature profiles during solid-state fermentation in rotating drum bioreactors. Biotechnology and Bioengineering, 80(1): 114–122.

Mitchell, D.A. and Von-Meien, O.F. 2000. Mathematical modelling as a tool to investigate the design and operation of the *Zymotis* packed-bed bioreactor for solid-state fermentation. Biotechnology and Bioengineering, 68(2): 127–135.

Mitchell, D.A., Von-Meien, O.F. and Krieger, N. 2003. Recent developments in modeling of solid-state fermentation: Heat and mass transfer in bioreactors. Biochemical Engineering Journal, 13: 137–147.

Mitchell, D.A., Von-Meien, O.F., Krieger, N. and Dalsenter, F.D.H. 2004. A review of recent developments in modelling of microbial growth kinetics and intraparticle phenomena in solid-state fermentation. Biochemical Engineering Journal, 17: 15–26.

Mitchell, D.A., Von-Meien, O.F., Luiz, F.L., Luz, Jr. and Krieger, N. 2006. A model of an intermittently-mixed forcefully-aerated bioreactor. pp. 349–362. *In*: D.A. Mitchell, N. Krieger and M. Berovic (eds.). Solid-state Fermentation Bioreactors: Fundamentals of Design and Operation. Germany: Springer-Verlag Berlin Heidelberg.

Okazaki, N., Sugama, S. and Tanaka, T. 1980. Mathematical model for surface culture of Koji mold: Growth of Koji mold on the surface of steamed rice grains (IX). Journal of Fermentation Technology, 58(5): 471–476.

Oosterhuis, N.M.G., Kossen, N.W.F., Oliver, A.P.C. and Schenk, E.S. 1985. Scale-down and optimisation studies of the gluconic acid fermentation by *Gluconobacter oxydans*. Biotechnolgy and Bioengineering, 27: 711–720.

Panda, S.K. and Ray, R.C. 2015. Microbial processing for valorization of horticultural wastes. pp. 203–221. *In*: L.B. Sukla, N. Pradhan, S. Panda and B.K. Mishra (eds.). Environmental Microbial Biotechnology. Springer International Publishing.

Panda, S.K., Mishra, S.S., Kayitesi, E. and Ray, R.C. 2016. Microbial-processing of fruit and vegetable wastes for production of vital enzymes and organic acids: Biotechnology and scopes. Environmental Research, 146: 161–172.

Pandey, A. 2003. Solid-state fermentation. Biochemical Engineering Journal, 13(2-3): 81–84.

Pitol, L.O., Biz, A., Mallmann, E., Krieger, N. and Mitchell, D.A. 2016. Production of pectinases by solid-state fermentation in a pilot-scale packed-bed bioreactor. Chemical Engineering Journal, 283: 1009–1018.

Prasad, R., Abraham, T.K. and Nair, A.J. 2014. Scale up of production in a bioreactor of a halotolerant protease from moderately halophilic *Bacillus* sp. isolated from soil. Brazilian Archives of Biology and Technology, 57(3): 448–455.

Rai, B., Shrestha, A., Sharma, S. and Joshi, J. 2014. Screening, optimization and process scale up for pilot scale production of lipase by *Aspergillus niger*. Biomedicine and Biotechnology, 2(3): 54–59.

Ratkowsky, D.A., Lowry, R.K., McMeekin, T.A., Stokes, A.N. and Chandler, R.E. 1983. Model for bacterial culture growth rate throughout the entire biokinetic temperature range. Journal of Bacteriology, 154(3): 1222–1226.

Rodríguez-Fernández, D.E., Rodríguez-León, J.A., De Carvalho, J.C., Sturm, W. and Soccol, C.R. 2011. The behavior of kinetic parameters in production of pectinase and xylanase by solid-state fermentation. Bioresource Technology, 102(22): 10657–10662.

Roussos, S., Raimbault, M., Prebois, J.P. and Lonsane, B.K. 1993. *Zymotis*, a large-scale solid-state fermentation: Design and evaluation. Applied Biochemistry and Biotechnology, 42: 37–52.

Sahir, A.H., Kumar, S. and Kumar, S. 2007. Modelling of a packed bed solid-state fermentation bioreactor using the *N*-tanks in series approach. Biochemical Engineering Journal, 35(1): 20–28.

Saucedo-Castaneda, G., Gutierrez-Rojas, M., Bacquet, G., Raimbault, M. and Viniegra-Gonzalez, G. 1990. Heat transfer simulation in solid-substrate fermentation. Biotechnolgy and Bioengineering, 35(8): 802–808.

Saxena, S. 2015. Microbial enzymes and their industrial applications. pp. 121–154. *In*: Applied Microbiology. Springer India.

Soccol, C.R., Iloki, I., Marin, B. and Raimbault, M. 1994. Comparative production of alpha-amylase, glucoamylase and protein enrichment of raw and cooked cassava by Rhizopus strains in submerged and solid-state fermentations. Journal of Food Science and Technology, 31: 320–323.

Silva, E.M. and Yang, S.T. 1998. Production of amylases from rice by solid-state fermentation in a gas-solid spouted-bed bioreactor. Biotechnology Progress, 14(4): 580–587.

Sosa, D., Boucourt, R. and Dustet, J.C. 2012. Use of mathematical modeling on the solid-state fermentation processes of fibrous substrates for animal feeding. Cuban Journal of Agricultural Science, 46(2): 119–126.

Stuart, D.M. 1996. Solid-state Fermentation in Rotating Drum Bioreactor. Ph.D thesis, The University of Queensland, Queensland.

Sukumprasertsri, Monton, Unrean, P., Pimsamarn, J., Kitsubun, P.S. and Tongta, A. 2013. Fuzzy logic control of rotating-drum bioreactor for improved production of amylase and protease enzymes by *Aspergillus oryzae* in solid-state fermentation. Journal of Microbiology and Biotechnology, 23(3): 335–342.

Takamine, J. 1914. Enzymes for *Aspergillus oryzae* and the application of its amyloclastic enzyme to the fermentation industry. Industrial and Engineering Chemistry, 6: 824–828.

Trilli, A. 1986. Scale up of fermentation. pp. 227–307. *In*: A.L. Demain and N.A. Solomon (eds.). Industrial Microbiology and Biotechnology. Washington, USA: American Society of Microbiology.

Von-Meien, O.F. and Mitchell, D.A. 2002. A two-phase model for water and heat transfer within an intermittently-mixed solid-state fermentation bioreactor with forced aeration. Biotechnology and Bioengineering, 79: 416–428.

Wang, E.-Q., Li, S.-Z., Tao, L., Geng, X. and Li, T.-C. 2010. Modeling of rotating-drum bioreactor for anaerobic solid-state fermentation. Applied Energy, 87: 2839–2845.

Weber, F.J., Oostra, J., Tramper, J. and Rinzema, A. 2002. Validation of a model for process development and scale-up of packed-bed solid-state bioreactors. Biotechnology and Bioengineering, 77(4): 381–393.

Xue, M., Liu, D., Zhang, H., Hongyan, Q. and Lei, Z. 1992. A pilot process of solid-state fermentation from sugar beet pulp for the production of microbial protein. Journal of Fermentation and Bioengineering, 73: 203–220.

[1] Department of Food Process and Quality Control, University Institute of Technology of the University of Ngaoundere, P.O. Box 455, Ngaoundere, Cameroon.
[2] Department of Biodiversity and Conservation of Natural Resources, Central University of Orissa, Koraput-764020.
E-mail: swatisakambarimishra@gmail.com
[3] Department of Metallurgy, Faculty of Engineering and the Built Environment, University of Johannesburg, P.O. Box 17911, Doornfontein Campus, 2028, Johannesburg, South Africa.
E-mail: skbehera2020@gmail.com
[4] Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein Campus, Johannesburg, South Africa.
E-mail: sandeeppanda2212@gmail.com
* Corresponding author: desobgo.zangue@gmail.com

Résumé du livre

Microbial Enzyme Technology in Food Applications

Chapter 25: Scaling-up and Modelling Applications of Solid State Fermentation and Demonstration in Microbial Enzyme Production Related to Food Industries: An Overview

Steve C. Z. Desobgo*, Swati S. Mishra, Sunil K. Behera and Sandeep K. Panda

Summary of the book

The aim of food processing is to produce food that is palatable and tastes good, extend its shelflife, increase the variety, and maintain the nutritional and healthcare quality of food. To achieve favorable processing conditions and for the safety of the food to be consumed, use of food grade microbial enzymes or microbes (being the natural biocatalysts) is imperative. This book discusses the uses of enzymes in conventional and non-conventional food and beverage processing as well as in dairy processing, brewing, bakery and wine making. Apart from conventional uses, the development of bioprocessing tools and techniques have significantly expanded the potential for extensive application of enzymes such as in production of bioactive peptides, oligosaccharides and lipids, flavor and colorants. Some of these developments include extended use of the biocatalysts (as immobilized/encapsulated enzymes), microbes (both natural and genetically modified) as sources for bulk enzymes, solid state fermentation technology for enzyme production. Extremophiles and marine microorganisms are another source of food grade enzymes. The book throws light on potential applications of microbial enzymes to expand the base of food processing industries.

IV.4.6) Derivation and Application of a Simultaneous Volatile Formation and Stripping Kinetics Equation for Wort Boiling

Titre de la revue

American Society of Brewing Chemists
FREE ACCESS

Comité de lecture

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, pleas
contact our customer service department to purchase a subscription.

Journal

Journal of the American Society of Brewing Chemists ›
The Science of Beer

This journal

Editorial board

Editor-in-Chief
Inge Russell

Editorial Board
G. Aerts
R. Agu
P. Aldred
M. Andersen
P. Aron
C. Boulton
S. Britton
D. Cook
C. Curtin
S. Deckers
J. De Clippeleer
S. Duke
A. Egi
R. Foster
L. Garbe
C. Henson

A. Hill
J. Hort
N. Kageyama
M. Kanauchi
S. Lawrence
Q. Li
B. Lodolo
A. Macintosh
D. Maskell
C. Powell
G. Sanchez
D. Sedin
S. Serna-Saldivar
T. Shellhammer
J. Sheppard
A. Speers
D. Stewart
E. Storgards
L. Van Nedervelde
K. Verstrepen
D. Vollmer
G. Walker
D. Wang
H. Wedler
X. Yin
M. Zarnkow
B. Ziola

Publisher
Amy L. Hope

Director of Publications
Greg Grahek

Technical Editor

Carol Duling

Circulation Coordinator

Dawn Wuest

Table des matières

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, please contact our customer service department to purchase a subscription.

Journal of the American Society of Brewing Chemists

The Science of Beer

2017 Impact Factor
0.880

Publish open access in this journal

Advanced search

Submit an article | New content alerts | RSS | Citation search

Current issue | Browse list of issues

Official Journal of the American Society of Brewing Chemists

This journal

Investigations into the Transfer Rate of Volatile Compounds in Dry Hopping using an Ethanol-Water Partition Coefficient Model

Published online: 6 Jul 2018

Kirkendall et al.

Published online: 11 Jun 2018

Control of Fermentation By-Products and Aroma Features of Beer Pr... with Sc... Ale Yeast by Variation of Fermentation Temperature and Wort Aeration Rate

Published online: 7 Jun 2018

Analysis of Physicochemical Indices, Volatile Flavor Components, and Microbial Community of a Light-Flavor *Daqu*

Published online: 29 Mar 2018

See all volumes and issues

Vol 76, 2018 | Volume 75, 2017 | Vol 74, 2...ed

Issue 4 | Issue 3 | Issue 2 | Issue 1

Original Articles

Article

High Phenolic Beer Inhibits Protein Glycation in Vitro

Susan M. Elrod, Phillip Greenspan & Erik H. Hofmeister

Pages: 1-5

Published online: 05 Feb 2018

4 Views | 0 CrossRef citations | 0 Altmetric

Article

Mosaic (HBC 369): A New Flavor Hop Variety

Gene Probasco, Jason Perrault, Scott Varnum & David Hysert

Pages: 6-10

Published online: 05 Feb 2018

12 Views | 0 CrossRef citations | 0 Altmetric

Article

Derivation and Application of a Simultaneous Volatile Formation and Stripping Kinetics Equation for Wort Boiling

Z. S. C. Desobgo, R. A. Stafford & D. J. A. Metcalfe

Pages: 11-21

Published online: 05 Feb 2018

5 Views | 1 CrossRef citations | 0 Altmetric

Article

Aroma Properties of Lager Beer Dry-Hopped with Oxidized Hops ›

Daniel M. Vollmer, Victor Algazzali & Thomas H. Shellhammer

Pages: 22-26

Published online: 05 Feb 2018

15 Views | 1 CrossRef citations | 0 Altmetric

Article

Influence of Ethyl Esters, Oxygenated Terpenes, and Aliphatic γ- and δ-Lactones ($C_{9–12}$) on Beer Fruit Aroma ›

Rachel A. Hotchko & Thomas H. Shellhammer

Pages: 27-34

Published online: 05 Feb 2018

15 Views | 1 CrossRef citations | 0 Altmetric

Note

Note

Advancing Flavor Stability Improvements in Different Beer Types Using Novel Electron Paramagnetic Resonance Area and Forced Beer Aging Methods ›

Laura Marques, Maydelin Hernandez Espinosa, William Andrews & Robert T. Foster II

Pages: 35-40

Published online: 05 Feb 2018

7	0	0
Views	CrossRef citations	Altmetric

Original Articles

Article

Hop Constituents Suppress the Formation of 3-Methylbutanal and 2-Furfural in Wort-Like Model Solutions ›

Philip C. Wietstock, Matthias Baldus, Magdalena Öhlschläger & Frank-Jürgen Methner

Pages: 41-51

Published online: 05 Feb 2018

9	0	0
Views	CrossRef citations	Altmetric

Article

Volatility of Benzaldehyde in Water/Wort ›

Hans Scheuren & Karl Sommer

Pages: 52-57

Published online: 05 Feb 2018

3	0	0
Views	CrossRef citations	Altmetric

Acknowledgements

Acknowledgment of *ASBC Journal* Referees for 2016 ›

Page: 58

Published online: 05 Feb 2018

1	0	0
Views	CrossRef citations	Altmetric

Pages de l’article

Derivation and Application of a Simultaneous Volatile Formation and Stripping Kinetics Equation for Wort Boiling

Z. S. C. Desobgo,[1] R. A. Stafford, and D. J. A. Metcalfe, *Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein, Johannesburg 2028, South Africa*

ABSTRACT

J. Am. Soc. Brew. Chem. 75(1):11-21, 2017

The paper showed the derivation of an equation to represent simultaneous dimethyl sulfide (DMS) formation and stripping during wort boiling. It also demonstrated a framework of linearization techniques for the resulting equation, which should facilitate its implementation. DMS formation and stripping were modelled by first-order rate equations with the rate constants k_1 and k_2 representing the rate constants for rate of DMS formation and DMS removal via stripping, respectively. The simultaneous processes of DMS formation and stripping were represented using an instantaneous differential mass balance. The resulting solution was seen to be similar to an equation stated previously by Mitani et al. Linearization of the derived simultaneous DMS formation and stripping model was done using a MacLaurin series coming from Taylor's series expansion.

Keywords: Dimethyl sulfide, *S*-Methylmethionine, Wort boiling, Volatile formation, Volatile stripping, Nonlinear MacLaurin series

Dimethyl sulfide (DMS) is a standout among the most critical off-flavors in the mashing process (1–3,6,12,16,21,26,30); the stripping of that unstable volatile is an exceptionally complex procedure, and it is made of two synchronous reactions, which are the change of *S*-methylmethionine (SMM) into DMS and its stripping (5,17). That difficult circumstance created numerous sorts of methodologies as far as boiling vessels and equations so as to handle disposal of DMS (8–11,19,20,23,24,27,28). For that reason, the principal model known for DMS stripping is the one of Mitani et al. (23,24), which is of a nonlinear form. Such nonlinear models are frequently linearized to ease implementation.

In this work, the detailed derivation of a simultaneous DMS formation and stripping model is described, and the final nonlinear model is compared with the model stated by Mitani et al. (23) and found to be identical in form. To facilitate implementation, linearization of the nonlinear model was conducted using a MacLaurin–Taylor series expansion.

EXPERIMENTAL

Derivation of a DMS Stripping Model

In these methods differential equations that gave the conversion of SMM to DMS and DMS stripping with time ($d[SMM]/dt$ and $d[DMS]/dt$) were integrated to give a rate equation that followed the concentration of SMM or DMS elimination (stripping) as a function of time.

MacLaurin Series Approach for SMM and DMS Nonlinear Models

The MacLaurin series (which is a particular Taylor series when $x_0 = 0$) is utilized to approximate infinitely differentiable nonlinear equations. The MacLaurin polynomial function is built up according to the derivatives of the SMM and DMS functions at a 0. The main idea behind the MacLaurin series is as follows: Derivatives, practically speaking, correlate to the contour of a curve, so the higher derivatives that two models have similarly at one point (0), the more comparable they appear at other nearby points (7,22). MacLaurin series are essential because they permit the figuring out of models that could not be computed directly or are difficult to handle. Although the MacLaurin polynomial for the exponential model seems confusing and irritating, it can be reduced to addition, subtraction, multiplication, and division. One can acquire an estimate of the original function by truncating the infinite MacLaurin series into a limited-degree MacLaurin polynomial, which can be assessed.

Determination of Constants: $[SMM]_{t=0}$, $[DMS]_{t=0}$, k_1, and k_2

The methodology consists of, on the first hand (for each case, SMM and DMS), determining the best polynomial equation that correlates the experimental data. For each case, the obtained polynomial equation allows the determination of $[SMM]_{t=0}$ and $[DMS]_{t=0}$ via its constant. The constant value of the derivate polynomial equation for each case permits the calculation of k_1 and k_2.

RESULTS AND DISCUSSION

Derivative Approach of Establishing DMS Stripping Model

Most chemical reactions take place in several stages; that is to say they evolve by successive elementary chemical reactions in which each step has its own rate with respect to time. DMS elimination from wort can also be considered the result of two consecutive irreversible reactions (namely, SMM conversion into DMS and thereafter DMS volatilization). The rate of each reaction can be considered to be concentration dependent, and more specifically as a first-order reaction, in which the rate of progress of each reaction with respect to time is proportional to the concentration of the reactant, where the constant of proportionality (k) is termed the reaction rate coefficient (31). These consecutive reactions are presented as follows: $SMM \xrightarrow{k_1} DMS \xrightarrow{k_2} DMS^{evap}$, where k_1 is the reaction rate coefficient of SMM conversion to DMS and k_2 is the volatilization rate coefficient of DMS,

Considering the depletion of SMM as a first-order reaction, where the concentration of SMM at any time t, denoted as $[SMM]_t$ is proportional to the concentration of SMM,

$$-\frac{d[SMM]_t}{dt} = k_1[SMM]_t^1 = k_1[SMM]_t \quad (1)$$

The negative sign is owing to depletion, and the first-order refers to the power index = 1.

Because the DMS produced, which is denoted $[DMS]_t^{prod}$, increases with time and is also proportional to the concentration of SMM, it is then expressed with a positive as follows:

$$\frac{d[DMS]_t^{prod}}{dt} = k_1[SMM]_t^1 = k_1[SMM]_t \quad (2)$$

[1] Corresponding author. Phone: +27725061322. E-mail: desobgo.zangue@gmail.com

http://dx.doi.org/10.1094/ASBCJ-2017-1688-01

© 2017 American Society of Brewing Chemists, Inc.

The reaction conditions are as follows:

$$\begin{array}{lccccc} t=0 & [SMM]_{t=0} & \longrightarrow & 0 & \longrightarrow & 0 \\ t=t & [SMM]_t & \xrightarrow{k_1} & [DMS]_t & \xrightarrow{k_2} & [DMS]_t^{evap} \\ t=\infty & 0 & \longrightarrow & 0 & \longrightarrow & [SMM]_{t=0} \end{array}$$

where $[SMM]_{t=0}$ is the initial SMM concentration, before the boiling stage.

In a similar way to $[DMS]_t^{prod}$, the concentration of volatized DMS, denoted as $[DMS]_t^{evap}$, increases with time and is proportional to the concentration of DMS. It is then expressed with as positive sign as follows:

$$\frac{d[DMS]_t^{evap}}{dt} = k_2[DMS]_t^1 = k_2[DMS]_t \tag{3}$$

The rate of $[DMS]_t$ remaining in the wort owing to the consecutive reactions is expressed as the difference between the rate of SMM conversion to DMS and the rate of DMS volatilized denoted $[DMS]_t^{evap}$:

$$\begin{aligned} \frac{d[DMS]_t}{dt} &= \frac{d[DMS]_t^{prod}}{dt} - \frac{d[DMS]_t^{evap}}{dt} \\ &= k_1[SMM] - k_2[DMS] \end{aligned} \tag{4}$$

With respect to the mass balance, the initial concentration of SMM, denoted $[SMM]_{t=0}$, can be expressed at any time as follows:

$$[SMM]_t + [DMS]_t + [DMS]_t^{evap} = [SMM]_{t=0} \tag{5}$$

Rearranging equation 1 gives

$$\frac{d[SMM]_t}{[SMM]_t} = -k_1 dt \tag{6}$$

By integrating both sides of equation 5 we get

$$\begin{aligned} \int_{[SMM]_{t=0}}^{[SMM]_t} \frac{d[SMM]_t}{[SMM]_t} = -\int_0^t k_1 dt \Rightarrow \int_{[SMM]_{t=0}}^{[SMM]_t} \frac{1}{[SMM]_t}\, d[SMM]_t \\ = -\int_0^t k_1 dt \end{aligned} \tag{7}$$

where $[SMM]_{t=0}$ is the initial SMM concentration, before the boiling stage.

After completing integration and from the law of logarithms we obtain

$$\begin{aligned} \ln[SMM]_t - \ln[SMM]_{t=0} = -k_1 t \Rightarrow \ln\left(\frac{[SMM]_t}{[SMM]_{t=0}}\right) \\ = -k_1 t \end{aligned} \tag{8}$$

A transformation of the equation 8 gives

$$\begin{aligned} \ln\left(\frac{[SMM]_t}{[SMM]_{t=0}}\right) = -k_1 t \Leftrightarrow \exp\left(\ln\left(\frac{[SMM]_t}{[SMM]_{t=0}}\right)\right) \\ = \exp(-k_1 t) \end{aligned} \tag{9}$$

When simplifying equation 9, the rate law becomes

$$\begin{aligned} \frac{[SMM]_t}{[SMM]_{t=0}} = \exp(-k_1 t) \Rightarrow [SMM]_t \\ = [SMM]_{t=0}\exp(-k_1 t) \end{aligned} \tag{10}$$

To determine $[DMS]_t$ remaining in the system during the two consecutive reactions, equation 4 is used. After rearranging that equation, the relation obtained is as follows:

$$\begin{aligned} \frac{d[DMS]_t}{dt} &= k_1[SMM]_t - k_2[DMS]_t \\ \Rightarrow \frac{d[DMS]_t}{dt} &+ k_2[DMS]_t = k_1[SMM]_t \end{aligned} \tag{11}$$

Substituting the expression for $[SMM]_t$, equation 10, into equation 11 gives

$$\frac{d[DMS]_t}{dt} + k_2[DMS]_t = k_1[SMM]_{t=0}\exp(-k_1 t) \tag{12}$$

Let us consider the following relation in order to understand and use equation 12:

$$\frac{d}{dt}\left([DMS]_t \exp(k_2 t)\right) \tag{13}$$

Recall that mathematical calculus states

$$\begin{aligned} \frac{d}{dx}\left[f(x)\exp(g(x))\right] &= \exp(g(x))\frac{d}{dx}(f(x)) \\ &+ f(x)\frac{d}{dx}(\exp(g(x))) \end{aligned} \tag{14}$$

So equation 13 can be rewritten as

$$\begin{aligned} \frac{d}{dt}\left([DMS]_t \exp(k_2 t)\right) &= \exp(k_2 t)\frac{d[DMS]_t}{dt} \\ &+ [DMS]_t \frac{d}{dt}(\exp(k_2 t)) \end{aligned} \tag{15}$$

Then, we obtain from equation 15 the following relation:

$$\begin{aligned} \exp(k_2 t)\frac{d[DMS]_t}{dt} + [DMS]_t \frac{d}{dt}(\exp(k_2 t)) \\ = \exp(k_2 t)\frac{d[DMS]_t}{dt} + k_2[DMS]_t \exp(k_2 t) \end{aligned} \tag{16}$$

Finally, it can be written as

$$\begin{aligned} \frac{d}{dt}\left([DMS]_t \exp(k_2 t)\right) &= \exp(k_2 t)\frac{d[DMS]_t}{dt} \\ &+ k_2[DMS]_t \exp(k_2 t) \end{aligned} \tag{17}$$

By distributing $\exp(k_2 t)$ in equation 17, we get the following:

$$\frac{d}{dt}\left([DMS]_t \exp(k_2 t)\right) = \exp(k_2 t)\left(\frac{d[DMS]_t}{dt} + k_2[DMS]_t\right) \tag{18}$$

Considering the right hand-side of equation 18 only, and substituting the result of equation 12 for the term within the large brackets gives

$$\exp(k_2 t)\left(\frac{d[DMS]_t}{dt}+k_2[DMS]_t\right)=k_1[SMM]_{t=0}\exp(-k_1 t)\exp(k_2 t) \quad (19)$$

By rearranging equation 19, we have

$$\exp(k_2 t)\left(\frac{d[DMS]_t}{dt}+k_2[DMS]_t\right)=k_1[SMM]_{t=0}\exp\left((k_2-k_1)t\right) \quad (20)$$

Substituting equation 20 into equation 18 gives

$$\frac{d}{dt}\left([DMS]_t\exp(k_2 t)\right)=k_1[SMM]_{t=0}\exp\left((k_2-k_1)t\right) \quad (21)$$

Rearranging equation 21 gives

$$d\left([DMS]_t\exp(k_2 t)\right)=k_1[SMM]_{t=0}\exp\left((k_2-k_1)t\right)dt \quad (22)$$

Integrating both sides, we obtain the following relation:

$$\int_0^{[DMS]_t\exp(k_2 t)} d\left([DMS]_t\exp(k_2 t)\right)=k_1[SMM]_{t=0}\int_0^t\exp\left((k_2-k_1)t\right)dt \quad (23)$$

(Note that the lower limit of the left-hand integral at $t = 0$ reduces to 0.)

Continuing on, we know that

$$\begin{aligned}\int_0^{[DMS]_t\exp(k_2 t)} d\left([DMS]_t\exp(k_2 t)\right)&=\left[[DMS]_t\exp(k_2 t)\right]_0^{[DMS]_t\exp(k_2 t)}\\&=[DMS]_t\exp(k_2 t)\end{aligned} \quad (24)$$

We know also that

$$\begin{aligned}\int_0^t\exp\left((k_2-k_1)t\right)dt&=\left[\frac{1}{(k_2-k_1)}\exp\left((k_2-k_1)t\right)\right]_0^t\\&=\left(\frac{1}{(k_2-k_1)}\left[\exp\left((k_2-k_1)t\right)-1\right]\right)\end{aligned} \quad (25)$$

After combining equations 24 and 25 with equation 23, we can then write

$$[DMS]_t\exp(k_2 t)=k_1[SMM]_{t=0}\left(\frac{1}{(k_2-k_1)}\left[\exp\left((k_2-k_1)t\right)-1\right]\right) \quad (26)$$

Then,

$$[DMS]_t=k_1[SMM]_{t=0}\left(\frac{1}{(k_2-k_1)}\left[\exp\left((k_2-k_1)t\right)-1\right]\right)\exp(-k_2 t) \quad (27)$$

After using exponential laws and expanding equation 27, we obtain the following:

$$[DMS]_t=\left[\frac{k_1[SMM]_{t=0}}{(k_2-k_1)}\left[\exp\left((k_2-k_1-k_2)t\right)-\exp(-k_2 t)\right]\right] \quad (28)$$

After simplifying equation 28, the relation obtained is

$$[DMS]_t=\left[\frac{k_1[SMM]_{t=0}}{(k_2-k_1)}\left(\exp(-k_1 t)-\exp(-k_2 t)\right)\right] \quad (29)$$

In a real situation, at the end of mashing, the wort contains a certain amount of DMS coming from the conversion of SMM during the mashing process ($[DMS]_t^{mash}$), and it is also reduced by volatilization during the boiling stage. That additional DMS in the wort follows also the first-order kinetic, and therefore it is expressed as follows:

$$[DMS]_t^{mash}=[DMS]_{t=0}\exp(-k_2 t) \quad (30)$$

where $[DMS]_{t=0}$ is the initial DMS concentration, before the boiling stage.

The total concentration of DMS residual in the wort (denoted $[DMS]_t^{total}$) at the end of the boiling phase is, therefore, in respect of mass balance, equal to the residual DMS owing to the two consecutive irreversible reactions ($[DMS]_t$) during wort boiling, to which is added the residual amount of DMS coming from the conversion of SMM during mashing ($[DMS]_t^{mash}$). It is expressed as follows:

$$[DMS]_t^{total}=[DMS]_t^{mash}+[DMS]_t \quad (31)$$

Knowing the expressions of $[DMS]_t$ from equation 29 and the one of $[DMS]_t^{mash}$ from equation 30, the total amount of DMS ($[DMS]_t^{total}$) could be written from equation 31 as follows:

$$\begin{aligned}[DMS]_t^{total}&=[DMS]_{t=0}\exp(-k_2 t)\\&\quad+\left[\frac{k_1[SMM]_{t=0}}{(k_2-k_1)}\left(\exp(-k_1 t)-\exp(-k_2 t)\right)\right]\end{aligned} \quad (32)$$

where $[DMS]_0$ and $[SMM]_0$ are the initial DMS and SMM concentrations, respectively, k_1 is the reaction rate coefficient of SMM conversion to DMS, and k_2 is the volatilization rate coefficient of DMS.

Equation 32 developed from reaction kinetics and for DMS stripping was identical in form to that of Mitani et al. (23).

MacLaurin Series Approximations for SMM and DMS Nonlinear Models

MacLaurin series approach. The linearization is done using the MacLaurin series, which is a particular expression of a Taylor series. That Taylor series is expressed as follows (4,7,14,29):

$$f(t)=\sum_{n=0}^{\infty}\frac{f^{(n)}(t_0)}{n!}(t-t_0)^n \quad (33)$$

The most typical form of useful sequence is the power series, which employs powers of the separate variables as basic functions. The first kind of polynomial series is the MacLaurin series (25):

$$f(t)=s(t)=a_0+a_1 t+a_2 t^2+\ldots+a_{n-1}t^{n-1}+a_n t^n \quad (34)$$

whereby $f(t)$ (the function to be symbolized) and $s(t)$ hold for the series. We want then to identify the coefficients. As a way for the function and the series to be equivalent at all values of t in some interval as well as $t = 0$, they need to be identical at $t = 0$, which suggests that all of the terms in the series disappear apart from the following for the first expression:

$$f(0)=s(0)=a_0 \quad (35)$$

This decides a_0. To be able to illustrate a function by a power series, we need that the function and all of its derivatives remain differentiable at $t = 0$. This kind of a function is stated to be logical at $t = 0$. After that, it is needed to have all derivatives of the

function as well as the series equate at $t = 0$. The nth derivation of the series at $t = 0$ is

$$\left(\frac{d^n s}{dt^n}\right)_{t=0} = n! a_n \tag{36}$$

where $n!$ (n factorial) is prescribed for $n \geq 1$ and for instance (18)

$$n! = n(n-1)(n-2)(n-3)(n-4)\cdots(4)(3)(2)(1) \tag{37}$$

where 0! is considered to be equal to 1 based to the agreement for an empty product (15). The standard formula for the MacLaurin series coefficients to characterize the function $f(t)$ is therefore

$$a_n = \frac{1}{n!}\left(\frac{d^n f}{dt^n}\right)_{t=0} = \frac{1}{n!}\left(f^{(n)}\right)_{t=0} = \frac{1}{n!} f^{(n)}(0) \quad (n = 1,2,3,4,5,6,\ldots) \tag{38}$$

The MacLaurin series development for $f(t)$ around $t = 0$ therefore evolves into (7,22)

$$f(t) = f(0) + \frac{f^{(1)}(0)}{1!}t + \frac{f^{(2)}(0)}{2!}t^2 + \frac{f^{(3)}(0)}{3!}t^3 + \frac{f^{(4)}(0)}{4!}t^4 + \ldots + \frac{f^{(n)}(0)}{n!}t^n \tag{39}$$

Then, that power series could be expressed in complete form, by using the sum symbol as follows:

$$f_\infty(t) = \sum_{n=0}^{\infty} \frac{f^{(n)}(0)}{n!}\left(t^n\right) \tag{40}$$

Approximating $[SMM]_t$ and $[DMS]_t^{total}$ nonlinear models using the MacLaurin series. Let us now consider equations 10 and 32, which are exponential functions. To be able to transform them as a power series (equation 38), it is therefore necessary to derive these nonlinear functions and expand them around $t = 0$.

Let us define these nonlinear functions (equations 10 and 32) as follows:

$$[SMM]_t = g(t) = [SMM]_{t=0}\exp(-k_1 t) \tag{41}$$

and

$$[DMS]_t^{total} = h(t) = [DMS]_{t=0}\exp(-k_2 t) + \left[\frac{k_1[SMM]_{t=0}}{(k_2 - k_1)}\left(\exp(-k_1 t) - \exp(-k_2 t)\right)\right] \tag{42}$$

The values of $g(t)$ and $h(t)$ around $t = 0$ and expressed respectively by $g(0)$ and $h(0)$ are

$$g(0) = [SMM]_{t=0} \tag{43}$$

$$h(0) = [DMS]_{t=0} \tag{44}$$

Recall from mathematical calculus that

$$f^{(n)}(x) = \frac{d^n}{dx^n}\left(f(x)\right) = \frac{d}{dx}\left(f^{(n-1)}(x)\right) \tag{45}$$

and

$$\frac{d}{dx}\left(a\exp(f(x))\right) = a\left(\frac{d}{dx}f(x)\right)\exp(f(x)) = a\left[f'(x)\right]\exp(f(x)) \tag{46}$$

So by doing successive derivations of equations 41 and 42, we have the following series of derivations:

first derivation:

$$g^{(1)}(t) = -[SMM]_{t=0} k_1 \exp(-k_1 t) \tag{47}$$

$$h^{(1)}(t) = [SMM]_{t=0}\frac{k_1}{k_1 - k_2}\left(k_1\exp(-k_1 t) - k_2\exp(-k_2 t)\right) - [DMS]_{t=0} k_2 \exp(-k_2 t) \tag{48}$$

second derivation:

$$g^{(2)}(t) = k_1^2 [SMM]_{t=0}\exp(-k_1 t) \tag{49}$$

$$h^{(2)}(t) = -\begin{pmatrix}[SMM]_{t=0}\frac{k_1}{k_1 - k_2}\left(k_1^2\exp(-k_1 t) - k_2^2\exp(-k_2 t)\right) \\ -[DMS]_{t=0} k_2^2 \exp(-k_2 t)\end{pmatrix} \tag{50}$$

third derivation:

$$g^{(3)}(t) = -k_1^3 [SMM]_{t=0}\exp(-k_1 t) \tag{51}$$

$$h^{(3)}(t) = [SMM]_{t=0}\frac{k_1}{k_1 - k_2}\left(k_1^3\exp(-k_1 t) - k_2^3\exp(-k_2 t)\right) - [DMS]_{t=0} k_2^3 \exp(-k_2 t) \tag{52}$$

fourth derivation:

$$g^{(4)}(t) = k_1^4 [SMM]_{t=0}\exp(-k_1 t) \tag{53}$$

$$h^{(4)}(t) = -\begin{pmatrix}[SMM]_{t=0}\frac{k_1}{k_1 - k_2}\left(k_1^4\exp(-k_1 t) - k_2^4\exp(-k_2 t)\right) \\ -[DMS]_{t=0} k_2^4 \exp(-k_2 t)\end{pmatrix} \tag{54}$$

$$\vdots$$

nth derivation:

$$g^{(n)}(t) = (-1)^n [SMM]_{t=0} k_1^n \exp(-k_1 t) \tag{55}$$

$$h^{(n)}(t) = (-1)^n \left[-\begin{pmatrix}[SMM]_{t=0}\frac{k_1}{k_1 - k_2}\left(k_1^n\exp(-k_1 t) - k_2^n\exp(-k_2 t)\right) \\ -[DMS]_{t=0} k_2^n \exp(-k_2 t)\end{pmatrix}\right] \tag{56}$$

where $n \geq 1$.

The calculus of the derivative functions around $t = 0$ ($g^{(n)}(0)$ and $h^{(n)}(0)$), and with $n = 1, 2, 3, \ldots$ are then expressed as in the following series of derivations:

first derivation:

$$g^{(1)}(0) = -[SMM]_{t=0} k_1 \tag{57}$$

$$h^{(1)}(0) = k_1[SMM]_{t=0} - k_2[DMS]_{t=0} \tag{58}$$

second derivation:

$$g^{(2)}(0) = k_1^2[SMM]_{t=0} \tag{59}$$

$$h^{(2)}(0) = -\left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^2-k_2^2\right) - [DMS]_{t=0}k_2^2\right) \tag{60}$$

third derivation:

$$g^{(3)}(0) = -k_1^3[SMM]_{t=0} \tag{61}$$

$$h^{(3)}(0) = \left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^3-k_2^3\right) - [DMS]_{t=0}k_2^3\right) \tag{62}$$

fourth derivation:

$$g^{(4)}(0) = k_1^4[SMM]_{t=0} \tag{63}$$

$$h^{(4)}(0) = -\left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^4-k_2^4\right) - [DMS]_{t=0}k_2^4\right) \tag{64}$$

$$\vdots$$

*n*th derivation:

$$g^{(n)}(0) = (-1)^n k_1^n[SMM]_{t=0} \tag{65}$$

$$h^{(n)}(0) = (-1)^n\left[-\left([SMM]_0\frac{k_1}{k_1-k_2}\left(k_1^n-k_2^n\right) - [DMS]_0k_2^n\right)\right] \tag{66}$$

where $n \geq 1$.

The power series of $[SMM]_t$ and $[DMS]_t^{total}$ is then expressed as follows:

$$\begin{aligned}[SMM]_t = [SMM]_{t=0} &- \frac{\left([SMM]_{t=0}k_1\right)}{1!}t \\ &+ \left(\frac{[SMM]_{t=0}k_1^2}{2!}\right)t^2 - \left(\frac{[SMM]_{t=0}k_1^3}{3!}\right)t^3 \\ &+ \left(\frac{[SMM]_{t=0}k_1^4}{4!}\right)t^4 + \cdots + \left(\frac{(-1)^n k_1^n[SMM]_{t=0}}{n!}\right)t^n\end{aligned} \tag{67}$$

$$\begin{aligned}[DMS]_t^{total} = [DMS]_{t=0} &+ \frac{\left([SMM]_{t=0}k_1 - [DMS]_{t=0}k_2\right)}{1!}t \\ &- \frac{\left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^2-k_2^2\right) - [DMS]_{t=0}k_2^2\right)}{2!}t^2 \\ &+ \frac{\left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^3-k_2^3\right) - [DMS]_{t=0}k_2^3\right)}{3!}t^3 \\ &- \frac{\left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^4-k_2^4\right) - [DMS]_{t=0}k_2^4\right)}{4!}t^4 + \cdots \\ &+ \frac{(-1)^n\left[-\left([SMM]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^n-k_2^n\right) - [DMS]_{t=0}k_2^n\right)\right]}{n!}t^n\end{aligned} \tag{68}$$

Determination of SMM and DMS Equations Constants

In this section, the aim is to ease the determination of constant coefficients of $[SMM]_t$ and $[DMS]_t^{total}$ nonlinear functions by means of linearization using the MacLaurin series. That transformation of nonlinear functions into power series could be one of the solutions to coefficient determination because that series looks much easier to handle.

Use of nonlinear equation for determination of constants. The constants to be determined here are k_1, k_2, $[SMM]_{t=0}$, and $[DMS]_{t=0}$.

From the nonlinear equation of $[SMM]_t$, it is possible to determine k_1 and $[SMM]_{t=0}$ by using the logarithm:

$$\begin{aligned}[SMM]_t &= [SMM]_{t=0}\exp(-k_1t) \Rightarrow \ln\left([SMM]_t\right) \\ &= \ln\left([SMM]_{t=0}\exp(-k_1t)\right)\end{aligned} \tag{69}$$

Recall from logarithm laws that

$$\ln(ab) = \ln(a) + \ln(b) \tag{70}$$

$$\ln\left(\exp(a)\right) = a \tag{71}$$

From these laws, it is written

$$\begin{aligned}\ln\left([SMM]_t\right) &= \ln\left([SMM]_{t=0}\exp(-k_1t)\right) \Rightarrow \ln\left([SMM]_t\right) \\ &= \ln\left([SMM]_{t=0}\right) + \ln\left(\exp(-k_1t)\right)\end{aligned} \tag{72}$$

$$\begin{aligned}\ln\left([SMM]_t\right) &= \ln\left([SMM]_{t=0}\right) + \ln\left(\exp(-k_1t)\right) \\ &\Rightarrow \ln\left([SMM]_t\right) = \ln\left([SMM]_{t=0}\right) - k_1t\end{aligned} \tag{73}$$

From equation 73, it is observed that the introduction of the logarithm transformed it into a linear form in which $\ln[SMM]_{t=0}$ is obtained when $t = 0$ and $-k_1$ is the slope after obtaining the linear regression equation from the experimental data, when plotting $\ln([SMM])_t = f(t)$. An illustration is presented in Figure 1.

For the $[DMS]_t^{total}$ equation, the determination of k_2 and $[DMS]_{t=0}$ are the main concern because k_1 and $[SMM]_{t=0}$ are already estimated. For this case, the structure of that nonlinear equation 42 is so complex that an easy way of determining the constants is diffi-

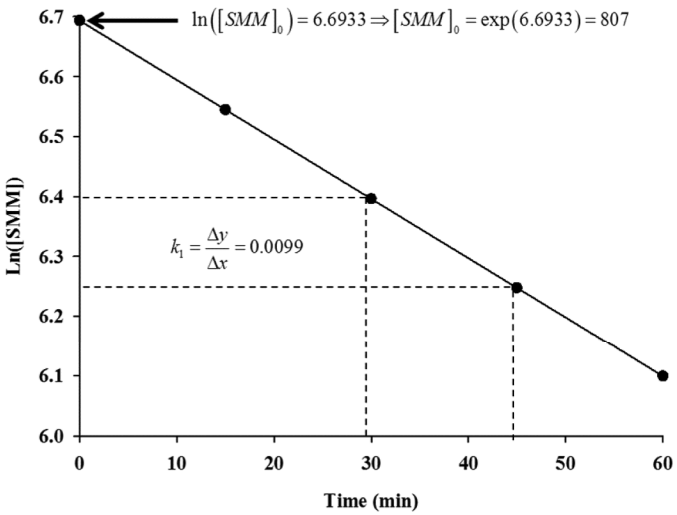


Fig. 1. Simplification of *S*-methylmethionine (SMM) nonlinear equation using logarithm.

cult to implement. For that purpose, we need to apply nonlinear regression fitting, but that is possible only with specific software such as Sigmaplot, Matlab, or BrainMaker, for which a program must be written for these software packages to solve the equation and give the desired results. This last software (BrainMaker version 2.3) was used by Mitani et al. in 1999 (23). This justifies thereby the necessity of finding another way of acquiring these data.

Use of power series for determination of constants. For $[SMM]_t$ equation constants determination, equation 67 is considered. When fitting that equation with the experimental data, we then deduce graphically that the value of $[SMM]_{t=0}$ is obtained at $t = 0$. By making a correspondence with the MacLaurin series of equation 34, we can therefore state that

$$\left[SMM\right]_{t=0} = a_0 \tag{74}$$

After obtaining the value of $[SMM]_{t=0}$, the remaining constant to determine for the $[SMM]_t$ equation is k_1. One of the ways of determining it is graphically after deriving the $[SMM]_t$ equation and plotting the derivation. Deriving of equation 67 gives the following:

$$\begin{aligned}\frac{d}{dt}\left[SMM\right]_t = &-\left(\left[SMM\right]_{t=0}k_1\right) + 2\left(\frac{\left[SMM\right]_{t=0}k_1^2}{2!}\right)t \\ &-3\left(\frac{\left[SMM\right]_{t=0}k_1^3}{3!}\right)t^2 + 4\left(\frac{\left[SMM\right]_{t=0}k_1^4}{4!}\right)t^3 \\ &+\cdots + n\left(\frac{(-1)^n k_1^n \left[SMM\right]_{t=0}}{n!}\right)t^{n-1}\end{aligned} \tag{75}$$

An analysis of equation 75 permits stating that, by plotting it, the value of $[-([SMM]_{t=0}k_1]$ is obtained at $t = 0$. By comparing that equation 75 to the derivative equation of the MacLaurin series (equation 34), which is expressed as

$$\begin{aligned}\frac{d}{dt}\left(f(t)\right) = f^{(1)}(t) = a_1 + 2a_2 t + 3a_3 t^2 + \ldots \\ + (n-1)a_{n-1}t^{n-2} + na_n t^{n-1}\end{aligned} \tag{76}$$

we can say that

$$\left[-\left(\left[SMM\right]_{t=0}k_1\right)\right] = a_1 \tag{77}$$

Knowing that $[SMM]_{t=0} = a_0$, we can then finally have

$$\left[-\left(\left[SMM\right]_{t=0}k_1\right)\right] = a_1 \Rightarrow -a_0 k_1 = a_1 \Rightarrow k_1 = -\frac{a_1}{a_0} \tag{78}$$

For $[DMS]_t^{total}$ equation constants, the same approach is used. For this case, the constants to determine are k_2 and $[DMS]_{t=0}$, knowing that k_1 and $[SMM]_{t=0}$ are already determined. The approach again is to fit the $[DMS]_t^{total}$ power series approximation (equation 68) with experimental data. By that method, the value of $[DMS]_{t=0}$ is obtained at $t = 0$. If the MacLaurin series is rewritten as follows

$$f(t) = b_0 + b_1 t + b_2 t^2 + \ldots + b_{n-1}t^{n-1} + b_n t^n \tag{79}$$

we can then write by comparison of equations 68 and 79 that

$$\left[DMS\right]_{t=0} = b_0 \tag{80}$$

When deriving $[DMS]_t^{total}$ and the MacLaurin power series equations, we obtain

$$\begin{aligned}\frac{d}{dt}\left(\left[DMS\right]_t^{total}\right) = &\left(\left[SMM\right]_{t=0}k_1 - \left[DMS\right]_{t=0}k_2\right) \\ &-\left(\left[SMM\right]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^2-k_2^2\right) - \left[DMS\right]_{t=0}k_2^2\right)t + \cdots \\ &+n\frac{(-1)^n\left[-\left(\left[SMM\right]_{t=0}\frac{k_1}{k_1-k_2}\left(k_1^n-k_2^n\right) - \left[DMS\right]_{t=0}k_2^n\right)\right]}{n!}t^{n-1}\end{aligned} \tag{81}$$

$$\frac{d}{dt}\left(f(t)\right) = f^{(1)}(t) = b_1 + 2b_2 t + \ldots + (n-1)b_{n-1}t^{n-2} + nb_n t^{n-1} \tag{82}$$

By comparing the two derivative equations 81 and 82, we deduce the following:

$$\left(\left[SMM\right]_{t=0}k_1 - \left[DMS\right]_{t=0}k_2\right) = b_1 \tag{83}$$

That value of b_1 is obtained when the derivative equation 76 is around $t = 0$. The value of k_2 is then calculated from equation 77 as the following:

$$\begin{aligned}\left(\left[SMM\right]_{t=0}k_1 - \left[DMS\right]_{t=0}k_2\right) = b_1 \Rightarrow \left[DMS\right]_{t=0}k_2 \\ = \left(\left[SMM\right]_{t=0}k_1\right) - b_1\end{aligned} \tag{84}$$

Then,

$$k_2 = \frac{\left(\left[SMM\right]_{t=0}k_1\right) - b_1}{\left[DMS\right]_{t=0}} \tag{85}$$

Application of the MacLaurin Series on Evaluating Reaction Rate Coefficient of SMM Conversion to DMS (k_1), Initial SMM Concentration ($[SMM]_{t=0}$), Initial DMS Concentration ($[DMS]_{t=0}$), and Volatilization Rate Coefficient (k_2)

In this part, we provide a range of illustrative cases to exhibit the use of equations 66 and 67. In all of these cases concerning wort boiling, we have applied MacLaurin series approximation of the functions to resolve k_1, k_2, $[SMM]_{t=0}$, and $[DMS]_{t=0}$. All the polynomial regressions were done using CurveExpert Professional version 2.3 software (©2011–2016 Daniel G. Hyams) and verified with TableCurve 2D version 5.01 software (Systat Software, San Jose, CA, U.S.A.). The method in all the subsequent cases is identical.

First, the linearized equation is built into experimental data as a way to figure out $[SMM]_{t=0}$. Second, the linearized equation is derived and the formula obtained is plotted to be able to determine k_1. Third, the linearized model of $[DMS]_t^{total}$ evolution is also fitted to its experimental data to determine $[DMS]_{t=0}$. Finally, that equation is derived, and the derivative equation is one more time plotted to calculate the value of k_2, being aware of the values of k_1, $[SMM]_{t=0}$, and $[DMS]_{t=0}$.

Example 1. Let us consider Mitani et al. (23) wort boiling experimental data obtained after using a pilot-scale kettle with a volume of 0.4 m^3, heat exchange area of 0.3 m^3, and heat supply rate of 160 $MJ \cdot m^{-3} wort \cdot h^{-1}$. That wort boiling process is realized for 90 min, and the data are compiled in Table I. Figures 2A and 3A show that the power series having the best regression with the experimental data is in both cases the third-order polynomial equation. These third-order polynomial equations are then chosen to determine their respective constants. From Figures 2 and 3 the respective values of $[SMM]_{t=0}$, k_1, $[DMS]_{t=0}$, and k_2 are 5.05 μM, 0.0147 min^{-1}, 1.89 μM, and 0.0519 min^{-1}, which were similar to

the ones obtained by Mitani et al. (23). The approximations of $[SMM]_t$ and $[DMS]_t^{total}$ functions using the MacLaurin series are therefore accurate for easier determination of all the constants.

Example 2. Let us consider again Mitani et al. (23) data, this time working on a commercial scale. The kettle is a 6 m^3 volume with a tubular heat exchanger area of 2.8 m^2 and a heat supply rate of 150 $MJ \cdot m^{-3}$ $wort \cdot h^{-1}$. The boiling time in this case is 80 min, and the data are reported in Table II.

Figure 4A shows that the best polynomial regression to be considered as an approximation of SMM equation is the third-order polynomial equation, while for Figure 5A, it is proven that the polynomial equation to be used is the sixth-order one for DMS. Also, from the analysis of Figures 4 and 5, the values of the constants were exhibited easily. From there, it is obtained for $[SMM]_{t=0}$, k_1, $[DMS]_{t=0}$, and k_2 the respective values 3.5 µM, 0.0172 min^{-1}, 1.889 µM, and 0.100 min^{-1}. These values are similar one more time to those obtained by Mitani et al. (23).

Example 3. Let us consider now our laboratory-scale boiling procedure in a 20 L insulated kettle. Different boiling conditions are applied with the same preheating protocol. The data are presented in Tables III and IV. Only one case is illustrated. The other results are following the same approach. The case to be considered in Table IV is the first column. The values of $[SMM]_{t=0}$ and k_1 are obtained using the nonlinear equation 41 and its polynomial approximation (equation 67). There are therefore obtained similar values of $[SMM]_{t=0}$ and k_1 as presented in Figures 1 and 6. The best polynomial regression in this case is the fourth-order polynomial equation. For DMS and the determination of $[DMS]_{t=0}$ and

TABLE I
Evolution of *S*-Methylmethionine (SMM) and Dimethyl Sulfide (DMS) Concentration with Time (Example 1)

Time (min)	SMM (ppb)	DMS (ppb)
0	5.05	1.77
30	3.23	1.82
60	2.07	1.84
90	1.32	1.86

TABLE II
Evolution of *S*-Methylmethionine (SMM) and Dimethyl Sulfide (DMS) Concentration with Time (Example 2)

Time (min)	SMM (ppb)	DMS (ppb)
0	3.50	1.89
30	2.06	0.49
60	1.21	0.26
80	0.85	0.18

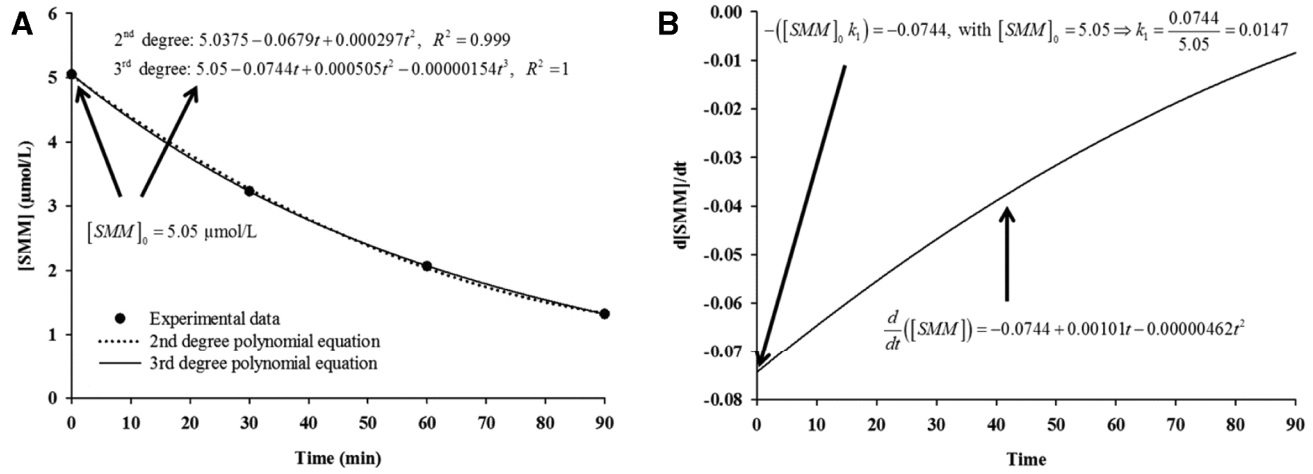


Fig. 2. A, Determination of $[SMM]_0 = [SMM]_{t=0}$ using linearized $[SMM]_t$ equation; and **B,** determination of k_1 using $[SMM]_t$ equation derivation (example 1).

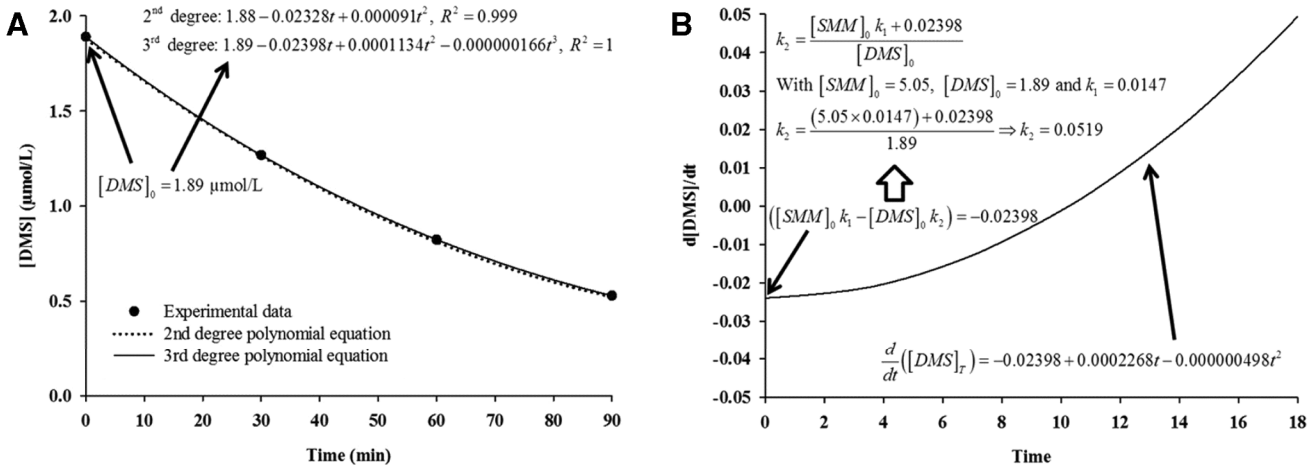


Fig. 3. A, Determination of $[DMS]_0 = [DMS]_{t=0}$ using linearized $[DMS]_T = [DMS]_t^{total}$ equation; and **B,** determination of k_2 using $[DMS]_t^{total}$ equation derivation (example 1).

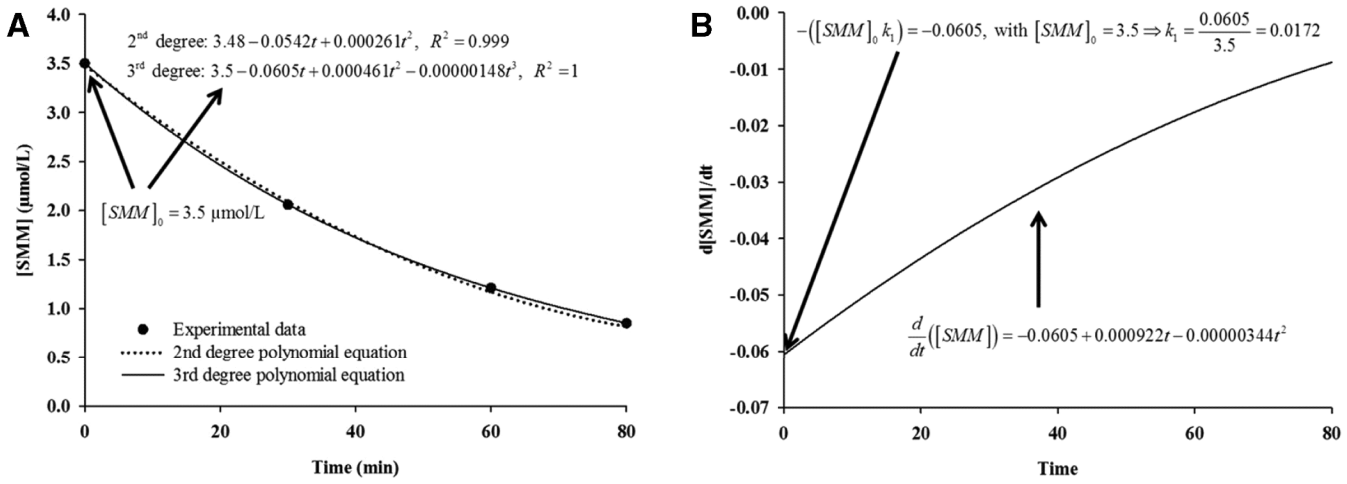


Fig. 4. A, Determination of $[SMM]_0$ using linearized $[SMM]$ equation; and **B,** determination of k_1 using $[SMM]$ equation derivation (example 2).

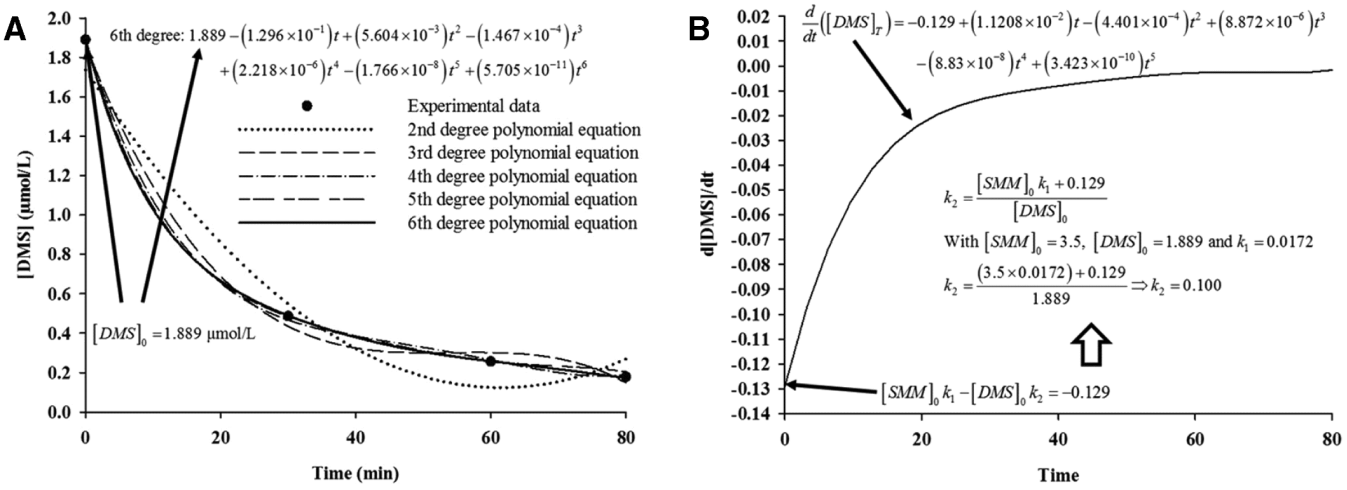


Fig. 5. A, Determination of $[DMS]_0$ using linearized $[DMS]$ equation; and **B,** determination of k_2 using $[DMS]$ equation derivation (example 2).

TABLE III
Comparative Evaluation of $[SMM]_0 = [SMM]_{t=0}$ and k_1 from First-Order Kinetic (Exponential) and Its Approximated Polynomial Equation (Example 3)

Time (min)	0	15	30	45	60
$[SMM]$ (ppb)	807	695.63	599.64	516.89	445.56

TABLE IV
Comparative Evaluation of $[DMS]_0 = [DMS]_{t=0}$ and k_2 from Nonlinear and Its Approximated Polynomial Equation (Example 3)

Time	1	2	3	4	5	6	7	8
Time (min)								
0	587.3	592.3	589.4	588.7	585.3	586.8	586.9	582.4
15	566.4	524.7	521.5	519.8	507.8	505.9	515.8	472.4
30	534.9	479.8	460.1	456.8	437.0	437.4	441.0	392.2
45	495.7	416.6	405.1	400.6	374.4	377.3	391.0	330.5
60	458.5	367.1	356.6	351.2	326.4	324.4	336.4	274.2
75	418.5	324.2	308.5	305.4	279.5	281.2	292.5	232.2
90	378.3	284.0	269.6	264.8	242.0	242.5	253.0	196.0
Calculated values								
$[DMS]_{0\,exp}$ (ppb)	589.6	591.2	585.2	588.4	585.9	586.8	587.5	580.9
$k_{2\,exp}$ (min^{-1})	**0.01544**	**0.02049**	**0.02133**	**0.02165**	**0.02341**	**0.02343**	**0.02260**	**0.02751**
$[DMS]_{0\,pol}$ (ppb)	587.8	591.2	589.4	588.7	585.9	586.8	587.5	582.4
$k_{2\,pol}$ (min^{-1})	**0.01557**	**0.02046**	**0.02110**	**0.02145**	**0.02341**	**0.02341**	**0.02240**	**0.02664**

(continued on next page)

[a] $[DMS]_{0\,exp} = [DMS]_{t=0,\,exp}$ and $[DMS]_{0\,pol} = [DMS]_{t=0,\,pol}$: Initial DMS concentration obtained respectively from equation 32 and linearized polynomial equation; $k_{2\,exp}$ and $k_{2\,pol}$: volatilization rate coefficient obtained respectively from equation 32 and linearized polynomial equation.

k_2, the adequate polynomial regression is the third-degree one. In this case, the calculation of these constants obtained using the linearization presented in Figure 7 is similar to the one acquired using the nonlinear function with the help of Matlab R2014a (MathWorks, Natick, MA, U.S.A.), as shown in Table IV (column 1). When analyzing Table IV for the other cases, it is therefore demonstrated that the MacLaurin series as an approximation of nonlinear equations for SMM and DMS evolution during wort boiling is very accurate, and the determination of constants is easier.

Example 4. Let us consider the data obtained from the boiling process of two wort substitutes using a 20 L insulated kettle (13). The boiling data are presented in Table V. The approach to calculate the different constants is the same as the previous examples.

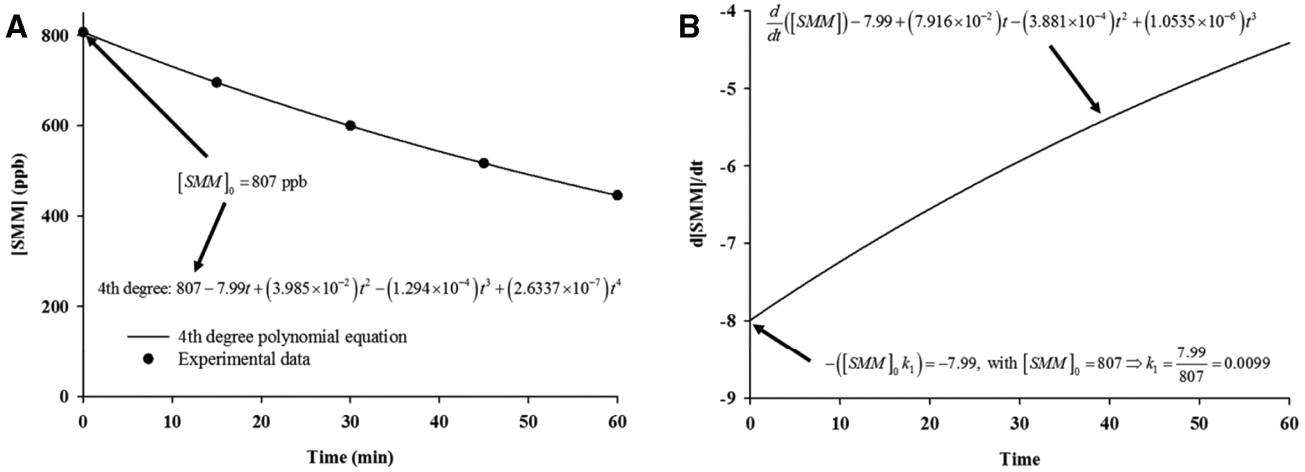


Fig. 6. A, Determination of $[SMM]_0$ using linearized $[SMM]$ equation; and **B,** determination of k_1 using $[SMM]$ equation derivation (example 3).

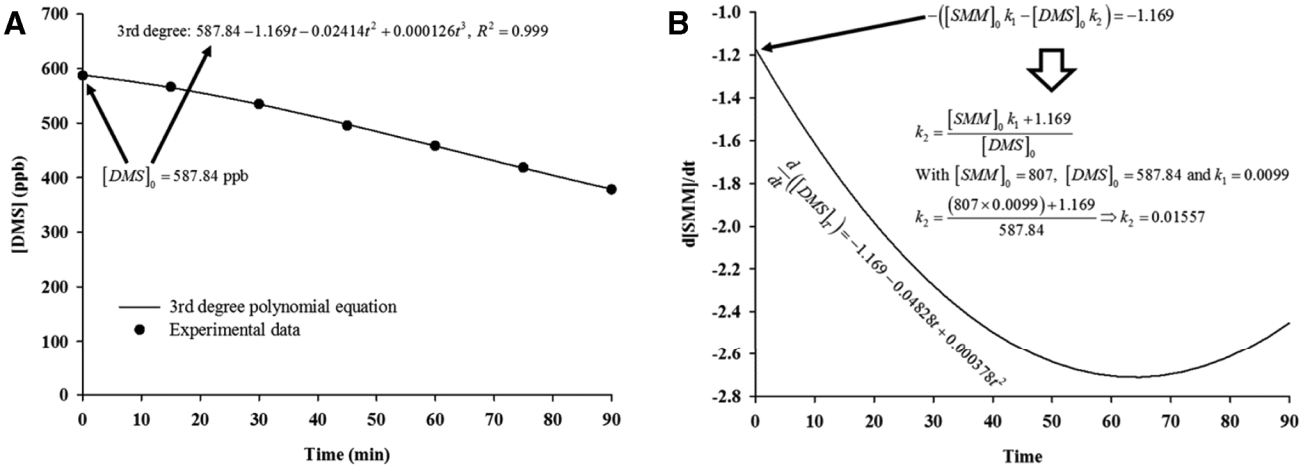


Fig. 7. A, Determination of $[DMS]_0$ using linearized $[DMS]$ equation; and **B,** determination of k_2 using $[DMS]$ equation derivation (example 3).

TABLE IV (*continued from previous page*)

9	10	11	12	13	14	15	16	17	18
584.4	585.7	586.3	587.7	586.4	589.1	587.6	586.5	586.6	586.1
463.5	454.0	443.7	433.8	392.9	320.3	306.3	291.3	261.4	243.9
380.9	360.4	341.8	333.4	286.9	193.9	184.4	176.4	144.6	129.2
311.0	290.3	274.4	256.4	213.0	137.6	125.7	119.1	95.7	88.8
257.1	242.6	219.1	212.9	160.3	102.7	96.0	90.9	74.9	69.4
216.3	199.7	198.4	182.8	133.3	83.7	78.4	73.6	60.0	55.9
182.4	166.0	165.9	151.4	109.6	69.0	66.6	61.3	52.6	47.3
583.6	584.9	586.8	587.5	586.3	589.4	587.8	585.8	586.7	586.0
0.02920	**0.03118**	**0.03342**	**0.03487**	**0.04180**	**0.05842**	**0.06141**	**0.06415**	**0.07358**	**0.07882**
583.9	585.6	585.8	587.5	585.6	589.1	587.6	586.4	586.6	586.1
0.02959	**0.03078**	**0.03187**	**0.03386**	**0.04110**	**0.05662**	**0.06167**	**0.06461**	**0.07417**	**0.07626**

TABLE V
Comparative Evaluation of $[DMS]_0 = [DMS]_{t=0}$ and k_2 from Nonlinear and Approximated Polynomial Equation at Various Power Heater Levels (Example 4)

	500 W		750 W		1,000 W		1,250 W		1,500 W	
Time	**Wort 1**	**Wort 2**	**Wort 1**	**Wort 2**	**Wort 1**	**Wort 2**	**Wort 1**	**Wort 2**	**Wort 1**	**Wort 2**
Time (min)										
0	593.00	582.00	605.00	598.00	610.00	607.00	609.00	608.00	602.00	600.00
5	536.03	541.84	537.66	545.98	530.04	540.25	512.51	519.66	484.08	501.16
10	484.54	504.45	477.82	498.49	460.57	480.84	431.31	444.16	389.26	418.61
15	437.99	469.64	424.63	455.13	400.20	427.96	362.97	379.62	313.02	349.65
20	395.91	437.23	377.37	415.54	347.74	380.90	305.46	324.46	251.70	292.05
25	357.88	407.06	335.37	379.40	302.16	339.01	257.06	277.32	202.40	243.94
30	323.50	378.98	298.04	346.40	262.55	301.73	216.33	237.03	162.76	203.76
35	292.42	352.82	264.87	316.27	228.14	268.55	182.06	202.59	130.88	170.19
40	264.33	328.48	235.39	288.76	198.24	239.02	153.21	173.15	105.24	142.16
45	238.94	305.81	209.19	263.64	172.25	212.73	128.94	147.99	84.63	118.74
50	215.98	284.71	185.90	240.71	149.67	189.34	108.51	126.49	68.05	99.18
55	195.23	265.06	165.21	219.77	130.06	168.52	91.32	108.11	54.72	82.84
60	176.48	246.77	146.82	200.66	113.01	149.98	76.85	92.40	44.00	69.20
Calculated values										
$[DMS]_{0\,exp}$ (ppb)	593.00	582.00	605.00	598.00	610.00	607.00	609.00	608.00	602.00	600.00
$k_{2\,exp}$ (min^{-1})	0.02020	0.01430	0.02360	0.01820	0.02810	0.02330	0.03450	0.03140	0.04360	0.03600
$[DMS]_{0\,pol}$ (ppb)	592.99	582.00	604.99	597.99	609.99	606.99	608.99	607.99	601.98	599.99
$k_{2\,pol}$ (min^{-1})	0.02019	0.01429	0.02359	0.01819	0.02808	0.02330	0.03447	0.03138	0.04352	0.03597

In this case, the best approximation of the nonlinear equation is obtained using the fifth-degree polynomial equation. One more time, the MacLaurin series appears to be accurate to estimate the constants $[SMM]_{t=0}$, k_1, $[DMS]_{t=0}$, and k_2, because the values obtained are similar to the ones obtained by Desobgo et al. in 2015 (Table V).

CONCLUSIONS

The derivation of a simultaneous DMS formation and stripping nonlinear model was described, utilizing a combination of an instantaneous mass balance and a first-order reaction equation to represent separately DMS formation and stripping. This nonlinear model was found to be identical to one proposed elsewhere in the literature by Mitani et al. (23). To facilitate the implementation of our model, linearization of our nonlinear model was conducted using a MacLaurin–Taylor series expansion. Several examples of implementation of both our nonlinear and linearized models were described.

ACKNOWLEDGMENTS

Our acknowledgements go to the Faculty of Science (Department of Biotechnology and Food Technology), Doornfontein Campus of the University of Johannesburg, for support of this study.

LITERATURE CITED

1. Anness, B. J., and Bamforth, C. W. Dimethyl sulfide—A review. *J. Inst. Brew.* 88:244-252, 1982.
2. Arfi, K., Spinnler, H. E., Tache, R., and, Bonnarme P. Production of volatile compounds by cheese-ripening yeasts: Requirement for a methanethiol donor for *S*-methyl thioacetate synthesis by *Kluyveromyces lactis*. *Appl. Microbiol. Biotechnol.* 58:503-510, 2002.
3. Bamforth, C. W. Dimethyl sulfide—Significance, origins, and control. *J. Am. Soc. Brew. Chem.* 72:165-168, 2014.
4. Barrio, R., Rodríguez, M., Abad, A., and Blesa, F. Breaking the limits: The Taylor series method. *App. Math. Comput.* 217:7940-7954, 2011.
5. Baxter, E. D., and Hughes, P. S. *Beer: Quality, Safety and Nutritional Aspects*. The Royal Society of Chemistry, Manchester, U.K., p. 138, 2001.
6. Berger, C., Martin, N., Collin, S., Gijs, L., Khan, J. A., Piraprez, G., Spinnler, H. E., and Vulfson, E. N. Combinatorial approach to flavor analysis. 2. Olfactory investigation of a library of *S*-methyl thioesters and sensory evaluation of selected components. *J. Agric. Food Chem.* 47:3274-3279, 1999.
7. Blinder, S. M. Series and integrals. In: *Guide to Essential Math, 2nd Ed*. Elsevier, Oxford, U.K., pp. 101-123, 2013.
8. Bonachelli, B., De-Brackeleire, C., and Harmegnies, F. Wort boiling—The Meura's concept with wort stripping. In: *Proc. Eur. Brew. Conv. Congr., Venice*, 2007.
9. Bonachelli, B., Harmegnies, F., and Gil, R. T. Continuous wort boiling and hot trub separation. In: *Proc. Eur. Brew. Conv. Congr., Dublin*, 2003.
10. Braekeleirs, R., and Bauduin, C. L. In: *Proc. 8th Brew. Conv., Inst. Brew. (Central and Southern Africa Section), Sun City*, p. 36, 2001.
11. De-Schutter, D. P., Saison, D., Delvaux, F., Derdelinckx, G., Rock, J.-M., Neven, H., and Delvaux, F. R. Optimization of wort volatile analysis by headspace solid-phase microextraction in combination with gas chromatography and mass spectrometry. *J. Chromatogr. A* 1179:75-80, 2008.
12. Dercksen, A., Laurens, J., Torline, P., Axcell, B. C., and Rohwer, E. Quantitative analysis of volatile sulfur compounds in beer using a membrane extraction interface. *J. Am. Soc. Brew. Chem.* 54:228-233, 1996.
13. Desobgo, Z. S. C., Stafford, R. A., and Metcalfe, D. J. A. Dimethyl sulfide stripping behavior during wort boiling using response surface methodology. *J. Am. Soc. Brew. Chem.* 73:84-89, 2015.
14. Ghosh, S., Deb, A., and Sarkar, G. Taylor series approach for function approximation using 'estimated' higher derivatives. *Appl. Math. Comput.* 284:89-101, 2016.
15. Graham, R. L., Knuth, D. E., and Patashnik, O. *Concrete Mathematics: A Foundation for Computer Science*. Addison-Wesley, Reading, MA, 1994.
16. Hill P. G., and Smith, R. M. Determination of sulphur compounds in beer using headspace solid-phase microextraction and gas chromatographic analysis with pulsed flame photometric detection. *J. Chromatogr. A* 872:203-213, 2000.
17. Hough, J. S., Briggs, D. E., Stevens, R., and Young, T. W. *Malting and Brewing Science: Hopped Wort and Beer*. Aspen, Gaithersburg, MD, p. 526, 1999.
18. Kramp, C. *Elements d'arithmetique universelle "Notations"*. Cologne, 1808.
19. Krottenthaler, M., and Back, W. The effects of wort precooling during cast-out. *Brew. Distill. Int.* 14-15, 2001.
20. Krottenthaler, M., Hartmann, K., and Back, W. Einsatz eines Entspannungsverdampfers zur Wurzebehandelung. *Brauwelt* 39:1690-1693, 2001.
21. Leppänen, O. A., Denslow, J., and Ronkainen, P. P. Determination of thioacetates and some other volatile sulfur compounds in alcoholic beverages. *J. Agric. Food Chem.* 28:359-362, 1980.

22. MacLaurin, C. In: *Encyclopædia Britannica*, edited by Chisholm-Hugh. Cambridge University Press, Cambridge, U.K., 1911.
23. Mitani, Y., Suzuki, H., Abe, T., Nomura, M., and Shinotsuka, K. Performance of wort boiling with inert gas sparging for the energy reduction. In: *Proc. EBC Congr.*, p. 619-626, 1999.
24. Mitani, Y., Suzuki, H., Ohshima, T., Kobayashi, M., Kurihara, T., Akiyama, H., and Ishida, F. Method of boiling wort and wort boiler used therefor. Patent application EP19970942255, 1998.
25. Mortimer, R. G. Mathematical series. In: *Mathematics for Physical Chemistry, 4th Ed*. Elsevier, Boston, MA, pp. 119-128, 2013.
26. Seaton, J. C. Special malt types and beer quality. In: *Proceedings of the International Symposium—Malting and Brewing Technology: Progress Through Increased Knowledge,* Brussels, Belgium, pp. 29-30, 1993.
27. Seldeslachts, D., Van-Den-Eynde, E., and Degelin, L. Wort stripping. In: *Proc. Eur. Brew. Conv. Congr.*, *Maastricht*, 1997.
28. Stippler, K. The Merlin wort boiling system. *Ferment* 13:34-36, 2000.
29. Toutounian, F., and Nasabzadeh, H. A new method based on generalized Taylor expansion for computing a series solution of the linear systems. *Appl. Math. Comput.* 248:602-609, 2014.
30. Ullrich, S. E. *Barley: Production, Improvement, and Uses*. Blackwell Publishing, Hoboken, NJ, p. 640, 2011.
31. van Boekel, M. A. J. S. *Kinetic Modeling of Reactions In Foods*. CRC Press, Boca Raton, FL, p. 767, 2008.

Résumé de l’article

Derivation and Application of a Simultaneous Volatile Formation and Stripping Kinetics Equation for Wort Boiling

Z. S. C. Desobgo*, R. A. Stafford, and D. J. A. Metcalfe

Abstract

The paper showed the derivation of an equation to represent simultaneous dimethyl sulphide (DMS) formation and stripping during wort boiling. It also demonstrated a framework of linearization techniques for the resulting equation, which should facilitate its implementation. DMS formation and stripping were modelled by first-order rate equations with the rate constants k_1 and k_2 representing the rate constants for rate of DMS formation and DMS removal via stripping, respectively. The simultaneous processes of DMS formation and stripping were represented using an instantaneous differential mass balance. The resulting solution was seen to be similar to an equation stated previously by Mitani et al. Linearization of the derived simultaneous DMS formation and stripping model was done using a MacLaurin series coming from Taylor's series expansion.

Keywords: Dimethyl sulfide, S-Methylmethionine, Wort boiling, Volatile formation, Volatile stripping, Nonlinear MacLaurin series

IV.4.7) Comparative Study of Limit Dextrinase Potential of Three Sorghum Cultivars (*Safrari*, *Madjeru*, and *S.35*)

Titre de la revue

American Society of Brewing Chemists
FREE ACCESS

Comité de lecture

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, pleas
contact our customer service department to purchase a subscription.

Journal

Journal of the American Society of Brewing Chemists ›
The Science of Beer

This journal

Editorial board

Editor-in-Chief
Inge Russell

Editorial Board
G. Aerts
R. Agu
P. Aldred
M. Andersen
P. Aron
C. Boulton
S. Britton
D. Cook
C. Curtin
S. Deckers
J. De Clippeleer
S. Duke
A. Egi
R. Foster
L. Garbe
C. Henson

A. Hill
J. Hort
N. Kageyama
M. Kanauchi
S. Lawrence
Q. Li
B. Lodolo
A. Macintosh
D. Maskell
C. Powell
G. Sanchez
D. Sedin
S. Serna-Saldivar
T. Shellhammer
J. Sheppard
A. Speers
D. Stewart
E. Storgards
L. Van Nedervelde
K. Verstrepen
D. Vollmer
G. Walker
D. Wang
H. Wedler
X. Yin
M. Zarnkow
B. Ziola

Publisher
Amy L. Hope

Director of Publications
Greg Grahek

Technical Editor

Carol Duling

Circulation Coordinator

Dawn Wuest

Table des matières

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, please contact our customer service department to purchase a subscription.

Journal of the American Society of Brewing Chemists

The Science of Beer

2017 Impact Factor
0.880

Publish open access in this journal

Advanced search

Submit an article New content alerts RSS Citation search

Current issue Browse list of issues

Official Journal of the American Society of Brewing Chemists

This journal

Havlik et al.
Published online: 6 Jul 2018

Kirkendall et al.
Published online: 11 Jun 2018

Vanbeneden et al.
Published online: 7 Jun 2018

Fan et al.
Published online: 29 Mar 2018

Investigations into the Transfer Rate of Volatile Compounds in y in tanol-Water Partition Coefficient Model

Control of Fermentation By-Products and Aroma Features of Beer Pr ed with Sc Ale Yeast by Variation of Fermentation Temperature and Wort Aeration Rate

Analysis of Physicochemical Indices, Volatile Flavor Components, and Microbial Community of a Light-Flavor *Daqu*

See all volumes and issues

Volume 75, 2017 | Vol 74, 2016 | Vol 73,

Issue 4 | Issue 3 | Issue 2 | Issue 1

Review

Review

The Bitter, Twisted Truth of the Hop: 50 Years of Hop Chemistry

Patrick L. Ting & David S. Ryder

Pages: 161-180

Published online: 05 Feb 2018

42	0	0
Views	CrossRef citations	Altmetric

Original Articles

Article

Fusarium Profiling and Barley Malt Gushing Propensity

Vertti Virkajärvi, Tuija Sarlin & Arja Laitila

Pages: 181-192

Published online: 05 Feb 2018

5	0	0
Views	CrossRef citations	Altmetric

Article

Analyzing Differences in Freshness of SA-1 Hops by Headspace Solid-Phase Microextraction Gas Chromatography–Mass Spectrometry Combined with Chemometrics

Zechang Liu, Liping Wang & Yumei Liu

Pages: 193-200

Published online: 05 Feb 2018

6 Views | 0 CrossRef citations | 0 Altmetric

Article

Flavor Contribution of Esters in Lager Beers and an Analysis of Their Flavor Thresholds ›

Yang Xu, Deliang Wang, Hon g Li, JianQin Hao, Wei Jiang, Zhushui Liu & Qian Qin

Pages: 201-206

Published online: 05 Feb 2018

22 Views | 0 CrossRef citations | 0 Altmetric

Article

Sour Brewing: Impact of *Lactobacillus Amylovorus* FST2.11 on Technological and Quality Attributes of Acid Beers ›

Lorenzo C. Peyer, Martin Zarnkow, Fritz Jacob, David P. De Schutter & Elke K. Arendt

Pages: 207-216

Published online: 05 Feb 2018

19 Views | 0 CrossRef citations | 0 Altmetric

Article

Model Solution as a Beer Foam Standard Should Contain Fatty Acids ›

Petr Kosin, Jan Savel, Tomas Branyik & Filip Ulmann

Pages: 217-220

Published online: 05 Feb 2018

5 Views	1 CrossRef citations	0 Altmetric

Article

Ethanol Content Has Little Effect on the Sensory Orthonasal Detection Threshold of Hop Compounds in Beer ›

Meghan Peltz & Thomas Shellhammer

Pages: 221-227

Published online: 05 Feb 2018

13 Views	0 CrossRef citations	0 Altmetric

Article

Investigation of 2-Sulfanylethyl Acetate Cysteine-*S*-Conjugate as a Potential Precursor of Free Thiols in Beer ›

Marie-Lucie Kankolongo Cibaka, Thi Thu Hang Tran, Jacques Gros, Raphaël Robiette & Sonia Collin

Pages: 228-235

Published online: 05 Feb 2018

5 Views	0 CrossRef citations	0 Altmetric

Article

Mechanical Characterization of Individual Brewing Yeast Cells Using Microelectromechanical Systems (MEMS): Cell Rupture Force and Stiffness ›

Bruno Barazani, Stephan Warnat, Ted Hubbard & Andrew J. MacIntosh

Pages: 236-243

Published online: 05 Feb 2018

6 Views	0 CrossRef citations	0 Altmetric

Article

Impact of Extracellular Osmolality on *Saccharomyces* Yeast Populations during Brewing Fermentations ›

Shiwen Zhuang, Katherine Smart & Chris Powell

Pages: 244-254

Published online: 05 Feb 2018

9 Views | 0 CrossRef citations | 0 Altmetric

Article

Comparative Study of Limit Dextrinase Potential of Three Sorghum Cultivars (Safrari, Madjeru, and S.35) ›

A. C. Nguemogne, Z. S. C. Desobgo & E. J. Nso

Pages: 255-261

Published online: 05 Feb 2018

3 Views | 0 CrossRef citations | 0 Altmetric

Article

Reduction of Hordein Content in Beer by Applying Prolyl Endoprotease to the Malting Process ›

Joshua P. Taylor, Fritz Jacob, Emanuele Zannini & Elke K. Arendt

Pages: 262-268

Published online: 05 Feb 2018

5 Views | 0 CrossRef citations | 0 Altmetric

Article

Modeling of Dimethyl Sulfide Stripping Behavior When Applying Delayed Onset of Boiling during Wort Boiling ›

Z. S. C. Desobgo, R. A. Stafford & D. J. A. Metcalfe

Pages: 269-275

Published online: 05 Feb 2018

4 Views | 0 CrossRef citations | 0 Altmetric

Article

Profiling of Hop-Derived Flavan-3-ols from Lager Beer in Relation to Hopping Technology ›

Patricia M. Aron & Thomas H. Shellhammer

Pages: 276-282

Published online: 05 Feb 2018

8 Views | 0 CrossRef citations | 0 Altmetric

Explore

Most read articles | Most cited articles | Open access articles

Review article
Hop Aroma and Hoppy Beer Flavor: Chemical Backgrounds and Analytical Tools—A Review ›
Rettberg et al.

Article
The Freshening Power of Centennial Hops ›
Kirkendall et al.

Article
Impacts of Copper, Iron, and Manganese Metal Ions on the EPR Assessment of Beer Oxidative Stability ›
Jenkins et al.

Article
Use of Sorbents to Increase Beer Foam Stability ›
Kosin et al.

Pages de l’article

Comparative Study of Limit Dextrinase Potential of Three Sorghum Cultivars (Safrari, Madjeru, and S.35)

A. C. Nguemogne, *Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455 ENSAI, Ngaoundere, Cameroon;* **Z. S. C. Desobgo,**[1] *Department of Food Processing and Quality Control, University Institute of Technology (UIT), University of Ngaoundere, P.O. Box 455 UIT, Cameroon;* **and E. J. Nso,** *Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455 ENSAI, Ngaoundere, Cameroon*

ABSTRACT

J. Am. Soc. Brew. Chem. 75(3):255-261, 2017

Limit dextrinase extracted from three sorghum cultivar malts (Safrari, S.35, and Madjeru) used for the production of *bili-bili*, a traditional beer in the northern part of Cameroon, was subjected to comparison using dextrin as a substrate. A four-factor Doehlert experimental design was used to build a model in order to optimize the impact of factors (temperature, pH, buffer concentration, and incubation time) involved in the extraction of free limit dextrinase from sorghum. The response surface methodology revealed that the action of those factors was different for each sorghum cultivar, with closer behavior between Safrari and S.35. Madjeru was revealed to be completely different. Optimizing the concerted actions of the factors for limit dextrinase specific activity gave the following combinations: for Safrari, 43°C, pH 4, 135 mM, and 300 min, with maximal specific activity of 3.10 U/μg; for Madjeru, 35°C, pH 5.77, 50 mM, and 60 min, with maximal specific activity of 1.51 U/μg; and for S.35, 50°C, pH 4, 191 mM, and 205 min, with maximal specific activity of 3.05 U/μg.

Keywords: Sorghum, Limit dextrinase, Modeling, Optimization

Sorghum is a native African cereal, very well adapted to the semiarid and soudano-Sahelian conditions of Africa. Like rice and barley, sorghum belongs to the family of Gramineae (2,31). The disponibility of sorghum and its high content in starch and protein should encourage local use. Its nourishing wort allows it to be one of best choices as a raw material in the brewing process (31). Although sorghum was used for centuries to brew traditional (opaque) beer in Africa, in recent years, the brewing of sorghum beer has been developed in breweries. These types of beers are different from European beers because they contain large quantities of materials that are not respectively solubilized and fermented during mashing and fermentation (2). Several works were published on sorghum, sorghum malt, and sorghum mashing technology (1,2,20,30,33,36). These publications focused on remarkable problems in mashing that are peculiar to the characteristics of sorghum grains and malt. Among the generally highlighted problems are insufficient enzymes, especially those hydrolyzing starch (1). Essays on the improvement of the brewing properties of sorghum were written for the malting and mashing processes with the aim of enabling the development of starch hydrolyzing enzymes (10,11,14,21,32) such as α-amylase, β-amylase, and limit dextrinase. The main role played by limit dextrinase on the α-1,6-glycosidic bond cleavage of starch has been recognized for years. Many studies were conducted to isolate and purify that enzyme from cereals and also to characterize its action on amylopectin and its degradation products. This was mainly done on barley (19,22,26,35) and other cereals such as maize (7), rice (41), and sorghum (18). The results of the study conducted on properties of three sorghum cultivars used for the production of *bili-bili* beverage in northern Cameroon revealed a high enzymatic potential of local *bili-bili* malt compared with the one produced in laboratory (30). The aim of the present work was therefore to extract limit dextrinase of malt of three sorghum cultivars (Madjeru, Safrari, and S.35) produced in Cameroon and compare its specific activity by modeling and optimization.

[1] Corresponding author. E-mail: desobgo.zangue@gmail.com

http://dx.doi.org/10.1094/ASBCJ-2017-3015-01

© 2017 American Society of Brewing Chemists, Inc.

EXPERIMENTAL

Biological Material

Sorghum cultivars (Safrari, Madjeru, and S.35) were obtained from IRAD, Maroua, Cameroon.

Chemicals

Dextrin from potato starch and Coomassie blue 98% were obtained from Sigma-Aldrich Chemie GmbH (Munich, Germany). Sodium acetate buffer solution was obtained from SERVA Electrophoresis GmbH (Heidelberg, Germany). Potassium iodide, hydrochloric acid solution, ethanol 95%, and phosphoric acid 85% were from Fisher Scientific UK (Loughborough, U.K). Iodine was obtained from Thermo Fisher Scientific (Geel, Belgium). The grade filter papers Whatman No. 1 (Ø 90 mm) were obtained from Whatman, GE Healthcare UK Ltd.

Malting

Sorghum grains (200 g) (Safrari, Madjeru, and S.35 cultivars) were washed three times using 600 mL of distilled water to remove dirt and foreign bodies. The grains were steeped in 600 mL of distilled water for 48 h at 31°C in a Heraeus-type incubator (D-63450, Hanau, Germany) with two changes of water at intervals of 12 h before steep out. Germination was carried out for 72 h in the same Heraeus-type incubator at a temperature of 28.5°C with water (18 mL) sprinkled on the grains on a daily basis. The malt was then air dried at 28°C for 24 h using a ventilated Memmert-type incubator. The malt was rubbed off of its rootlets and afterward underwent grinding using Phinx Brilliant G250's manual grindstone. Finally, the obtained flour was sieved (Ø ≤ 0.5 mm) using manual sieving equipment (CSC Scientific, Fairfax, VA, U.S.A.) and stored in plastics sachets at 4°C until further use.

Enzymatic Extraction

The enzymatic extraction was made by modification of the technique of McCleary (29) (Megazyme International, Ireland). The modifications brought here concerned the buffer (sodium acetate) and the malt flour/volume of buffer ratio (1/10); no reducing agent was used during the extraction. After extraction, centrifugation was made at 6,000 × *g* for 30 min at 4°C.

Experimental Design, Modeling, Validation of the Model, and Optimization

Response surface methodology with a Doehlert design was used to carry out the experiments in order to model and optimize

the limit dextrinase extraction. The independent variables (factors) were the temperature (x_1), pH (x_2), buffer concentration (x_3), and incubation time (x_4). The intervals of these factors were: X_1, 30–50°C; X_2, 4–7; X_3, 50–200 mM, and X_4, 60–300 min. The response was the specific activity of limit dextrinase.

From the coded variables, many equations were used to transform them into real values to realize experiments in the laboratory. Those equations were as follows:

$$X_i = X_{0i} + x_i \times \Delta X_i \quad (1)$$

$$N = k^2 + k + k_0 \quad (2)$$

The four-factor Doehlert design gave a total of 25 experiments (with five replicates at the central point) as shown in Table I.

Mathematical models describing the relationships among the process-dependent variable and the independent variables in a second-order equation were developed (17). Design-based experimental data were matched according to the following second-order polynomial equation:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum\sum_{i<j}^{k} \beta_{ij} x_i x_j + \varepsilon \quad (3)$$

where Y was the response, x_i and x_j were the variables, β_0 was the constant, β_i was the coefficient of the linear terms, β_{ii} was the coefficient of the quadratic terms, and β_{ij} is the coefficient of the interaction terms.

The coefficients of the models were obtained using Minitab version 16 software (Minitab, Coventry, U.K.). This software had also given a statistical analysis (ANOVA) on the models, and the curves were plotted using Sigmaplot version 12.5 (Systat Software, San Jose, CA, U.S.A.).

The validation of the models was obtained by calculating average absolute deviation (AAD), the bias factor (B_f), and the accuracy factor (A_f) (6,34), which were expressed as follows:

$$\mathrm{AAD} = \frac{\left[\sum_{i=1}^{N}\left(\frac{\left|Y_{i,\exp} - Y_{i,cal}\right|}{Y_{i,\exp}}\right)\right]}{N} \quad (4)$$

$$B_f = 10^{\frac{1}{N}\sum_{i=1}^{N}\log\left(\frac{Y_{i,cal}}{Y_{i,\exp}}\right)} \quad (5)$$

$$A_{f1} = 10^{\frac{1}{N}\sum_{i=1}^{N}\left|\log\left(\frac{Y_{i,cal}}{Y_{i,\exp}}\right)\right|} \quad (6)$$

where $Y_{i,\exp}$ and $Y_{i,cal}$ were respectively experimental and calculated responses and N was the number of experiments used in the calculation.

Lastly, optimization was done using Mathcad 15.0 software (build 15.0.0.436 Parametric Technology, Needham, MA, U.S.A.).

Analysis

Moisture content. Moisture content of sorghum was determined on a ground sample by oven drying at 105°C for 24 h (3).

Analysis of total protein content. Total protein content was determined by a standard method (12) after sulfuric acid mineralization of samples in the presence of selenium catalyst, with a coefficient of conversion of nitrogen into protein of 6.25 (5).

Germinative capacity. Three lots of 200 grains of sorghum were immersed in 200 mL of hydrogen peroxide solution at 7.5

TABLE I
Doehlert Experimental Design: Coded Variables, Real Variables, and Responses[a]

	Coded variables				Real variables				Responses (specific activity of limit dextrinase [U/µg])								
									Safrari			Madjeru			S.35		
Number	x_1	x_2	x_3	x_4	X_1	X_2	X_3	X_4	Exp.	Cal.	Res.	Exp.	Cal.	Res.	Exp.	Cal.	Res.
1	1	0	0	0	50	5.50	125	180	1.254	1.182	0.072	0.510	0.540	0.031	1.171	1.102	0.070
2	–1	0	0	0	30	5.50	125	180	0.987	1.059	–0.072	0.668	0.638	–0.031	0.689	0.759	–0.070
3	0.5	0.866	0	0	45	7.00	125	180	0.821	0.832	–0.012	0.305	0.274	–0.031	0.814	0.917	–0.102
4	–0.5	–0.866	0	0	35	4.00	125	180	1.971	1.959	0.012	0.145	0.176	0.031	1.607	1.505	0.102
5	0.5	–0.866	0	0	45	4.00	125	180	1.942	2.011	–0.069	0.189	0.313	0.124	1.929	2.040	–0.111
6	–0.5	0.866	0	0	35	7.00	125	180	0.830	0.762	0.069	0.632	0.508	–0.124	1.219	1.108	0.111
7	0.5	0.289	0.816	0	45	6.00	200	180	1.107	0.972	0.134	0.766	0.731	–0.035	1.268	1.180	0.088
8	–0.5	–0.289	–0.816	0	35	5.00	50	180	1.577	1.712	–0.134	0.862	0.897	0.035	0.947	1.034	–0.088
9	0.5	–0.289	–0.816	0	45	5.00	50	180	1.714	1.781	–0.067	0.956	0.864	–0.092	0.711	0.725	–0.014
10	0	0.577	–0.816	0	40	6.50	50	180	1.223	1.146	0.077	0.816	0.894	0.078	0.623	0.593	0.029
11	–0.5	0.289	0.816	0	35	6.00	200	180	0.985	0.919	0.067	0.705	0.796	0.092	0.542	0.528	0.014
12	0	–0.577	0.816	0	40	4.50	200	180	1.458	1.534	–0.077	0.708	0.631	–0.078	1.298	1.327	–0.029
13	0.5	0.289	0.204	0.791	45	6.00	143.75	300	1.338	1.532	–0.195	0.771	0.806	0.035	0.799	0.855	–0.055
14	–0.5	–0.289	–0.204	–0.791	35	5.00	106.25	60	2.042	1.848	0.195	1.008	0.973	–0.035	0.911	0.855	0.055
15	0.5	–0.289	–0.204	–0.791	45	5.00	106.25	60	1.902	1.839	0.063	0.937	0.874	–0.063	1.053	0.997	0.056
16	0	0.577	–0.204	–0.791	40	6.50	106.25	60	1.765	1.899	–0.134	0.765	0.843	0.077	0.629	0.667	–0.038
17	0	0	0.612	–0.791	40	5.50	181.25	60	1.458	1.582	–0.124	0.686	0.707	0.021	0.680	0.753	–0.073
18	–0.5	0.289	0.204	0.791	35	6.00	143.75	300	1.338	1.401	–0.063	0.741	0.805	0.063	0.599	0.654	–0.056
19	0	–0.577	0.204	0.791	40	4.50	143.75	300	2.844	2.710	0.134	0.655	0.578	–0.077	1.294	1.256	0.038
20	0	0	–0.612	0.791	40	5.50	68.75	300	2.130	2.006	0.124	0.726	0.706	–0.021	0.680	0.607	0.073
21	0	0	0	0	40	5.50	125	180	1.434	1.523	–0.089	0.802	0.773	–0.029	0.780	0.767	0.012
22	0	0	0	0	40	5.50	125	180	1.465	1.523	–0.058	0.780	0.773	–0.007	0.788	0.767	0.021
23	0	0	0	0	40	5.50	125	180	1.503	1.523	–0.020	0.788	0.773	–0.016	0.769	0.767	0.001
24	0	0	0	0	40	5.50	125	180	1.669	1.523	0.146	0.745	0.773	0.028	0.764	0.767	–0.003
25	0	0	0	0	40	5.50	125	180	1.543	1.523	0.021	0.749	0.773	0.024	0.736	0.767	–0.031

[a] Exp. = experimental results; Cal. = calculated (theoretical) results obtained from the models; and Res. = residue coming from the difference between experimental and calculated values.

g/L at room temperature (25°C) for 2 days. After this time, the hydrogen peroxide solution was replaced by a fresh solution (at the same concentration) for an additional 24 h, after which the solution was poured. The germinated grains were counted, and the result was expressed as a percentage (3).

Germinative energy. Germinative energy was determined by placing 100 kernels of sorghum on two layers of Whatman No. 1 filter paper, in a 9.0 cm diameter Petri dish, and adding 4.0 mL of purified water. Samples were controlled at 25°C and 90% relative humidity in a germination chamber. Germinated kernels were removed after 24 and 48 h, and a final count was made at 72 h (3).

Water sensitivity. Water sensitivity is determined exactly as described for germination energy, except that 8.0 mL of purified water is added to each Petri dish (3). The water sensitivity value is the numerical difference between the 4 and 8 mL tests.

Assay of limit dextrinase. The limit dextrinase assay was a modification of the literature technique (16) using for that purpose dextrin as a substrate. In a containing test tube, 0.5 mL of dextrin (1%), 0.3 mL of acetate buffer, and 0.2 mL of distilled water were introduced. The mixture was heated at 70°C for 10 min and cooled to approximately 40°C in a water bath (Memmert, type F-Nr 760). Enzymatic extract (0.1 mL) was added to this mixture and maintained at 40°C for 10 min (Memmert, type F-Nr 760). The reaction was stopped by addition of 1 mL of hydrochloric acid 1M and cooled quickly at the ambient temperature (25°C). A volume of 0.1 mL of this mixture was taken, to which 15 mL of distilled water and 1 mL of iodized solution (0.2% of iodine in 2% of KI) were added. A blank was prepared by adding 0.1 mL of enzymatic extract after the reaction was stopped by addition of the hydrochloric acid. Absorbance was measured at 620 nm. The total activity was then obtained in U/mL. The specific activity was obtained in U/μg by integrating the protein content.

RESULTS AND DISCUSSION

Characterization of Sorghum Grains

The results of the characterization of sorghum grains with the aim of estimating their viabilities are presented in Table II. According to that table, the viability of grains was at the standard level (3) and the water sensitivity was similar to the literature (30).

Modeling

The limit dextrinase was extracted using a four-factor Doehlert experimental design (25 experiments), and in each case the specific activity was determined (Table I). This permitted us to obtain models via matrix calculation using Minitab version 16 software. The models were as follows:

$$\begin{aligned} Y_{Saf}(x_1,x_2,x_3,x_4) = {} & 1.5228 + 0.0615x_1 - 0.6860x_2 \\ & - 0.2473x_3 + 0.0765x_4 - 0.402x_1^2 \\ & - 0.042x_2^2 - 0.157x_3^2 + 0.647x_4^2 \\ & + 0.012x_1x_2 - 0.013x_1x_3 + 0.088x_1x_4 \\ & + 0.135x_2x_3 - 0.851x_2x_4 + 0.154x_3x_4 \end{aligned} \quad (7)$$

$$\begin{aligned} Y_{Mad}(x_1,x_2,x_3,x_4) = {} & 0.7728 - 0.0485x_1 + 0.0846x_2 \\ & - 0.1015x_3 - 0.0795x_4 - 0.1838x_1^2 \\ & - 0.5455x_2^2 + 0.2267x_3^2 + 0.1217x_4^2 \\ & - 0.214x_1x_2 + 0.056x_1x_3 + 0.128x_1x_4 \\ & - 0.042x_2x_3 + 0.105x_2x_4 + 0.471x_3x_4 \end{aligned} \quad (8)$$

$$\begin{aligned} Y_{S.35}(x_1,x_2,x_3,x_4) = {} & 0.7674 + 0.1713x_1 - 0.4390x_2 \\ & + 0.1394x_3 + 0.0158x_4 + 0.1626x_1^2 \\ & + 0.7790x_2^2 - 0.0393x_3^2 - 0.0792x_4^2 \\ & - 0.420x_1x_2 + 0.738x_1x_3 - 0.000x_1x_4 \\ & + 0.085x_2x_3 + 0.026x_2x_4 + 0.048x_3x_4 \end{aligned} \quad (9)$$

where $Y_{Saf}(x_1,x_2,x_3,x_4)$ represents the mathematical model for Safrari, $Y_{Mad}(x_1,x_2,x_3,x_4)$ the mathematical model for Madjeru, and $Y_{S.35}(x_1,x_2,x_3,x_4)$ the mathematical model for S.35; x_1 is temperature (°C), x_2 is pH, x_3 is buffer concentration (mM), and x_4 is time (min).

The mathematical models were polynomials having four variables with R^2 equal to 0.947, 0.914, and 0.964, respectively, for Safrari, Madjeru, and S.35. These coefficients, coupled to AAD values of 0.06, 0.10, and 0.06, respectively, for Safrari, Madjeru, and S.35, allowed the validation of the models for specific activities of limit dextrinase. In addition, a bias factor of 1.00, 1.01, and 1.00 coupled to exactitude factors of 1.06, 1.10, and 1.06 for Safrari, Madjeru, and S.35, respectively, also allowed for validation of the models according to the method described (34). The factors of the models were of first degree (x_1, x_2, x_3, and x_4), of second degree (x_1^2, x_2^2, x_3^2, and x_4^2), and of interaction (x_1x_2, x_1x_3, x_1x_4, x_2x_3, x_2x_4, and x_3x_4) form. They were statistically significant or not if the probability (P) was ≤0.05 or ≥0.05, respectively (Table III).

The factor x_1, corresponding to temperature as the sole factor, had no significant impact on the limit dextrinase activity of Safrari and Madjeru cultivars, with a respective probability of 0.414 and 0.283. However, it had significant impact on the limit dextrinase activity of S.35 with a probability of 0.003. Its contribution was 1.71, 2.00, and 5.45% (Table III), respectively, for Safrari, Madjeru, and S.35. Concerning S.35, that factor contributed to increase the limit dextrinase activity. In fact, the observation was similar to the literature, where an increase of limit dextrinase activity with temperature was noted (24,27,35). The temperature factor in the second degree (x_1^2) had significant impact on the reduction of limit dextrinase activity of Safrari and Madjeru, with respective probabilities of 0.014 corresponding to 11.25% contribution and 0.044 corresponding to 7.62% contribution. It also had no significant impact on the limit dextrinase activity of S.35, with a probability of 0.081, corresponding to 5.17% contribution. This impact on the reduction of limit dextrinase activity was explained by the fact that enzyme proteins are precisely folded polypeptide chains, held together by relatively weak molecular forces. The folded structure determined the integrity of the catalytic site within the enzyme, and this was easily disrupted (denatured) by energy changes in the enzyme's environment by higher temperature (23).

The factor x_2 (pH), as the sole factor, had no significant impact on the limit dextrinase activity of Madjeru cultivar, with a probability of 0.076 and 3.52% contribution. But it had significant impact on the reduction of limit dextrinase activity of Safrari and S.35 with a probability of 0.000 for both and with a contribution

TABLE II
Characterization of Cultivars Safrari, Madjeru, and S.35[a]

Characteristics	Safrari	Madjeru	S.35	Norms (3)
Germination energy, 4 mL (%)	99	98	94	60–99
Germination energy, 8 mL (%)	97	97	90	40–99
Water sensitivity (%)	2	1	4	ND
Germinative capacity (%)	98	99.5	98	92–100
Moisture (%)	10.8 ± 0.5	10.4 ± 0.3	9.96 ± 0.7	≤13

[a] ND = not determined.

of 19.21 and 13.97% (Table III), respectively, for Safrari and S.35. That impact on the reduction of the limit dextrinase activity was observed for *Pokko* and barley malt extract after reaching a pH of 4.5 (28,35). It could be explained by the fact that pH affects the solubility of limit dextrinase and the detailed structure of its active site, and by then impacted on the activity of the enzyme (25,42). If the shape or polarity of the active site changes, that will alter its effectiveness as a catalyst. The pH factor in the second degree (x_2^2) had significant impact on the reduction of limit dextrinase activity of Safrari and Madjeru, with both probabilities of 0.000. It also had no significant impact on the limit dextrinase activity of S.35, with a probability of 0.0764 corresponding to 5.17% contribution.

The factor x_3 (buffer concentration) had a significant impact on the limit dextrinase activity of Safrari, Madjeru, and S.35 cultivars, with a probability of 0.006, 0.039, and 0.011, respectively. The contributions were 6.94, 4.22, and 4.44%, respectively, for Safrari, Madjeru, and S.35 (Table III). This could be explained by the fact that, the larger the difference between the pI and the pH of interest, the greater the net charge on the protein. This implies that the ability of ionic compounds to cause either stabilization (the case of S.35) or destabilization (the case of Safrari and Madjeru) of the protein by binding to specific residues should increase as the difference between pI and pH becomes greater (4). Literature has suggested that any proton transfer event associated with allosteric or catalytic enzyme sites was associated with a partial denaturation that was cooperative within considerable but localized regions of the protein domain (8,39). The buffer concentration factor in the second degree (x_3^2) had no significant impact on the limit dextrinase activity of Safrari and S.35, with respective probabilities of 0.243 corresponding to 4.41% contribution and 0.628 corresponding to 1.28% contribution. It also had significant impact on the increasing limit dextrinase activity of Madjeru, with a probability of 0.013 corresponding to 9.41% contribution. In this system, the higher buffer concentration stabilized the enzyme and contributed to increase the limit dextrinase activity.

The factor x_4 (incubation time) had no significant impact on the limit dextrinase activity of Safrari, Madjeru, and S.35 cultivars, with probabilities of 0.313, 0.093, and 0.732, respectively. The contributions were 2.15, 3.30, and 0.51%, respectively, for Safrari, Madjeru, and S.35 (Table III). Most enzyme activities were relatively constant with varying incubation times (37). The incubation time factor in the second degree (x_4^2) had no significant impact on the limit dextrinase activity of Madjeru and S.35, with respective probabilities of 0.116 corresponding to 5.07% contribution and 0.311 corresponding to 2.53% contribution. It had significant impact on the increasing limit dextrinase activity of Safrari, with a probability of 0.000 corresponding to 18.12% contribution. In this case, the better expression of Safrari limit dextrinase was observed for a longer incubation time.

The interaction x_1x_2 (temperature/pH) had a significant impact on the reduction of the limit dextrinase activity of S.35, as shown in Figure 1, with a probability of 0.005 and a contribution of 13.34%. That impact was not significant for Safrari and Madjeru, because the respective probabilities were 0.957 and 0.081 with respective contributions of 0.29% and 8.91% (Table III). For S.35, at lower pH (4–4.5), the decrease of limit dextrinase activity was significant but lower whatever the temperature, and that reduction became higher at pH higher than 4.5. Increasing the temperature increases the energy of the bonds and atoms in the protein, to the

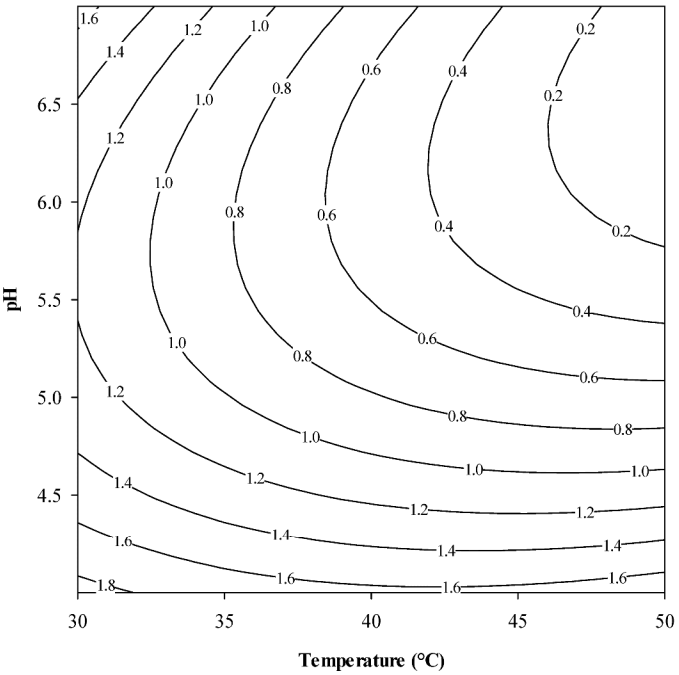


Fig. 1. Impact of temperature/pH interaction on the activity of limit dextrinase (incubation time, 60 min; buffer concentration, 50 mM) for the cultivar S.35.

TABLE III
Estimated Coefficients Impact and Contributions to the Limit Dextrinase Activity[a]

	Safrari			Madjeru			S.35		
Source	**Coefficients**	***P***	**Contribution (%)**	**Coefficients**	***P***	**Contribution (%)**	**Coefficients**	***P***	**Contribution (%)**
A: x_1	0.0615	0.414	1.71	–0.0485	0.283	2.00	0.1713	**0.003**	5.45
B: x_2	–0.0594	**0.000**	19.21	0.0732	0.076	3.52	–0.3802	**0.000**	13.97
C: x_3	–0.2018	**0.006**	6.94	–0.0828	**0.039**	4.22	0.1137	**0.011**	4.44
D: x_4	0.0605	0.313	2.15	–0.0629	0.092	3.30	0.0125	0.732	0.51
AA	–0.402	**0.014**	11.25	–0.1838	**0.044**	7.62	0.1626	0.081	5.17
AB	0.010	0.952	0.29	–0.1855	0.081	8.91	–0.364	**0.005**	13.34
AC	–0.011	0.950	0.37	0.045	0.662	2.37	0.602	**0.000**	23.47
AD	0.069	0.694	2.45	0.101	0.343	5.29	–0.000	0.998	0.03
BB	–0.031	0.764	1.16	–0.4091	**0.000**	22.63	0.5842	**0.000**	24.79
BC	0.095	0.532	3.77	–0.0299	0.739	1.76	0.0601	0.525	2.71
BD	–0.583	**0.003**	23.85	0.0716	0.434	4.34	0.0176	0.852	0.82
CC	–0.1048	0.243	4.41	0.1509	**0.013**	9.41	–0.0262	0.628	1.28
CD	0.099	0.494	4.31	0.0716	**0.004**	19.56	0.0308	0.730	1.50
DD	0.4046	**0.000**	18.12	0.0762	0.116	5.07	–0.0496	0.310	2.53
			100.00			100.00			100.00

[a] Bolded *P* values are significant.

point at which there was enough energy to overcome the force of the intermolecular reactions, resulting in them breaking. Disruption of the interactions in any case led to some of the protein losing its ability to be held in a certain shape, which then reduced its catalytic activity (because catalytic activity relied on the shape). The loss of activity was proportional to the extent of the disruptions, which were in turn proportional to the extent of the change in pH or temperature (9).

The interaction x_1x_3 (temperature/buffer concentration) had a significant impact on the increasing of the limit dextrinase activity of S.35, as shown in Figure 2, with a probability of 0.000 and a contribution of 23.47%. It was not significant for Safrari and Madjeru because their respective probabilities were 0.951 and 0.654 with contributions of 0.37 and 2.37%. This augmentation of limit dextrinase activity was explained by the positive influence of increases in ionic strength (which was attributable to the increase of buffer concentration), which stabilized the enzyme by increasing its thermostability so that whatever temperature was used, activity increased. The same observation was made in the literature on alkaline phosphatase activity in *Escherichia coli* (40).

The interaction x_2x_4 (pH/incubation time) had no significant impact on the limit dextrinase activity of Madjeru and S.35 cultivars (Table III) with respective probabilities of 0.434 and 0.852. However, its impact is significant with Safrari (Fig. 3), with a probability of 0.003, and it tends to slow down the enzyme activity here, given the negative coefficient. This can be explained by the fact that if the pH of the buffer is not at the optimum pH range of the enzyme for a relatively long time, the enzyme activity could decrease due to instability and even loss of activity by the enzyme out of its optimum pH range (38).

The interactions x_1x_4 and x_2x_3 (temperature/incubation time and pH/buffer concentration, respectively) had no significant impact on the limit dextrinase activity of Safrari, Madjeru, and S.35 cultivars, with respective probabilities of 0.694, 0.343, 0.998 and 0.532, 0.739, 0.525. The contributions were 2.45, 5.29, and 0.03% and 3.77, 1.76, and 2.71%, respectively, for Safrari, Madjeru, and S.35 (Table III).

The interaction x_3x_4 (buffer concentration/incubation time) had a significant impact on increasing the limit dextrinase activity of Madjeru as shown in Figure 4, with a probability of 0.004 and a contribution of 19.56%. It was not significant for Safrari and S.35, and the respective probabilities were 0.494 and 0.730 with contributions of 4.31 and 1.50%. Because the buffer concentration contributed to stabilize the limit dextrinase, one observed that as incubation time increased, enzyme activity increased too.

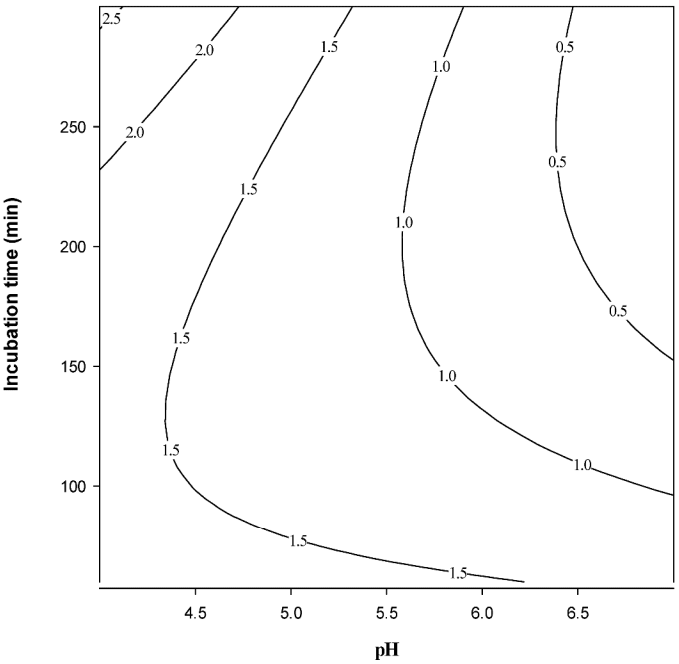


Fig. 3. Impact of incubation time/pH interaction on the activity of limit dextrinase (temperature, 30°C; buffer concentration, 50 mM) for the cultivar Safrari.

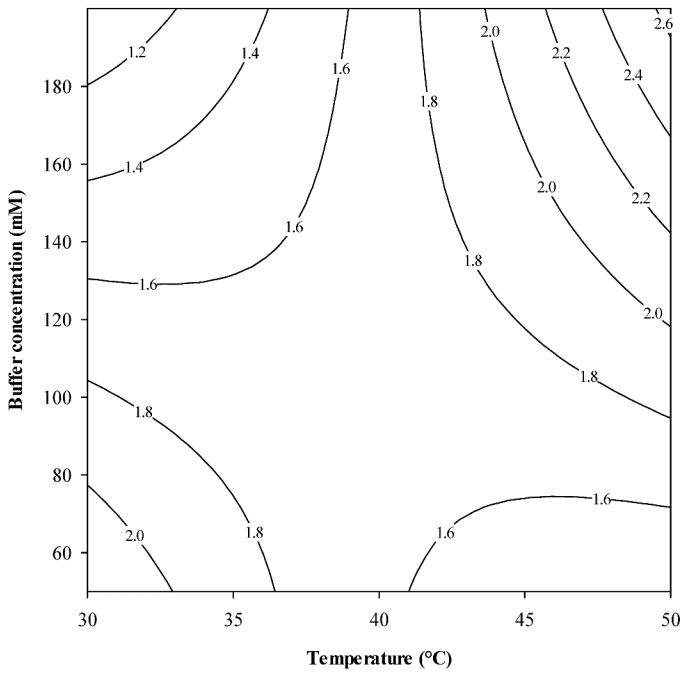


Fig. 2. Impact of temperature/buffer concentration interaction on the activity of limit dextrinase (incubation time, 60 min; pH 4) for the cultivar S.35.

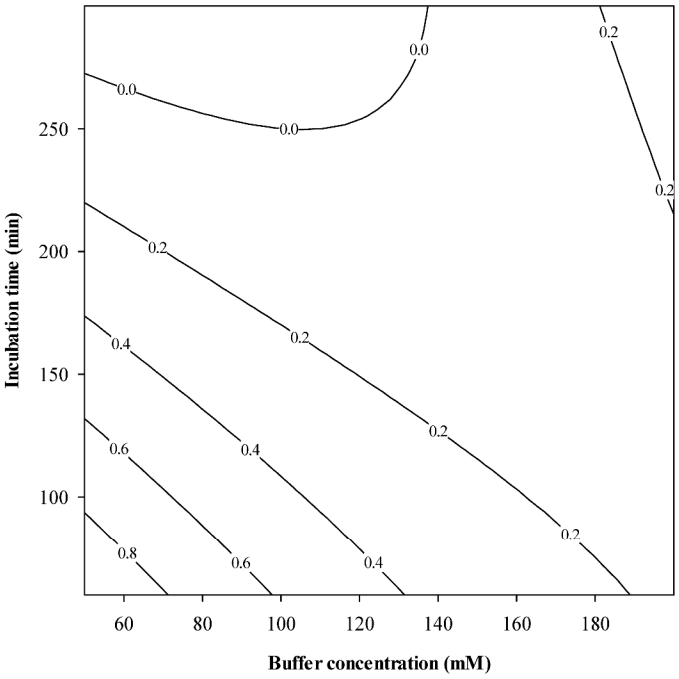


Fig. 4. Impact of buffer concentration/incubation time interaction on the activity of limit dextrinase (temperature, 30°C; pH 4) for the cultivar Madjeru.

TABLE IV
Optimal Extraction Conditions for Limit Dextrinase Activity of Safrari, Madjeru, and S.35 Cultivars

	Safrari		Madjeru		S.35	
Parameter	**Coded**	**Real**	**Coded**	**Real**	**Coded**	**Real**
Temperature (°C)	0.307	43	–0.471	35	0.992	50
pH	–0.865	4.00	0.158	5.77	–0.866	4.00
Buffer concentration (mM)	0.108	135	–0.816	50	0.816	200
Incubation time (min)	0.791	300	–0.791	60	0.199	210
Specific activity (U/μg)	3.10		1.51		3.05	

This observation was also noticed for α-amylase in the literature (13).

Optimization

After modeling and understanding the impact of the factors on limit dextrinase activity, optimization was done to obtain the optimal conditions for limit dextrinase extraction of each sorghum cultivar. The summary appears in Table IV as follows.

According to Table IV, the cultivar Safrari had the stronger limit dextrinase activity, followed by S.35 and Madjeru. Also, the conclusion was that the characteristics of an enzyme depend on the cultivar (29). The optimal temperature conditions obtained were similar to the one for cereal flour (43°C) in general (29) and rice (40°C) in particular (15). The optimal pHs of 4 and 5.7 obtained for Safrari and S.35, respectively, were in agreement with the results obtained from malted barley (19,26). Incubation times of 300 and 210 min for Safrari and S.35, respectively, were obtained.

CONCLUSIONS

This work shows that the factors of temperature, pH, buffer concentration, and incubation time are of different importance on limit dextrinase extraction and activation, and depend on the cultivar used. The modeling permitted understanding the action of each factor and the interactions in the extraction process. By that way, factors implemented for limit dextrinase extraction and optimization are each statistically significant in at least one model or another, apart from the case of the factor incubation time, which was statistically insignificant in all three models. After optimizing the extraction conditions, higher temperature, lower pH, higher buffer concentration, and longer incubation time were found to be best for most cases (Safrari and S.35). That optimization also shows that Safrari and S.35 have closer optima of limit dextrinase activity, with Safrari the highest and Madjeru the lowest.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the departments of Process Engineering and Food Science and Nutrition of the National School of Agro-Industrial Sciences (ENSAI), The University of Ngaoundere (Cameroon), for providing necessary facilities for the successful completion of this research work.

LITERATURE CITED

1. Agu, R. C., and Palmer, G. H. The effect of temperature on the modification of sorghum and barley during malting. *Process Biochem.* 32:501-507, 1997.
2. Agu, R. C., and Palmer, G. H. A reassessment of sorghum for lager-beer brewing. *Bioresource Technol.* 66:253-261, 1998.
3. Analytica-EBC. *European Brewery Convention*. Fachverlag Hans Carl, Nürnberg, Germany, 1998.
4. Antosiewiez, J., McCammonb, J. A., and Gilson, M. K. Prediction of pH dependent properties of proteins. *J. Mol. Biol.* 238:415-436, 1994.
5. AOAC. *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington, DC, 1980.
6. Baranyi, J., Pin, C., and Ross, T. Validating and comparing predictive models. *Int. J. Food Microbiol.* 48:159-166, 1999.
7. Beatty, M. K., Rahman, A., Cao, H., Woodman, W., Lee, M., Myers, A. M., and James, M. G. Purification and molecular genetic characterization of ZPU1, a pullulanase-type starch-debranching enzyme from maize. *Plant Physiol.* 119:255-266, 1999.
8. Belrhali, H., Nollert, P., Royant, A., Menzel, C., Rosenbush, J. P., Landau, E. M., and Pebay-Peyroula, E. Protein, lipid and water organization in bacteriorhodopsin crystals: A molecular view of the purple membrane at 1.9 Å resolution. *Structure* 7:909-917, 1999.
9. Bennett, T. P., and Frieden, E. *Modern Topics in Biochemistry*. Macmillan, London, 1969.
10. Desobgo, Z. S. C., Nso, E. J., and Tenin, D. Optimisation of the action of commercial mashing enzymes on wort extracts and free amino nitrogen of the Safrari sorghum cultivar. *Tech. Q. Master Brewers Assoc. Am.* 48:77-86, 2011.
11. Desobgo, Z. S. C., Nso, E. J., and Tenin, D. The response surface methodology as a reliable tool for evaluating the need of commercial mashing enzymes for alleviating the levels of reducing sugars of worts of malted sorghum: Case of the Safrari cultivar. *J. Brew. Distill.* 2:5-15, 2011.
12. Devani, M. B., Shishoo, C. J., Shah, S. A., and Suhagia, B. N. Microchemical methods: Spectrophotometric methods for microdetermination of nitrogen in Kjeldahl digest. *J. Assoc. Anal. Chem.* 72:953-956, 1989.
13. El-Safey, E. M., and Ammar, M. S. Purification and characterization of alpha-amylase isolated from *Aspergillus flavus* var. *columnaris*. *Ass. Univ. Bull. Environ. Res.* 7:94-100, 2004.
14. Ezeogu, L. I., and Okolo, B. N. Effects of air rest period on the mobilization of sorghum reserve proteins. *J. Inst. Brew.* 101:463-468, 1995.
15. Furegon, L., Peruffo, A. D. B., and Curion, A. Immobilization of rice limit dextrinase on γ-alumina beads and its possible use in starch processing. *Process Biochem.* 32:113-120, 1997.
16. Fuwa, H. A new method for microdetermination of amylase activity by the use of amylose as the substrate. *J. Biochem.* 41:583-603, 1954.
17. Giovanni, M. Response surface methodology and product optimization. *J. Food Technol.* 37:41-45, 1983.
18. Hardie, D. G., Manners, D. J., and Yellowlees, D. The limit dextrinase from malted sorghum (*Sorghum vulgare*). *Carbohydr. Res.* 50:75-85, 1976.
19. Heisner, C. B., and Bamforth, C. W. Thioredoxin in barley: Could it have a role in releasing limit dextrinase in brewery mashes? *J. Inst. Brew.* 114:122-126, 2008.
20. Igyor, M. A., Ogbonna, A. C., and Palmer, G. H. Effect of malting temperature and mashing methods on sorghum wort composition and beer flavor. *Process Biochem.* 36:1039-1044, 2001.
21. Igyor, M. A., Ogbonna, A. C., and Palmer, G. H. Effect of malting temperature and time on enzyme development and sorghum wort properties. *J. Inst. Brew.* 104:101-104, 1998.
22. Kristensen, M., Planchot, V., Abe, J., and Svenson, B. Large-scale purification and characterization of barley limit dextrinase, a member of the α-amylase structural family. *Cereal Chem.* 75:473-479, 1998.
23. Law, B. A. The nature of enzymes and their action in foods. In: *Enzymes in Food Technology*. R. J. Whitehurst and B. A. Law, eds. Sheffield Academic Press, Sheffield, U.K., pp. 1-18, 2002.
24. Lee, W. J., and Pyler, R. E. Barley malt limit dextrinase: Varietal, environmental, and malting effects. *J. Am. Soc. Brew. Chem.* 42:11-17, 1984.

25. Longstaff, M. A., and Bryce, J. H. Development of limit dextrinase in germinated barley (*Hordeum vulgare* L.) (Evidence of proteolytic activation). *Plant Physiol.* 101:881-889, 1993.
26. MacGregor, A. W., Macri, L. J., Schoeder, S. W., and Bazin, S. L. Limit dextrinase from malted barley: Extraction, purification, and characterization. *Cereal Chem.* 71:610-617, 1994.
27. Manners, D. J., and Rowe, K. L. Studies of carbohydrate-metabolizing enzymes Part XXV. The debranching enzyme system in germinated barley. *J. Inst. Brew.* 77:358-365, 1971.
28. McCafferty, C. A., Jenkinson, H. R., Brosnan, J. M., and Bryce, J. H. Limit dextrinase—Does its malt activity relate to its activity during brewing? *J. Inst. Brew.* 110:284-296, 2004.
29. McCleary, B. V. Measurement of the content of limit dextrinase in cereal flours. *Carbohydr. Res.* 227:257-268, 1992.
30. Nso, E. J., Ajebesone, P. E., Mbofung, C. M., and Palmer, G. H. Properties of three sorghum cultivars used for the production of *bilibili* beverage in northern Cameroon. *J. Inst. Brew.* 109:245-250, 2003.
31. Odibo, F. J. C., Nwankwo, L. N., and Agu, R. C. Production of malt extract and beer from Nigerian sorghum varieties. *Process Biochem.* 37:851-855, 2002.
32. Okolo, B. N., and Ezeogu, L. I. Enhancement of amylolytic potential of sorghum malts by alkaline steep treatment. *J. Inst. Brew.* 102:79-85, 1996.
33. Owuama, C. I. Brewing beer with sorghum. *J. Inst. Brew.* 105:23-34, 1999.
34. Ross, T. Indices for performance evaluation of predictive models in food microbiology. *J. Appl. Bacteriol.* 81:501-508, 1996.
35. Stenholm, K., and Home, S. A new approach to limit dextrinase and its role in mashing. *J. Inst. Brew.* 105:205-210, 1999.
36. Taylor, J. R. N., Schober, J. T., and Bean, S. R. Novel food and non-food uses for sorghum and millets. *J. Cereal Sci.* 44:252-271, 2006.
37. Verchot, V. L., and Borelli, T. Application of para-nitrophenol (pNP) enzyme assays in degraded tropical soils. *Soil Biol. Biochem.* 37:625-633, 2005.
38. Vidyalakshmi, R., Paranthaman, R., and Indhumathi, J. Amylase production on submerged fermentation by *Bacillus* spp. *World J. Chem.* 4:89-91, 2009.
39. Williams, R. J. P. The problem of proton transfer in membranes. *Theor. Biol.* 219:389-396, 2002.
40. Wilson, I. B., Dayan, J., and Cyr, K. Some properties of alkaline phosphatase from *Escherichia coli*. *J. Biol. Chem.* 239:4182-4185, 1964.
41. Yamasaki, Y., Nakashima, S., and Konno, H. Pullulanase from rice endosperm. *Acta Biochim. Pol.* 55:507-510, 2008.
42. Zhang, N., and Jones, B. L. Characterization of germinated barley endoproteolytic enzymes by two-dimensional gel electrophoresis. *J. Cereal Sci.* 21:145-153, 1995.

Résumé de l’article

Comparative Study of Limit Dextrinase Potential of Three Sorghum Cultivars (*Safrari*, *Madjeru*, and *S.35*)

A. C. Nguemogne, **Z. S. C. Desobgo***, E. J. Nso,

Abstract

Limit dextrinase extracted from three sorghum cultivar malts (*Safrari*, *S.35*, and *Madjeru*) used for the production of bili-bili, a traditional beer in the northern part of Cameroon, was subjected to comparison using dextrin as a substrate. A four-factor Doehlert experimental design was used to build a model in order to optimize the impact of factors (temperature, pH, buffer concentration, and incubation time) involved in the extraction of free limit dextrinase from sorghum. The response surface methodology revealed that the action of those factors was different for each sorghum cultivar, with closer behavior between *Safrari* and *S.35*. *Madjeru* was revealed to be completely different. Optimizing the concerted actions of the factors for limit dextrinase specific activity gave the following combinations: for *Safrari*, 43°C, pH 4, 135 mM, and 300 min, with maximal specific activity of 3.10 U/µg; for *Madjeru*, 35°C, pH 5.77, 50 mM, and 60 min, with maximal specific activity of 1.51 U/µg; and for *S.35*, 50°C, pH 4, 191 mM, and 205 min, with maximal specific activity of 3.05 U/µg.

Keywords: Sorghum, Limit dextrinase, Modeling, Optimization

IV.4.8) Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains

Titre de la revue

beverages

MDPI

Comité de lecture

Beverages — Editors

Editor

Prof. Dr. Edgar Chambers IV
Editor-in-Chief
Distinguished Professor and Director, Sensory Analysis Center, Ice Hall, Kansas State University, Manhattan, KS 66506, USA
Website | E-Mail
Interests: sensory quality; consumer acceptance; health aspects; product development; shelf-life; quality control
Special Issues and Collections in MDPI journals

Editorial Board

Prof. Dr. Kris Berglund
University Distinguished Professor of Food Science and Chemical Engineering, Michigan State University, East Lansing, MI 48824, USA
Website | E-Mail
Interests: New and alternative uses of agricultural and forest raw materials; separation, purification, and crystallization processes for food, pharmaceutical, and chemical industries. Distilled beverage technology

Dr. Antonio Bevilacqua
Department of the Science of Agriculture, Food and Environment, University of Foggia, Italy
E-Mail
Interests: fermentation, probiotic, alternative approaches, shelf life definition, spoiling microorganisms

Dr. Julie Bower
Independent scholar
E-Mail
Interests: alcoholic beverages market structure; competition and merger policy; regulatory capture

Prof. Dr. Angel A. Carbonell-Barrachina
Universi dad Miguel Hernández de Elche (UMH), Escuela Politécnica Superior de Orihuela (EPSO), Spain
Website | E-Mail
Interests: Sensory evaluation of foods; Consumer studies; Food quality; Food safety; Volatile compounds; Pomegranate; Quinces; Unit operations; Rice based-foods; Arsenic and heavy metals; Turrón and nougat; Pistachios and almonds
Special Issues and Collections in MDPI journals:
Special Issue: Flavour Volatiles of Foods

Dr. Antonio Cilla
Nutrition and Food Chemistry Department, Faculty of Pharmacy, University of Valencia, Avn. Vicente Andrés Estellés s/n, Burjassot (Valencia), Spain
E-Mail
Interests: fruit juices; infussions; antioxidant capacity; polyphenols;phytochemicals; storage; in vitro gastrointestinal digestion; bioaccessibility; bioactivity; culture cells (Caco-2; HT-29; HepG2);chemoprevention; oxidative stress
Special Issues and Collections in MDPI journals:
Special Issue: Fruit Beverages: Nutritional Composition and Health Benefits
Special Issue: Fruit Beverages and Human Intervention Studies

Dr. Alessandra Durazzo
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di ricerca per gli Alimenti e la Nutrizione, Via Ardeatina 546, 00178, Rome, Italy

E-Mail
Interests: antioxidants, Bioactive compounds, Food Quality, Nutrition, Biodiversity

Dr. Palanivel Ganesan
Department of Applied Life Science and Biotechnology, College of Biomedical and Health Science, Konkuk University, Republic of Korea
Website | E-Mail
Interests: Food Technology - Value added food product development using underutilized plant foods; Food Processing- Plant foods and its biochemistry; Novel Healthy Foods –Product development using underutilized plant foods

Dr. Joerg Gruenwald
Analyze & Realize GmbH, Waldseeweg 6, 13467 Berlin, Germany
E-Mail
Interests: clinical trials; natural products; herbal medicines; functional beverages

Dr. Solomon Habtemariam
Pharmacognosy Research Laboratories, Medway School of Science, University of Greenwich, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK
Website | E-Mail
Interests: Targeting inflammatory cytokines and adhesion molecules by natural products; Search for anti-microbial agents: antileishmanial, antibacterial and antifungal agents; Identification of potential anti-cancer and immunomodulatory compounds; Search for anticachexic agents from natural sources; Modulation of reactive oxygen species in health and disease; Identification of antidiabetic agents from plant sources; Search of potential natural products that promote weight loss;_ etc.

Dr. James Harbertson
Wine Science Center, School of Food Science, Viticulture and Enology Program, Washington State University, USA
Website | E-Mail
Interests: red wine phenolics; proanthocyanidins; anthocyanins; tannins; winemaking; extended maceration; astringency; bitterness

Prof. Dr. Károly (Charles) Héberger
Hungarian Academy of Sciences, Budapest, Hungary
E-Mail
Interests: liquid phase oxidation; radical processes; inhibition; modeling; computer simulations; determination of rate constants by fast-flow technique LMR detection and by kinetic ESR spectroscopy; linear free energy relationships in radical reactions; quantitative - structure activity relationships; QSAR; QSPR; QSRR; quantitative - structure (gas-chromatographic) retention relationships; chemometrics

Dr. Debra Hector
Physical Activity, Nutrition and Obesity Research Group (PANORG), Prevention Research Collaboration (PRC), School of Public Health, The University of Sydney, NSW 2050, Australia
Website | E-Mail
Interests: prevention; health promotion; evidence-based policy and planning; translational research; evaluation tools and methods; food environment

Prof. Dr. Anet Režek Jambrak
Faculty of Food Technology and Biotechnology, University of Zagreb, Croatia
Website | E-Mail
Interests: alternative food processing; non-thermal techniques; thermodynamics; functional properties

Dr. António Manuel Jordão
Polytechnic Institute of Viseu, Agrarian Higher School - Department of Food Industries, Quinta da Alagoa - Estrada de Nelas 3500-606 Viseu, Portugal
E-Mail
Interests: Wine, grapes, phenolic compounds, enology, winemaking, wood in enology, barrels
Special Issues and Collections in MDPI journals:
Special Issue: Phenolic Compounds in Fruit Beverages

Dr. Kadri Koppel
Assistant Professor, Department of Human Nutrition, Kansas State University. 1310 Research Park Drive, 141 Ice Hall, 66502, Manhattan, KS, USA
E-Mail
Interests: method development and processing effect on sensory and aromatic properties and on consumer acceptance

Dr. Tatiana Koutchma
Agriculture and Agri-Food Canada, GFRC, 93 Stone Road West, Guelph, ON, N1G 5C9, Canada
E-Mail
Interests: novel food processing technologies; ultraviolet light; high hydrostatic pressure; electromagnetic heating; process development and validation; food safety engineering; regulations; technology transfer
Special Issues and Collections in MDPI journals:
Special Issue: Advanced Technology in Beverage Processing

Dr. Dirk W. Lachenmeier
Chemical and Veterinary Investigation Agency Karlsruhe, Weissenburger Strasse 3, 76187 Karlsruhe, Germany
Website | E-Mail
Interests: food toxicology; regulatory toxicology; food safety; epidemiology; risk assessment; chemical contaminants; cancer; alcoholic beverages; ethanol; acetaldehyde; thujone; formaldehyde; furan

Dr. Jeehyun Lee
Associate Professor, Department of Food Science and Nutrition, Pusan National University, Busan, 609-735, Korea
E-Mail
Interests: consumer acceptance; descriptive evaluation; green tea; alcoholic beverages

Prof. Dr. Olga Martín-Belloso
Food Technology Department, Faculty of Agrifood and Forestry Science and Engineering, University of Lleida, Rovira Roure, 191, 25198 Lleida, Spain
E-Mail
Interests: food safety; quality and functionality through nonthermal processing; mainly in fruits and vegetables: pulsed electric fields; intense light pulses; cold plasma; edible films and coatings; combined methods including modified atmosphere packaging (MAP); natural antimicrobials; antibrowning and stabilizing substances among others; Nanoemulsions and nanocoatings; Valorization of by-products from fruits and vegetables processing: obtention and characterization of bioactive compounds; functional food product development; modelling; process condition optimization; kinetics and shelf-life studies

Dr. Miranda Mirosa
Department of Food Science,University of Otago, Dunedin, New Zealand
Website | E-Mail
Interests: Consumer behavior and food/beverage choice; Consumer research methods; Cross cultural research on food/beverage preferences; Asian consumers' food/beverage preferences; The impact of food/beverage choice on consumers' health and wellness; Environmental and sustainability issues around food/beverage choice
Special Issues and Collections in MDPI journals:
Special Issue: Consumer behavior and beverage choice

Dr. Richard Owusu-Apenten
Faculty of Life and Health Sciences, School of Biomedical Sciences, Ulster University, Cromore Road, Coleraine BT52 1SA, UK
Website | E-Mail
Interests: antioxidants assays; phytochemicals; anticancer, antimicrobial effects
Special Issues and Collections in MDPI journals:
Special Issue: Tea Polyphenols and Antioxidants: Analysis, Chemistry and Biotechnological Applications

Dr. Salvatore Parisi
Leader of the Food and Beverage Science and Technology Team, the Science Advisory Board, Arlington, VA, USA
E-Mail
Interests: Food packaging; Predictive calculation of shelf life; Study of evolutive profiles for

different bacteriae; Development of new indirect methods and software for the study of cheeses

Dr. Lisa Ryan
Department of Nutrition and Dietetics, Monash University, VIC 3195, Australia
Website | E-Mail
Interests: analysis and development of novel functional foods for glycaemic control and weight loss; maintenance with a particular focus on the potential role of phytochemicals as functional food ingredients

Dr. James M. Seff
Pillsbury Winthrop Shaw Pittman LLP, Four Embarcadero Center, 22nd Floor, San Francisco, CA 94111, USA
Website | E-Mail
Interests: Alcoholic Beverages; Trade Practices law; Labeling; Tied-house law; Licensing; Regulatory Authorities in the U.S.; Federal Tax and Trade Bureau (TTB)

Dr. Lisa Solieri
Department of Life Sciences, University of Modena and Reggio Emilia, Italy
Website | E-Mail
Interests: Starter culture, stress response, wine, vinegar, yeast genetics, spoilage yeasts, Zygosaccharomyces, Saccharomyces hybrids, mating type, strain diversity, lactic acid bacteria, food carrier, probiotics

Dr. Jodi Stookey
Children's Hospital Oakland Research Institute, 5700 Martin Luther King Jr Way, Oakland CA 94609, USA
E-Mail
Interests: hydration epidemiology; water intake; hydration status; osmolality; acute and chronic health effects in healthy; free-living people

Dr. Christopher Taylor
Beverage Management Program and Fred Parks Wine Cellar; Conrad N. Hilton College of Hotel and Restaurant Management, University of Houston, USA
E-Mail
Interests: Consumer Behavior, Preference Development, Wine Education, Wine Tourism, Pro-environmental Beverages, Pro-environmental Beverage Tourism, Cellar Management

Prof. Dr. José António Couto Teixeira
Departamento de Engenharia Biológica, Universidade do Minho, Campus de Gualtar 4710-057, Braga, Portugal
E-Mail
Interests: new beverages; continuous production; processes; healthy drinks; yeast and bacterial physiology; enzymes and beverages

Dr. Laura Vázquez-Araújo
Responsible of Sensory Research and Development. Hijos de Rivera S.A.U. A Coruña, Spain
E-Mail
Interests: sensory analysis; sensory quality; beer; aromas; volatile composition of foodstuffs
Special Issues and Collections in MDPI journals:
Special Issue: Fruit Beverages: Sensory Evaluation and Consumer Acceptance

Dr. Quan V. Vuong
Nutrition Food & Health Research Group, School of Environmental and Life Sciences, University of Newcastle, Australia
E-Mail
Interests: Identification,extraction and isolation of bioactive compounds from natural resources and waste for further utilization in the food and pharmaceutical industries
Special Issues and Collections in MDPI journals:
Special Issue: Tea: Varieties, Production, Functional Applications and Health Benefits

Dr. Frank Welle
Business Development Manager - Packaging, Fraunhofer Institute for Process Engineering and Packaging (IVV), 85354 Freising, Germany

Website | E-Mail
Interests: beverage packaging; active and intelligent materials; food law compliance testing; packaging recycling
Special Issues and Collections in MDPI journals:
Special Issue: Beverage Packaging

Dr. Danyang Ying
CSIRO Animal, Food & Health Sciences 671 Sneydes Road, Werribee, Melbourne, VIC3030, Australia
E-Mail
Interests: microencapsulation; targeted and controlled release delivery; bioactives; functional foods; probiotics; materials science and process engineering; drying; fluid bed coating; extrusion; biomaterials; biopolymers; water sorption; physical properties; glass transition; reaction kinetics; computer modelling

---

Dr. Dimitrios Zabaras
Nestlé Purina Petcare Australia
Website | E-Mail
Interests: chemical contaminants; natural toxins; mass spectrometry; analytical chemistry; method development & validation
Special Issues and Collections in MDPI journals:
Special Issue: Chemical Contaminants in Beverages: 'Traditional' and Emerging Risks in an Ever-Changing World

---

Table des matières

Table of Contents

Beverages, Volume 3, Issue 2 (June 2017)

- Issues are regarded as officially published after their release is announced to the table of contents alert mailing list.
- You may sign up for e-mail alerts to receive table of contents of newly released issues.
- PDF is the official format for papers published in both, html and pdf forms. To view the papers in pdf format, click on the "PDF Full-text" link, and use the free Adobe Reader to open them.

order results:
content type | publication date
result details:
normal | extended | compact

Show export options Displaying articles 1-10

Research

Jump to: Review

Open Access Article

Exploring the Impact of Legislation on the Development of Craft Beer

by Alistair Williams

Beverages **2017**, *3*(2), 18; doi:10.3390/beverages3020018

Received: 4 December 2016 / Revised: 16 March 2017 / Accepted: 20 March 2017 / Published: 28 March 2017

PDF Full-text (725 KB) | HTML Full-text | XML Full-text

Abstract

The purpose of this paper is to discuss the ways in which federal and state legislation has impacted the growth of the US craft beer industry. In order to achieve this purpose, the city of Charlotte in North Carolina (N.C.) will be used

[...] Read more.

► **Figures**

Open Access Article

Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains

by C. W. Makebe, Z. S. C. Desobgo and E. J. Nso

Beverages **2017**, *3*(2), 19; doi:10.3390/beverages3020019

Received: 6 March 2017 / Revised: 24 March 2017 / Accepted: 6 April 2017 / Published: 13 April 2017

PDF Full-text (3376 KB) | HTML Full-text | XML Full-text

Abstract

The study was initiated to optimize the enzymabtic extraction process of plantain pulp using response surface methodology. Weight loss of plantain decreased until it became stable at an over-ripe stage. The significant regression model describing the changes of extraction yield and Brix with

[...] Read more.

(This article belongs to the Special Issue Phenolic Compounds in Fruit Beverages)

► Figures

Open Access Article

Process Parameters Affecting the Synthesis of Natural Flavors by Shiitake (*Lentinula edodes*) during the Production of a Non-Alcoholic Beverage

by Sibel Özdemir, Doreen Heerd, Hendrich Quitmann, Yanyan Zhang, Marco Alexander Fraatz, Holger Zorn and Peter Czermak

Beverages **2017**, *3*(2), 20; doi:10.3390/beverages3020020

Received: 28 December 2016 / Revised: 23 April 2017 / Accepted: 23 April 2017 / Published: 27 April 2017

PDF Full-text (2751 KB) | HTML Full-text | XML Full-text | Supplementary Files

Abstract

A novel alcohol-free beverage with a fruity, slightly sour, sweetish, fresh, and plum-like flavor was produced by incorporating the edible mushroom shiitake (*Lentinula edodes*) into the fermentation process. Shiitake pellets were used as a biocatalyst to promote the synthesis of the

[...] Read more.

(This article belongs to the Special Issue Fermented Beverages)

► Figures

Open Access Article

Nuclear Magnetic Resonance and Headspace Solid-Phase Microextraction Gas Chromatography as Complementary Methods for the Analysis of Beer Samples

by Sarah R. Johnson, Samantha E. Soprano, Laura M. Wickham, Neil Fitzgerald and John C. Edwards

Beverages **2017**, *3*(2), 21; doi:10.3390/beverages3020021

Received: 10 August 2016 / Revised: 5 April 2017 / Accepted: 23 April 2017 / Published: 27 April 2017

PDF Full-text (634 KB) | HTML Full-text | XML Full-text

Abstract

Chemical analysis of the organic components in beer has applications to quality control, authenticity and improvements to the flavor characteristics and brewing process. This study aims to show the complementary nature of two instrumental techniques which, in combination, can identify and quantify a

[...] Read more.

(This article belongs to the Special Issue Beer)

► Figures

Open Access Article

Automated Bioanalyzer Based on Amperometric Enzymatic Biosensors for the Determination of Ethanol in Low-Alcohol Beers

by Eva Vargas, Felipe Conzuelo, M. Asunción Ruiz, Susana Campuzano, Víctor Ruiz-Valdepeñas Montiel, Guillermo González de Rivera, Fernando López-Colino, Á. Julio Reviejo and José M. Pingarrón

Beverages **2017**, *3*(2), 22; doi:10.3390/beverages3020022

Received: 6 April 2017 / Revised: 28 April 2017 / Accepted: 9 May 2017 / Published: 13 May 2017

PDF Full-text (8408 KB) | HTML Full-text | XML Full-text | Supplementary Files

Abstract

In this work, a new automated bioanalyzer based on the use of enzymatic biosensors as amperometric detectors is reported. This automatic bioanalyzer is configurable both as continuous flow and flow injection analysis systems and enables both on-line and off-line monitoring of ethanol in

[...] Read more.

(This article belongs to the Special Issue Beer)

► **Figures**

Open Access Article

Evaluation of Soybean–Navy Bean Emulsions Using Different Processing Technologies

by Sean X. Liu, Mukti Singh, Ashley E. Wayman, Diejun Chen and James A. Kenar

Beverages **2017**, *3*(2), 23; doi:10.3390/beverages3020023

Received: 2 March 2017 / Revised: 19 May 2017 / Accepted: 22 May 2017 / Published: 25 May 2017

PDF Full-text (1305 KB) | HTML Full-text | XML Full-text

Abstract

In this study, an innovative emulsion made from soybean and navy bean blends of different proportionalities was developed. In addition, two processing methods were used: traditional cooking and jet-cooking. The physical attributes and storage stability were measured and compared. This study found that

[...] Read more.

(This article belongs to the Special Issue Beverage Emulsions)

► **Figures**

Open Access Article

An Overview of the Utilisation of Brewery By-Products as Generated by British Craft Breweries

by Clare Kerby and Frank Vriesekoop

Beverages **2017**, *3*(2), 24; doi:10.3390/beverages3020024

Received: 1 April 2017 / Revised: 31 May 2017 / Accepted: 9 June 2017 / Published: 12 June 2017

PDF Full-text (991 KB) | HTML Full-text | XML Full-text

Abstract

There is a wide range of information available on by-product disposal methods used by large national breweries. However, little information is available on the methods of by-product disposal used by craft breweries. An investigation was carried out in which 200+ British craft brewers

[...] Read more.

(This article belongs to the Special Issue Beer)

► **Figures**

Open Access Article

Assessing the Impact of Finings on the Perception of Beer

by Andrew Barnett, Georgiana Juravle and Charles Spence

Beverages **2017**, *3*(2), 26; doi:10.3390/beverages3020026

Received: 15 May 2017 / Revised: 29 May 2017 / Accepted: 14 June 2017 / Published: 16 June 2017

PDF Full-text (549 KB) | HTML Full-text | XML Full-text

Abstract

In recent years, a number of commentators have suggested that the use of finings to clarify beer can impair the flavour, because of the removal of key volatile aromatic molecules from the drink. However, are such claims necessarily correct? Unaware of any previous
[...] Read more.

(This article belongs to the Special Issue Beer)

► **Figures**

Open Access Article

Antioxidant Activity of Commercial Soluble Coffees

by Carolina Tolentino Marcucci, Rafael Carlos Eloy Dias, Mariana Bortholazzi Almeida and Marta de Toledo Benassi

Beverages **2017**, *3*(2), 27; doi:10.3390/beverages3020027

Received: 10 April 2017 / Revised: 14 June 2017 / Accepted: 15 June 2017 / Published: 21 June 2017

PDF Full-text (410 KB) | HTML Full-text | XML Full-text

Abstract

A product of easy preparation and high added value, soluble/instant coffee is obtained by drying the aqueous extract of roasted coffee and presents a high amount of bioactive compounds. The aim of the study was to evaluate the antioxidant activity of 33 Brazilian
[...] Read more.

(This article belongs to the Special Issue Beverage Powder)

► **Figures**

Review

Jump to: Research

Open Access Review

The Gushing Experience—A Quick Overview

by Kristina Mastanjević, Krešimir Mastanjević and Vinko Krstanović

Beverages **2017**, *3*(2), 25; doi:10.3390/beverages3020025

Received: 24 February 2017 / Revised: 1 June 2017 / Accepted: 9 June 2017 / Published: 12 June 2017

PDF Full-text (231 KB) | HTML Full-text | XML Full-text

Abstract

Beer lovers all over the world like to get their drink with a certain volume of stabile foam, which mainly depends on the beer style. However, sometimes this foam comes in form of a sudden, eruptive, and uncontrolled over-foaming (gushing) of beer. Gushing
[...] Read more.

(This article belongs to the Special Issue Beer)

Show export options Displaying articles 1-10

Pages de l’article

beverages

MDPI

Article

Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains

C. W. Makebe [1], Z. S. C. Desobgo [2,*] and E. J. Nso [1]

[1] Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455 Ngaoundere, Cameroon; cally_maya@yahoo.com (C.W.M.); nso_emmanuel@yahoo.fr (E.J.N.)

[2] Department of Food Processing and Quality Control, University Institute of Technology (UIT), The University of Ngaoundere, P.O. Box 455 Ngaoundere, Cameroon

* Correspondence: desobgo.zangue@gmail.com

Academic Editor: António Manuel Jordão
Received: 6 March 2017; Accepted: 6 April 2017; Published: 13 April 2017

Abstract: The study was initiated to optimize the enzymabtic extraction process of plantain pulp using response surface methodology. Weight loss of plantain decreased until it became stable at an over-ripe stage. The significant regression model describing the changes of extraction yield and Brix with respect to hydrolysis parameters was established. Temperature contributed to reducing the yield from 53.52% down to 49.43%, and the dilution factor increased the yield from 53.52% to 92.97%. On the contrary, the dilution factor significantly reduced Brix from 21.74 °Bx down to 0.15 °Bx, while the enzyme concentration increased Brix from 21.73 °Bx to 26.16 °Bx. The optimum conditions for juice extraction from plantain pulp were: temperature: 25 °C; enzyme concentration: 5%; dilution ratio: 1.10; and extraction time: 24 h. The implementation of these conditions led to (resulted in obtaining) obtaining a must yield of more than 70% and Brix between 10 °Bx and 15 °Bx. The total polyphenols and flavonoids were 7.70 ± 0.99 mg GAE /100 g and 0.4 ± 0.01 µg rutin/g for must and 17.01 ± 0.34 mg GAE/100 g and 4 ± 0.12 µg rutin/g and 7.70 ± 0.99 for wine, indicated the presence of antioxidant activity in the produced wine. On the other hand, the total soluble solids were between 16.06 ± 0.58 °Bx and 1.5 ± 0.10 °Bx, which permitted obtaining a wine with low alcohol content.

Keywords: plantains; losses; extraction; response surface methodology; wine

1. Introduction

Although banana/plantain is a staple for many African countries, it has until recently not been successfully exploited in food processing and assimilated industries due to the lack of adequate post-harvest preservation technologies [1]. The high level of post-harvest losses is one of the food security challenges facing African countries. In Sub-Saharan Africa, the annual value of these losses is estimated at about USD 48 billion [2]. Cameroon produces about 3,882,741 million tons of plantain annually [3]. Approximately half of this is consumed locally, while less than two fifths is exported. The remaining quantities rot in the fields because of rapid ripening of the fruits, poor handling, inadequate storage and transportation means and poor knowledge of food processing options [1]. It is estimated that more than 30% of the banana [4] and 35% of plantain [5] production are lost after harvest in developing countries. In Cameroon, studies have estimated that 30% of post-harvest losses are incurred during whole sale and about 70% during retailing [4].

Banana plants are important monocotyledonous perennial crops in the tropical and subtropical world regions [6]. They include dessert banana, plantain and cooking bananas. Plantain (*Musa paradisiaca*)

is one of the most important crops of the tropical plants. It belongs to the family Musaceae and the genus *Musa*. Lately, wine production has been honed with different natural products, for example apple, pear and strawberry, fruits, plum, pineapple, banana and oranges [7–9]. Wines are energizing drinks that have been viewed as a characteristic solution for man's disease from early days and are said to help recuperation amid the gaining strength period [10,11]. Studies to upgrade banana juice extraction were completed by utilizing diverse levels of pectinase enzymes and distinctive hatching periods at 28 ± 2 °C [12]. The juice recuperation from over-ripe bananas was higher (67.6%) than that from ordinary natural fruits (60.2%). A great quality wine was obtained from over-ripe banana fruits [12,13].

There is an extensive misuse of bananas, particularly those that do not meet the quality standards for export. Because of the way that the banana/plantain fruit is organically dynamic and completes transpiration, ripening and other biochemical exercises even after harvest, the losses are high [5]. This phenomenon has shifted to break down the nature of leafy foods, making them unmarketable. Wastage of the plantain fruit because of poor post-harvest handling or over-ripening remains a noteworthy issue today. The change of over-ripe plantain into other important items has been the main impetus behind this study. Over the span of this study, we chose to concentrate on the production of wine from giant horn over-ripe plantains. This will be done using response surface methodology and by applying industrial enzymes to quantitatively extract plantain juice, determining the parameters for optimum yield and analyzing some physicochemical parameters before and after fermentation.

2. Material and Methods

2.1. Material

2.1.1. Biological Material

Giant horn plantain (Figure 1) was obtained from a farmer in Mamfe in the South West Region, Cameroon. Enzymes' characteristics utilized were as mentioned in Table 1. The white wine yeast Lalvin ICV D-47 *Saccharomyces cerevisiae* was issued by The Home Brew Shop (Unit 3, Hawley Lane Business Park, United Kingdom).

Figure 1. Giant horn plantains ((**A**) unripe; (**B**) over-ripe).

Table 1. Enzyme properties.

Enzymes (Origins, Suppliers)	Enzymes Percentage in the Mixture	pH		Temperature	
		Tolerance	Optimal	Tolerance	Optimal
Amyloglucosidase (AMG 300 L, Novozymes)	43%	4.0–6.0	4.5	30–65 °C	60 °C
Alpha-amylase (BAN 480 L, Novozymes)	29%	5.0–6.0	5.4–5.8	37–75 °C	70 °C
Pectinase (*Aspergillus aculeatus*, Sigma Aldrich)	14%	3.5–6.0	4.5	30–55 °C	50 °C
Bioglucanase TX (*Trichoderma reesei*, Kerry Bioscience)	14%	4.5–6.5	4.5–6.5	/	60 °C

2.1.2. Chemicals

The following reagents were obtained from Fluka Chemika, Switzerland: 3,5-dinitrosalicylic acid (DNS), ethanol, fructose, D-Glucose, NaOH and maltose; while ninhydrin, sodium carbonate (Na_2CO_3), sodium potassium tartrate and sodium hydroxide were obtained from Chemphora Chemical, Netherlands.

2.2. Methods

2.2.1. Sample Ripening

Unripe mature plantains were over-ripened for 11 days at 25 ± 2 °C utilizing a Heraeus-type incubator (D-63450 Hanau, Germany) without the use of ethylene until they passed Stage 7 (over-ripe). After that, samples were used immediately for wine production.

2.2.2. General Process Overview

The methods involved in wine production from over-ripe giant horn plantain are given in Figure 2.

The over-ripe plantains coming from the ripening process were washed three times with tap water and peeled. After the peeling process, they were sized and crushed to get the pulp paste. Then, the blanching process was executed at 80 °C for 5 min. Pulp paste was mashed using Doehlert experimental design conditions when the enzyme mixture, sodium bicarbonate and water were added. At the end of the mashing process, the mash was centrifuged (6500× *g*, 15 min) to remove pellets, and the must was then pasteurized (90 °C, 3 min). After cooling, the must was fermented at 20 °C for 7 days using yeast (4 g/L) and aged for 90 days. At the end of the aging process, the wine was centrifuged (5000× *g*, 5 min) to remove pellets (trub and yeast) and bottled. The bottles containing wine were then pasteurized at 65 °C for 30 min.

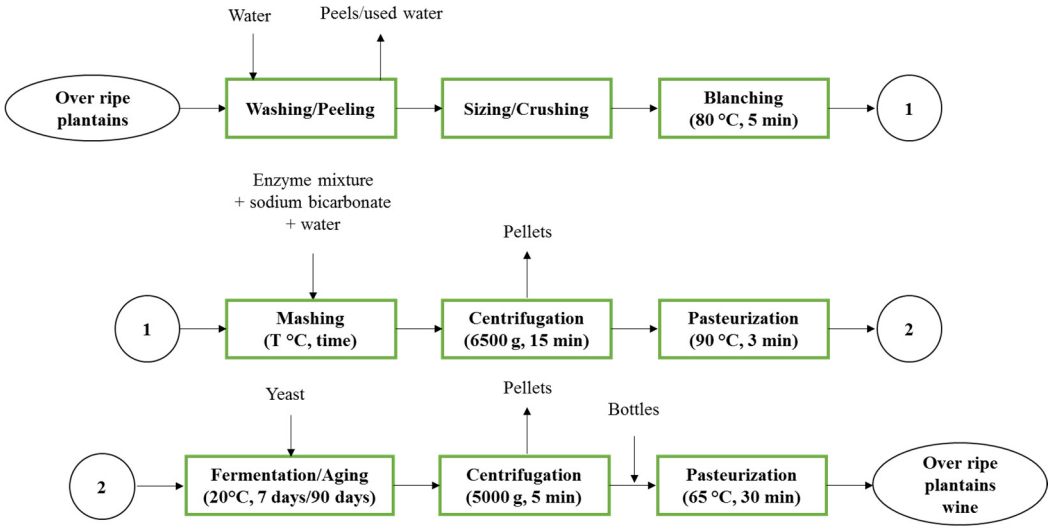


Figure 2. Process diagram for the ripe plantain wine production.

2.2.3. Experimental Design for the Extraction Process

Doehlert's experimental design [14] was used to model four factors: extraction temperature (°C), enzyme concentration (%), dilution factor and extraction time (h). The experimental domains (Table 2) over which factors were studied were based on the literature. These independent variables were studied using the response surface methodology (RSM) at three different levels (−1, 0, +1) to give a total of 25 experiments. The conversion of coded values into real values was done according to the literature [15].

Table 2. Experimental level of factors for ripe plantain fermentation.

Factors (Variables)	Level
Temperature (°C)	25–75
Enzyme mix concentration (%)	0.1–5
Dilution factor	0–4
Time (h)	0.5–24

2.2.4. Modelling and Optimizing

The model chosen was an empirical quadratic model, which determined the magnitude of the contributions of each factor in the linear, quadratic and interaction forms. The model used to determine the responses is given below:

$$Y_i = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} {x_i}^2 + \sum \beta_{ij} x_i x_j + \varepsilon \quad (1)$$

where Y_i is the response, β_0 a constant, $\beta_1, \beta_2, \beta_3$ the linear coefficients, $\beta_{11}, \beta_{22}, \beta_{33}$ the quadratic coefficients, $\beta_{12}, \beta_{23}, \beta_{13}$ the coefficients of interaction, and x_1, x_2, x_3, x_1x_2, x_1x_3, x_2x_3 and x_1^2, x_2^2, x_3^2, the linear, interaction and quadratic forms of the experimental variables respectively. ε is the error. The determination of the coefficients of the models was done by a multilinear regression in which we had: N the number of experiments in the design matrix, p the number of coefficients in the chosen model, y the vector of experimental responses y_i, $y = (y_1, y_2, ...y_N)$; η the vector of theoretical responses η_i, $\eta = (\eta_1, \eta_2, ..., \eta_N)$; X the matrix $N \times p$, matrix of the model.

$$X = \begin{pmatrix} 1 & x_{11} & x_{12} & . & . & . & x_{1,p-1} \\ 1 & x_{21} & x_{22} & . & . & . & x_{2,p-1} \\ & . & & . & & & . \\ 1 & . & . & & . & & . \\ & . & & & & . & . \\ 1 & x_{N1} & x_{N2} & . & . & . & x_{N,p-1} \end{pmatrix} \quad (2)$$

β is the column vector of the parameters to be estimated; $\beta_i \ldots$; $\beta = (\beta_1, \beta_2, \beta_3, ..., \beta_{p-1})$; $\hat{\beta}$ is the column vector of estimators $\hat{\beta}_i$, ε is the column vector of experimental error e_i, $\varepsilon = (e_1, e_2, ..., e_N)$.

Given the following classical matrix:

$$\eta = X\beta \quad (3)$$

$$y = X\beta + \varepsilon \quad (4)$$

$$\begin{pmatrix} y_1 \\ y_2 \\ . \\ . \\ . \\ y_N \end{pmatrix} = \begin{pmatrix} 1 & x_{11} & x_{12} & . & . & . & x_{1,p-1} \\ 1 & x_{21} & x_{22} & . & . & . & x_{2,p-1} \\ & . & & . & & & . \\ 1 & . & . & & . & & . \\ & . & & & & . & . \\ 1 & x_{N1} & x_{N2} & . & . & . & x_{N,p-1} \end{pmatrix} \begin{pmatrix} \beta_0 \\ \beta_1 \\ . \\ . \\ . \\ \beta_N \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \\ . \\ . \\ . \\ e_N \end{pmatrix} \quad (5)$$

when $N > p$, the least squares method is used to estimate the coefficients of the polynomial.

$$\hat{\beta} = (X'X)^{-1}X'Y \quad (6)$$

$\hat{\beta}$ is an estimator of β

To this effect, Minitab software was used to determine the coefficients of the models.

In order to write equations that allow for the prediction of responses in the domain defined for the studies, it was important to validate the models. To that effect, the observed values and the values predicted by the model were compared. Further statistical tools were used in addition to the determination coefficient. Absolute average deviation (AAD) was calculated as follows:

$$AAD = \frac{\sum_{i=1}^{p}\left(\frac{|Y_{i\,\mathrm{exp}} - Y_{itheo}|}{Y_{i\,\mathrm{exp}}}\right)}{N} \quad (7)$$

$Y_{i\,\mathrm{exp}}$ is the experimental response and Y_{itheo} the response calculated from model i; N is number of experiments.

The bias factor (B_f) and exactitude factor (A_f) were also expressed as follows:

$$B_f = 10^B \quad (8)$$

$$A_f = 10^A \quad (9)$$

with:

$$B = \frac{1}{N}\sum_{i=1}^{N}\log\left(\frac{Y_{itheo}}{Y_{i\,\mathrm{exp}}}\right) \quad (10)$$

$$A = \frac{1}{N}\sum_{i=1}^{N}\left|\log\left(\frac{Y_{itheo}}{Y_{i\,\mathrm{exp}}}\right)\right| \quad (11)$$

Table 3 gives the acceptable values of the different indicators of valid models. The graphs and contour plots were done using OriginPro 2016 b9.3.226 (OriginLab Corporation, www.originlab.com).

Optimization was done using the software Minitab® 17 (Build 17.3.1, Minitab, Inc.). The conditions were fixed to maximize the extraction yield and Brix. After that, a compromise was made. The use of Sigmaplot (Version 12.5, Systat Software, Inc.) allowed drawing the contour plots and superimpose the graphs in order to determine the interest zone.

Table 3. Standard and acceptable values of the indicators of the validation of the models.

Indicators of Validation	Standard Values	Acceptable Values	References
Adjusted R^2	1	≥0.8	[16]
AAD	0	[0–0.3]	[17]
Bias factor	1	[0.75–1.25]	[18]
Exactitude factor	1	[0.75–1.25]	[18]

The analysis of variance (Table 4) was used to identify the influence of each factor and also the significance of their effects. This was achieved by comparing the average square of each effect to the experimental error. The significance of each factor was determined by the Fischer test. The significance of the Fischer (F) 'ratio' indicates the values necessary to reject the null hypothesis at the 0.05 probability level.

Table 4. Analysis of variance (ANOVA).

Source of Variation	DF	SS	Mean Square	Fisher (F-Test)
Regression (between)	$p-1$	SSR	$\frac{SSR}{p-1}$	$\frac{\frac{SSR}{p-1}}{\frac{SSE}{N-p}}$
Residue (within)	$N-p$	SSE	$\frac{SSE}{N-p}$	
Validity	$(N-p)-(n_0-1)$	SSE_2	$\frac{SSE_2}{(N-p)-(n_0-1)}$	$\frac{\frac{SSE_2}{(N-p)-(n_0-1)}}{\frac{SSE_1}{n_0-1}}$
Error	(n_0-1)	SSE_1	$\frac{SSE_1}{n_0-1}$	
Total	$N-1$	TSS		

2.2.5. Juice Extraction

Over ripe plantains were washed 3 times, hand peeled and sized. A Panasonic blender (MX-GM1011) was used to crush the plantains, then they were blanched in water at 80 °C for 5 min in a water bath (Memmert). The four enzymes, amyloglucosidase, alpha amylase (BAN 480 L), pectinase and bioglucanase TX, were then introduced into biological reactors (beakers) containing 20 g of the pulp with its respective dilutions, which was then incubated at a temperature and time specified by the Doehlert experimental design in a water bath. After incubation, the pulp was then centrifuged at 6500× *g* for 15 min using a centrifuge (Heraeus-Kendro Lab products, model: Biofuge primo R, type: D-37520, Hanau, Germany). The supernatant was collected and pasteurized at 90 °C for 1 min in the water bath. Each experiment was conducted in triplicate.

2.2.6. Yeast Preparation and Must Fermentation

The white wine yeast Lalvin ICV D-47 *Saccharomyces cerevisiae* obtained from The Home Brew Shop (Unit 3, Hawley Lane Business Park, United Kingdom) was used for the fermentation of the giant horn plantain. Yeast, which was kept at 2–4 °C, was rehydrated at 30 °C in tap water (10 mL of water/g of yeast) for about 10 min and stirred for 5 s. After rehydration, yeast was introduced to the giant horn plantain juice extracted utilizing optimal conditions, and the mixture was mixed to ensure must aeration and yeast distribution. The principal fermentation was then done at 20 °C during 7 days and aging for 90 days in an incubator (SHP Biochemical Incubator 250 L, Shanghai, Guangzhou, China).

2.2.7. Determination of Extraction Yield

The percentage of juice yield (% *w*/*w*) was calculated as the difference between the initial mass and the weight of the pellet after centrifugation divided by the initial mass as follows:

$$Yield(\%) = \frac{mass\ of\ pulp\ -\ mass\ of\ pellet}{mass\ of\ pulp} \times 100 \quad (12)$$

2.2.8. Determination of Total Soluble Solids [19]

Before reading the value of total soluble solids, the Hanna HI 96801 refractometer (Hanna instruments Inc., Woonsocket, RI, USA) was calibrated using distilled water. An equal number of drops from the prepared plantain juice was placed onto the refractometer prism plate. The reading on the prism scale is generated numerically. After each test, the prism plate was cleaned with (distilled) water and wiped dry with a soft tissue.

2.2.9. Determination of pH

The initial pH of each plantain juice was determined using a pH meter (HANNA® Calibration Check™ pH meter, HI 223 Type, Johannesburg, South Africa). Twenty milliliters of each freshly-prepared plantain juice was placed in a glass beaker on a thermostatically-controlled electric hotplate (mark: GMARK) at 25 °C. Before reading its pH, each sample was agitated (using a magnetic stirrer) for 30 s until a stable reading was assessed. Each test was made in triplicate. Between readings, the electrode was rinsed with distilled water for the accuracy of the measurement.

2.2.10. Determination of Turbidity

To the turbidimeter cell, the plantain juice was added up to the horizontal mark. After closing the cell, it was wiped using a tissue and placed in the turbidimeter (Hach, Model 2100 N, Hach Company, Loveland, CO, USA), and the sample was covered. The turbidity value was then assessed when the reading was stable.

2.2.11. Determination of Total Phenolic Compounds: Folin–Ciocalteu Method [20]

The volume of 0.02 mL of plantain juice before and after fermentation was mixed with 0.1 mL of Folin–Ciocalteu reagent previously diluted with distilled water. A volume of 0.3 mL of 20% sodium carbonate solution was added to the mixture, shaken thoroughly and diluted to 2 mL by adding distilled water. The mixture was allowed to stand for 120 min, and the blue color formed was measured at 760 nm with a spectrophotometer (JENWAY, Model: 7310, Serial No. 39756, JENWAY Limited, Staffordshire, UK). Gallic acid was invoked as a standard for the calibration curve. The concentrations of gallic acid in the solution, utilized for obtaining the calibration curve, were 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 mg/L (R^2 = 0.965). The total polyphenol content was expressed as mg of gallic acid equivalent (GAE) per 100 g of fruit juice. All measurements were carried out in triplicate.

2.2.12. Determination of Titratable Acidity [21]

Titratable acidity was established according to the standardized method, with 0.1 N sodium hydroxide (NaOH) in the presence of the phenolphthalein indicator. Ten milliliters of sample were pipetted into a conical flask and 0.1 mL of phenolphthalein (0.05%) added. Titration is halted when the initial color changes to pink and persisting for at least 30 s. The burette reading is noted. The titratable acidity (TA) is expressed in g/L tartaric acid:

$$TA = \frac{75 \times C \times V}{T} \quad (13)$$

where: V is the volume (mL) of the sodium hydroxide noted at the end point; C is the concentration of the base; T is the volume of titrate.

2.2.13. Determination of Color by the Spectrophotometric Method [22]

The wavelength of the spectrophotometer (JENWAY, Model: 7310, Serial No. 39756, JENWAY Limited, Staffordshire, UK) was set at 430 nm. The cell was filled with water and the absorbance set to read as 0.00. The cell was then rinsed and filled with the sample (must and wine) and the absorbance read. For samples with a turbidity above 1 EBC, a filtration was done before using a 0.45-µm membrane filter (Whatmann, GE Healthcare, Chicago, IL, USA). The results were then expressed as follows:

$$Color\ (EBC)\ =\ A \times f \times 25 \quad (14)$$

where: A is absorbance at 430 nm; f is the dilution factor; EBC is the European Brewery Convention units.

2.2.14. Dry Matter and Water (Moisture) Contents

Crushed plantain pulp (5 g) was weighed using a balance (SCIENTECH, ZSP250 MG Balance, Scientech Inc., Boulder, CO, USA) and placed in a drying dish. The dish was then placed in an oven (Heraeus, model: Kendro laboratory products, D-63450, GmbH, Hanau, Germany) previously set at 105 °C and left there till it attained constant weight. It was removed from the oven at the end of 24 h. After cooling in a desiccator, the dish was then weighed again. The dry matter content represents the difference in mass before and after drying in the oven. The dry matter (DM) content in 100 g of fresh sample was calculated using the following formula:

$$DM(\%) = \frac{M_2 - M_0}{M_1} \times 100 \quad (15)$$

where: M_0 is mass (in g) of empty drying dish; M_1 is mass (in g) of sample before drying; M_2 is mass (in g) of drying dish + sample after drying.

The water or moisture content (%W) was calculated using the following expression:

$$W(\%) = 100 - DM \quad (16)$$

2.2.15. Determination of Reducing Sugars by the DNS Method [23,24]

The 3,5-Dinitrosalicylic acid (DNS) reagent was made by mixing in 5 g of dinitrosalicylic acid (Fluka Chemika, Fluka Chemie GmbH, Buchs, Switzerland) in 250 mL of distilled water at 80 °C in a water bath (Memmert, Memmert GmbH + Co., Äußere Rittersbacher Straße 38 D-91126 Schwabach, Germany). When this solution dropped to room temperature (25 °C), 100 mL of NaOH, 2 N (Fluka Chemika, Switzerland) and 150 g of sodium potassium tartrate (Fluka Chemika, Fluka Chemie GmbH, Buchs, Switzerland) were introduced, and the volume was completed with distilled water to 500 mL. The standard calibration curves were on glucose. According to the traditional method, 2 mL of dinitrosalicylic acid reagent and 0.1 mL of sample (must or wine), or distilled water (blank), were added to test tubes. The tubes were plunged in a water bath (100 °C) for 5 min and then cooled in cold water, while 7.9 mL of distilled water were introduced to each tube, resulting in the final reaction mixture. The addition of water while the tubes are plunged in cold water is performed to stop the reaction immediately. The optical density at 540 nm is read in the UV-visible spectrophotometer (JENWAY, Model: 7310, Serial No. 39756, JENWAY Limited, Staffordshire, UK).

2.2.16. Flavonoids

The flavonoid contents in the produced must and wine were determined utilizing spectrophotometric method [25]. The sample (20 µL) was added to 2 mL of 2% $AlCl_3$ solution dissolved in methanol. The samples were incubated for 1 h at room temperature (25 °C). The absorbance was assessed using the spectrophotometer at λ_{max} = 415 nm. The same steps were repeated for the standard solution of rutin, and the calibration line was built. Based on the determined absorbance, the concentration of flavonoids was read (mg/mL) on the calibration curve; and the flavonoid contents of must and wine were expressed in rutin equivalents (µg rutin/g of extract).

3. Results and Discussion

3.1. Ripening of Plantain

3.1.1. Percentage of Weight Loss

The weight loss evolution of giant horn plantain with ripening time is presented in Figure 3.

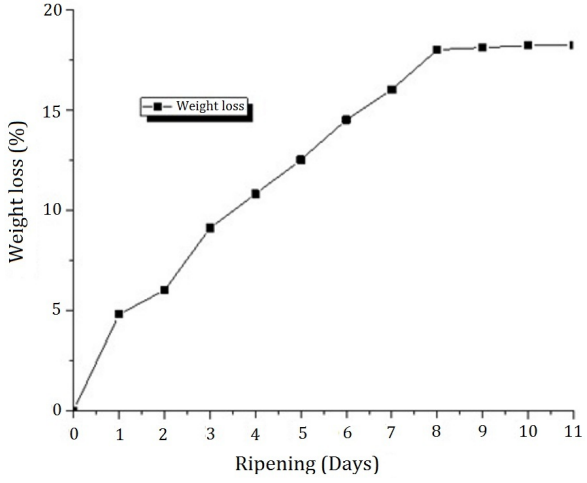


Figure 3. Weight loss (%) of giant horn plantain during ripening.

It was observed from the figure that the weight loss increased to reach a maximum weight loss of 18.2% after 10 days. The weight loss percentage obtained was higher than the 14.01% obtained after plantain ripening for 10 days [26–29]. The percent of the weight reduction of 'giant horn' plantain expanded constantly due to ripening because of a high storage temperature, ~25 °C. Like every chemical reaction, the plant metabolism increments with temperature. Since high energy was required to run the procedure, consequently, starch was changed over to sugar and utilized as energy. The most striking post-harvest compound change that happens amid the post-harvest ripening of plantain was the hydrolysis of starch and the amassing of sugars, like, sucrose, glucose and fructose [30,31], which were responsible for the sweetening of the product (as it matures). In plantain, this breakdown was slower and less complete and proceeds in over-ripe and senescent fruit [32]. The abundant energy created therefore from the respiration process [33,34] was dismissed from the tissue by the vaporization of water, which will in this way be transpired from the fruit, bringing on a weight reduction. A portion of humidity reduction through the peel could be seen through shrinkage on the peel.

3.1.2. Moisture Content

The moisture content of the ripe plantain was 63.4% ± 0.52%. This value was in the range of the value (61.3%) obtained in the literature [35]. The high moisture contents in the ripe plantain could be as a result of moisture transfer from the peel to the pulp. It was reported that the increase in moisture content of pulp occurred due to the increase in sugar content in the pulp as a result of starch hydrolysis to sugar [35,36].

3.2. Modelling and Optimizing of Juice Extraction

Table 5 presents the findings of the juice extraction carried out on the blanched plantain pulp. These results were later computed to develop statistical models for responses, amongst which were the yield and Brix. They are written as follows:

$$Y_{rdt} = 80.50 - 3.72x_1 + 0.81x_2 + 21.30x_3 + 0.32x_4 - 2.08x_1^2 + 2.77x_2^2 - 16.55x_3^2 + 4.11x_4^2 \\ -2.11x_1x_2 + 0.33x_1x_3 - 0.15x_1x_4 + 3.12x_2x_3 + 0.41x_2x_4 - 3.90x_3x_4 \quad (17)$$

$$Y_B = 11.025 + 0.810x_1 + 1.166x_2 - 12.852x_3 + 0.821x_4 - 0.26x_1^2 - 2.25x_2^2 + 9.31x_3^2 - 2.018x_4^2 \\ +1.01x_1x_3 - 0.23x_1x_4 - 1.11x_2x_3 - 0.61x_2x_4 + 0.41x_3x_4 \quad (18)$$

with: Y_B, Brix; Y_{rdt}, yield; x_1, extraction temperature; x_2, enzyme concentration; x_3, dilution factor and x_4, extraction time.

The R^2 values, AAD, B_f and A_f permitted the validation of the model. This was in accordance with the literature [18,37,38]. Factors modeled were linear (x_1, x_2, x_3 and x_4), quadratic (x_1^2, x_2^2, x_3^2 and x_4^2) and with interactions (x_1x_2, x_1x_3, x_1x_4, x_2x_3, x_2x_4 and x_3x_4). They were considered statistically significant or not if the probability (p) was $\leq$0.1 or $\geq$0.1, respectively (Table 6).

These models were the second-degree multivariable polynomial with interactions equations with the following characteristics: R^2 = 0.98 an, AAD = 0 for both, A_f = 1.016 and 1.065 and B_f = 1.000 and 0.997, respectively, for yield and Brix.

Table 5. Doehlert experimental design: coded variables, real variables and responses.

Number	Coded Variables				Real Variables				Responses					
									Yield (%)			Brix (°Bx)		
	x_1	x_2	x_3	x_4	X_1	X_2	X_3	X_4	Exp	Cal	Res	Exp	Cal	Res
1	1	0	0	0	75	2.55	2	12.25	73.10	74.70	−1.60	12.65	11.58	1.08
2	−1	0	0	0	25	2.55	2	12.25	83.75	82.14	1.61	8.90	9.96	−1.06
3	0.5	0.866	0	0	62.5	5	2	12.25	80.23	79.99	0.24	10.45	10.69	−0.24
4	−0.5	−0.866	0	0	37.5	0.1	2	12.25	82.08	82.30	−0.22	8.10	7.86	0.24
5	0.5	−0.866	0	0	62.5	0.1	2	12.25	81.73	80.41	1.32	8.15	8.67	−0.52
6	−0.5	0.866	0	0	37.5	5	2	12.25	84.23	85.53	−1.30	10.40	9.88	0.52
7	0.5	0.289	0.816	0	62.5	3.37	4	12.25	87.78	85.51	2.27	6.35	7.38	−1.03
8	−0.5	−0.289	−0.816	0	37.5	1.73	0	12.25	51.75	54.00	−2.25	27.90	26.87	1.03
9	0.5	−0.289	−0.816	0	62.5	1.73	0	12.25	49.68	50.62	−0.94	27.10	26.85	0.25
10	0	0.577	−0.816	0	50	4.18	0	12.25	51.48	52.02	−0.54	28.60	28.16	0.44
11	−0.5	0.289	0.816	0	37.5	3.37	4	12.25	90.53	89.57	0.96	5.50	5.74	−0.24
12	0	−0.577	0.816	0	50	0.92	4	12.25	86.40	85.85	0.55	5.40	5.84	−0.44
13	0.5	0.289	0.204	0.791	62.5	3.37	2.5	24	83.50	84.38	−0.88	8.75	8.53	0.22
14	−0.5	−0.289	−0.204	−0.791	37.5	1.73	1.5	0.5	79.33	78.44	0.89	10.80	11.01	−0.21
15	0.5	−0.289	−0.204	−0.791	62.5	1.73	1.5	0.5	76.63	75.38	1.25	11.00	11.79	−0.79
16	0	0.577	−0.204	−0.791	50	4.18	1.5	0.5	79.63	77.99	1.64	11.80	12.53	−0.73
17	0	0	0.612	−0.791	50	2.55	3.5	0.5	87.78	91.54	−3.76	6.25	4.54	1.71
18	−0.5	0.289	0.204	0.791	37.5	3.37	2.5	24	87.53	88.77	−1.24	8.50	7.70	0.80
19	0	−0.577	0.204	0.791	50	0.92	2.5	24	84.63	86.25	−1.62	7.95	7.22	0.73
20	0	0	−0.612	0.791	50	2.55	0.5	24	69.75	65.98	3.77	19.85	21.56	−1.71
21	0	0	0	0	50	2.55	2	12.25	80.83	80.50	0.33	11.35	11.03	0.32
22	0	0	0	0	50	2.55	2	12.25	80.28	80.50	−0.22	10.80	11.03	−0.23
23	0	0	0	0	50	2.55	2	12.25	80.76	80.50	0.26	11.00	11.03	−0.03
24	0	0	0	0	50	2.55	2	12.25	80.15	80.50	−0.35	10.95	11.03	−0.08
25	0	0	0	0	50	2.55	2	12.25	73.10	80.50	−7.40	12.65	11.03	1.63

Exp: Experimental value; Cal: Calculated value; Res: Residue (difference between experimental and calculated value)

Table 6. Estimation of the regression coefficients and variables' contributions for the yield and Brix of over-ripe giant horn plantain juice.

Effects	Coefficients		*df*	Sum of Squares		Mean Square		*F*-Value		*p*-Value	
	Yield	Brix		Yield	Brix	Yield	Brix	Yield	Brix	Yield	Brix
Constant	80.50	11.025	14	2949.24	1045.51	210.66	74.679	31.57	48.12	0.000	0.000
Linear			4	2338.06	838.24	584.51	209.559	87.61	135.03	0.000	0.000
x_1	−3.72	0.810	1	69.19	3.28	69.19	3.281	10.37	2.11	0.010	0.180
x_2	0.70	1.010	1	3.29	6.80	3.29	6.801	0.49	4.38	0.500	0.066
x_3	17.378	−10.487	1	2264.98	824.84	2264.98	824.837	339.47	531.49	0.000	0.000
x_4	0.256	0.650	1	0.52	3.38	0.52	3.377	0.08	2.18	0.786	0.174
Square			4	591.34	190.62	147.83	47.656	22.16	30.71	0.000	0.000
x_1^2	−2.08	−0.25	1	5.76	0.08	5.76	0.083	0.86	0.05	0.377	0.822
x_2^2	2.08	−1.685	1	10.24	6.75	10.24	6.750	1.53	4.35	0.247	0.067
x_3^2	−11.02	6.200	1	409.86	129.75	409.86	129.748	61.43	83.60	0.000	0.000
x_4^2	2.57	−1.262	1	28.17	6.80	28.17	6.799	4.22	4.38	0.070	0.066
Interactions			6	18.61	1.86	3.10	0.310	0.46	0.20	0.818	0.968
x_1x_2	−1.82	0.00	1	3.33	0.00	3.33	0.000	0.50	0.00	0.498	1.000
x_1x_3	0.27	0.82	1	0.07	0.61	0.07	0.612	0.01	0.39	0.923	0.545
x_1x_4	−0.12	−0.18	1	0.01	0.03	0.01	0.029	0.00	0.02	0.966	0.894
x_2x_3	2.20	−0.79	1	5.83	0.74	5.83	0.742	0.87	0.48	0.374	0.507
x_2x_4	0.28	−0.41	1	0.09	0.20	0.09	0.204	0.01	0.13	0.909	0.725
x_3x_4	−2.52	0.27	1	8.45	0.10	8.45	0.095	1.27	0.06	0.290	0.810
Residual			9	60.05	13.97	6.67	1.552				
total			23	3009.28	1059.47						

3.2.1. Impact of Extraction Temperature

The impact of extraction temperature was only significant (p = 0.010, Table 6) on the extraction yield. In fact, that temperature contributed to reducing the yield from 53.52% at 25 °C to 49.43% at 75 °C (Figure 4) when fixing the enzyme concentration at 0.1%, the dilution factor at zero (no dilution) and

the extraction time at 0.5 h. It was found that for an average of several hybrids of plantains, an amount of water was absorbed after 30 min cooking [39,40]. When heated in excess water with a sufficient amount of heat, native starch granules undergo irreversible phase transition, called gelatinization [41]. The highly-ordered structure becomes disordered. Gelatinization of starch has been broadly defined as an irreversible endothermic transition, the "breakage of the molecular order", breaking the hydrogen bonds in the starch granule. Irreversible changes are observed: water gain, swelling of the granule, crystalline melting, loss of birefringence, the solubilization of the starch and the increase in viscosity [42]. During the heat treatment, the water enters in the first place in the amorphous regions, which swell and transmit disturbing forces in the crystalline regions [43,44]. All of this results in the reduction of yield extraction.

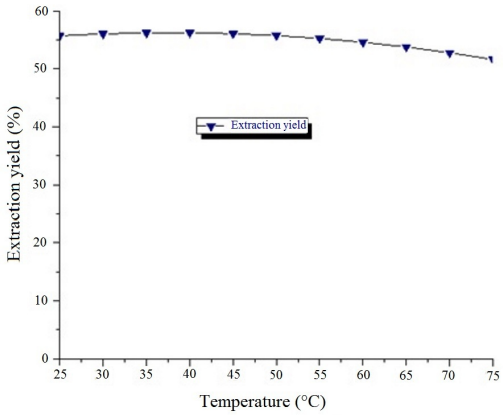


Figure 4. Evolution of extraction yield with temperature.

3.2.2. Impact of Enzyme Concentration

The impact of enzyme concentration was this time only significant (p = 0.066, Table 6) on the Brix. In fact, the enzyme concentration contributed to increase the Brix from 21.73 °Bx at 0.1% to 26.16 °Bx at 5% (Figure 5) when fixing the extraction temperature at 25 °C, the dilution factor at zero (no dilution) and the extraction time at 0.5 h. The use of multiple enzymes increased the TSS (total soluble solids) content of juice. The enzymatic effect permitted the cell walls to be more permeable, which generated the extraction of total soluble solids from the plantain puree. The presence of polysaccharide-degrading enzymes (amyloglucosidase, α-amylase, pectinase and bioglucanase activities) in the preparations was then linked to a higher degree of tissue breakdown, discharging more compounds, such as sugars [45], which contribute to total soluble solids.

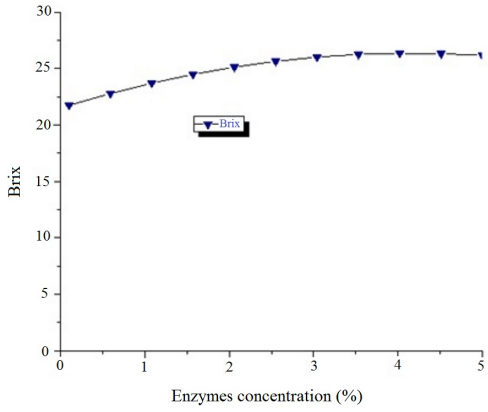


Figure 5. Evolution of Brix with enzyme concentration.

3.2.3. Impact of the Dilution Factor

The effect of the dilution factor was significant (p = 0.000 for both; Table 6) on the increase of extraction yield and the decrease of Brix.

The increase for extraction yield started from 53.52% at zero (no dilution) to 92.77% at four, while the decrease of Brix (Figure 6) started from 21.74 °Bx at zero (no dilution) to 0.15 °Bx at four; all this when fixing the temperature at 25 °C, the enzyme concentration at 0.1% and the extraction time at 0.5 h.

The increase of water during the extraction process contributed to the increase of extraction yield because at the fixed temperature of 25 °C, the starch granules were not gelatinized, and therefore, the more water was added during the process, the more it was recovered during centrifugation to obtain the juice; while, at the same time, the increase of water when proceeding to extraction contributed to diluting the total soluble solids of that juice, which had as the impact the reduction of the Brix, which expresses the concentration (in percentage) of total soluble solids in the juice.

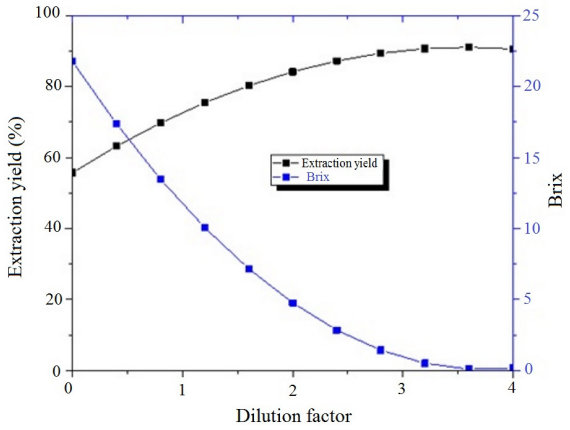


Figure 6. Evolution of extraction yield and Brix with the dilution factor.

3.2.4. Optimization of Juice Extraction

Production of the juice took globally into account the compromise between the extraction yield and the physicochemical composition of the juice extracted, since the extraction procedure could influence the composition.

When trying to maximize the responses singularly, different optimal combinations were obtained. For the Brix, the maximal value obtained was 28.19 °Bx for an optimal combination of 48.74 °C for temperature, 3.81% for enzyme concentration, zero (no dilution) for the dilution factor and 13.08 h for the extraction time; while the maximization of the extraction yield gave 99.47% using 25 °C for the temperature, 5% for the enzyme concentration, four for the dilution factor and 0.5 h for the extraction time. From the two singulars response maximization, it was obvious that a compromise should be found. For that purpose, an extraction yield $\geq$70% and 10 $\leq$ Brix $\leq$ 15 °Bx were fixed as "good" conditions. That choice was made because of the aim of producing a wine (low Brix) and to have at the same time enough juice volume (high extraction yield). After superimposing the graphs for Brix and extraction yield (Figure 7), it was obtained that the area that could permit reaching the target (extraction yield $\geq$ 70% and 10 $\leq$ Brix $\leq$ 15 °Bx) was within the interest zone highlighted (that zone was obtained after fixing the temperature at 25 °C and the extraction time at 24 h).

The optimal condition in the highlighted area was assessed as follows: temperature, 25 °C; enzyme concentration, 5%; dilution ratio, 1.10; and extraction time, 24 h. That optimal combination gave respectively for Brix 14.99 °Bx and for the extraction yield 80.22%.

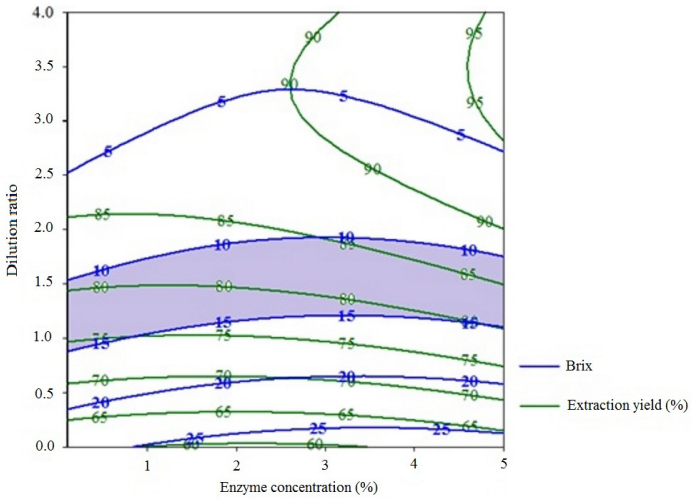


Figure 7. Interest zone for giant horn plantain juice extraction.

3.3. Evolution of Turbidity during Fermentation

Figure 8 shows the evolution of turbidity during the fermentation of over-ripe giant horn plantain juice extraction using optimal conditions and during the first fermentation. Turbidity increased from 144.33 ± 0.57 NTU (the initial day) to 1901.33 ± 26.31 NTU (the first day). After that first day, the turbidity decreased till the value of 88.66 ± 0.57 NTU. The high turbidity observed the first day of fermentation could be due to the fact that the yeast metabolized the sugars, and that produced a high volume of CO_2.

Gas escaping created turbulence in the medium and dispersing yeast. The progressive reduction of turbidity could be linked to the reduction of CO_2 production and, at the same time, the beginning of yeast and other solids' decantation. After 96 h, the drop of turbidity was drastic. This could be explained by a significant reduction of CO_2 gas and, therefore, a more efficient decantation.

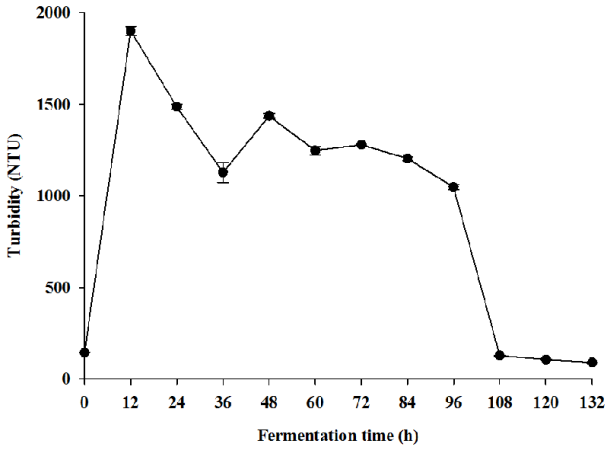


Figure 8. Evolution of turbidity during fermentation of over-ripe giant horn plantain juice.

3.4. Physicochemical Characteristics of Must and Wine

Some physicochemical characteristics of the must and the wine (Figure 9) at the end of the 90 days of the aging process are presented in Table 7.

After extraction in optimal conditions, which gives 15.1 ± 0.42 °Bx, the juice was then pasteurized to prevent fermentation starting prematurely by indigenous yeasts and bacteria.

Figure 9. Over-ripe giant horn plantain wine.

From Table 7, it was observed that the pH dropped from 4.26 ± 0.01 in must to 4.12 ± 0.21 in wine. During the alcoholic fermentation, the pH of the must was constantly changing. Organic acids consumed or produced undergo dissociation and release hydrogen ions in the fermentation medium, thus influencing the pH. All hydrogen ions did not come, however, from dissociation of organic acids. Some came from the assimilation of nitrogen source, including ammonium ions, probably amino acids, which could contribute to the pH drop by amino acid assimilation of a positive charge. Alcohol was the main product of fermentation and was also involved in the change in pH. It acted on the dissociation constants of organic acids, on the density and the dielectric constant of the solvent and, thus, indirectly on the pH [46].

Table 7. Physicochemical analysis of must and wine.

Analysis	Must	Wine
pH	4.26 ± 0.01	4.12 ± 0.21
Total soluble sugar (°Bx)	16.06 ± 0.58	1.5 ± 0.10
Titratable acidity (g/L tartaric acid)	4.4 ± 0.09	8.19 ± 0.03
Flavonoids (µg rutin/g of sample)	0.4 ± 0.01	4 ± 0.12
Polyphenols (mg GAE/100 g of sample)	7.70 ± 0.99	17.01 ± 0.34
Color (EBC: European Brewery Convention unit)	23.67 ± 1.50	20.03 ± 0.04
Total sugars (g/100 mL)	9.61 ± 0.14	3.23 ± 0.09
Free amino nitrogen (mg/L)	138.94 ± 5.23	78.77 ± 2.75

For the total soluble solids, a decrease of Brix from 16.06 ± 0.58 °Bx to 1.5 ± 0.10 °Bx was observed (Table 7). Yeasts are facultative aerobic organisms. When oxygen was available, glucose was metabolized aerobically. In the absence of air, yeast must go against this by alcoholic fermentation. As it produced less energy than aerobic respiration, the need for glucose increased significantly. This phenomenon is named the Pasteur effect. Due to the limited production of energy, yeast multiplied in the absence of air much less quickly than in its presence. In addition, the ethanol produced acted as a cellular poison. The need for glucose by the yeast contributed then to the decrease of sugar in the medium.

Furthermore, the fact that the residual sugar content was 1.5 ± 0.10 °Bx could then be explained as said earlier. The titratable acidity obtained was 4.4 ± 0.09 g/L tartaric acid for the must and

increased to 8.19 ± 0.03 g/L tartaric acid for wine (Table 7). Organic acids are essential elements of the constitution of musts and wines, their qualities and their defects. Nature and concentration regulate the acid-base balance and, therefore, control the acid taste of wine. During the fermentation, sugar consumption by the yeast (glycolysis) results in the formation of typical organic acid fermentation [46].

The flavonoid content of the giant horn plantain must and wine is shown in Table 7. The flavonoid content of must and wine samples was from 0.4 ± 0.01 µg rutin/g–4 ± 0.12 µg rutin/g, respectively. The augmentation in flavonoid content in giant horn plantain wine as a result of fermentation could be due to the increase in acidity during fermentation, which involves unchaining bound flavonoid components and making them more available [47].

The total phenolic content of the giant horn plantain must and wine expressed as mg gallic acid equivalent (GAE) per 100 g sample is shown in Table 7. Phenolic content for must and wine samples analyzed in this study ranged from 7.70 ± 0.99 mg GAE/100 g to 17.01 ± 0.34 mg GAE/100 g, respectively. In natural medium, phenolic compounds are linked with sugar, which decreases their disponibility. During fermentation, proteases hydrolyze complexes of phenolics into soluble-free phenols and other simpler and biologically more active ones that are readily absorbed [48,49].

From Table 7, a decrease in color from must to wine was also observed. That color level was 23.67 ± 1.50 EBC for must and 20.03 ± 0.04 EBC for wine. This could be explained by the yeast, which has been shown to absorb anthocyanins onto its cell walls and cause color loss [50].

After analyzing free amino nitrogen (FAN) of the must and at the end of the fermentation (wine) in Table 7, a drop from 138.94 ± 5.23 mg/L (must) to 78.77 ± 2.75 mg/L (wine) was observed. Generally, during alcoholic fermentation, ammonium ions and most amino acids are completely consumed after the first 50 h of fermentation [51,52]. It is also known that amino acids are involved in the synthesis of higher alcohols by the yeast mechanism. Thus, the more a must is concentrated in available nitrogen, a larger amount is consumed, as pointed out by the literature [53].

4. Conclusions

This study was aimed at valorizing over-ripe plantains in order to reduce post-harvest losses by processing them into wine owing to 35% of the total plantains produced being wasted as post-harvest losses. Mathematical models for the must extraction were successfully developed in order to predict the appropriate conditions for optimal yield and Brix. A compromise of the optimum processing conditions for both responses (extraction yield and Brix) was determined as 80.22% and 14.99 °Bx, respectively. The must and wine produced were characterized for pH, turbidity, total soluble sugars, total polyphenols, free amino nitrogen, color, total sugars, flavonoids and titratable acidity and tend to have suitable properties, as well. It has been determined that over-ripe plantains that may be available in bulk should not be wasted, as they can be processed with minimal problems to produce safe and quality alcoholic beverages (wines).

Acknowledgments: The authors gratefully acknowledge the Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI) of the University of Ngaoundere (Cameroon) for providing necessary facilities for the successful completion of this research work.

Author Contributions: W. C. Makebe, performed the experiments. Z. S. C. Desobgo, analyzed the data; contributed reagents/materials/analysis tools; wrote the paper. E. J. Nso, contributed reagents/materials/analysis tools.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

ANOVA	Analysis of variance
AAD	Absolute average deviation
AAE	Ascorbic acid equivalent
A_f	Exactitude factor
B_f	Bias factor
°Bx	Degree Brix
Cal	Calculated value from the model
DM	Dry matter
DF	Degree of freedom
EBC	European Brewing Convention
Exp	Experimental value
GAE	Gallic acid equivalent
N	Number of experiments
n_0	number of points repeated independently
NTU	Nephelometric turbidity unit
P	Number of model coefficients
R^2	Coefficient of determination
Res	Residue (Difference between experimental and calculated values)
RSM	Response surface methodology
SS	Sum of squares
SSE	Sum square of error
SSE_1	Sum of the squares of the experimental errors (at the repeated points)
SSE_2	Sum of the squares of the deviations (at other points) or validity.
SSR	Sum of squares due to regression
TSS	Total sum of squares

References

1. Olurunda, A.O. Recent advances in post-harvest technology of banana and plantains in Africa. *Acta Hort.* **2000**, *540*, 517–527. [CrossRef]
2. Essilfie, G. *Analysis of the Post-Harvest Knowledge System in Ghana: Case Study of Cassava*; CTA: Wageningen, The Netherlands, 2014; p. 10.
3. Food and Agriculture Organization (FAO). *Faostat Database Collections*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2014.
4. Adeniji, T.A.; Tenkouano, A.; Ezurike, J.N.; Ariyo, C.O.; Vroh-Bi, I. Value-adding post harvest processing of cooking bananas (*Musa spp*. Aab and abb genome groups). *Afr. J. Biotechnol.* **2010**, *9*, 9135–9141.
5. Hailu, M.; Workneh, T.S.; Belew, D. Review on postharvest technology of banana fruit. *Afr. J. Biotechnol.* **2013**, *12*, 635–647.
6. Strosse, H.; Schoofs, H.; Panis, B.; André, E.; Reyniers, K.; Swennen, R. Development of embryogenic cell suspensions from shoot meristematic tissue in bananas and plantains (*Musa* spp.). *Plant Sci.* **2006**, *170*, 104–112. [CrossRef]
7. Fleet, G.H. *Wine: Microbiology and Biotechnology*; Harwood Academic Publishers: London, UK, 1993; p. 130.
8. Webb, A.D. The science of making wine. *Am. Sci.* **1984**, *72*, 360–367.
9. Isitua, C.C.; Ibeh, I.N. Novel method of wine production from banana (*Musa acuminata*) and pineapple (ananas comosus) wastes. *Afr. J. Biotechnol.* **2010**, *9*, 7521–7524. [CrossRef]
10. Jay, J.M. *Modern Food Microbiology*, 5th ed.; Chapman and Hall: New York, NY, USA, 1996; p. 212.
11. Okafor, N. *Modern Industrial Microbiology and Biotechnology*; Science Publishers: Enfield, NH, USA, 2007; p. 530.
12. Kotecha, M.P.; Adsule, R.N.; Kadam, S.S. Preparation of wine from over-ripe banana fruits. *Beverage Food World* **1994**, *21*, 28–29.
13. Akingbala, J.O.; Oguntimein, G.B.; Olunlade, B.A.; Aina, J.O. Effects of pasteurization and packaging on properties of wine from over-ripe mango (mangifera indica) and banana (musaacuminata) juices. *Trop. Sci.* **1992**, *34*, 345–352.
14. Goupy, J.; Creighton, L. *Introduction Aux Plans D'expériences*, 3rd ed.; Dunod: Paris, France, 2006; p. 325.

15. Ekorong, A.A.J.F.; Zomegni, G.; Desobgo, Z.S.C.; Ndjouenkeu, R. Optimization of drying parameters for mango seed kernels using central composite design. *Bioresour. Bioprocess* **2015**, *2*, 1–9. [CrossRef]
16. Joglekar, A.M.; May, A.T. Product excellence through design of experiments. *Cereal Foods World* **1987**, *32*, 857–868.
17. Baş, D.; Boyac, I.H. Modeling and optimization i: Usability of response surface methodology. *J. Food Eng.* **2007**, *78*, 836–845. [CrossRef]
18. Dalgaard, P.; Jorgensen, L.V. Predicted and observed growth of listeria monocytogenes in seafood challenge tests and in naturally contaminated cold smoked salmon. *Int. J. Food Microbiol.* **1998**, *40*, 105–115. [CrossRef]
19. *ISO 2173:2003. Fruit and Vegetable Products—Determination of Soluble solids—Refractometric Method*; International Organization of Standardization (ISO): Geneva, Switzerland, 2003.
20. Marigo, G. Méthode de fractionnement et d'estimation des composés phénoliques chez les végétaux. *Analysis* **1973**, *2*, 106–110.
21. Association Française de Normalisation (AFNOR). *Recueil Des Normes Françaises Des Produits Dérivés Des Fruits Et Légumes*, 1st ed.; Association Française de Normalisation: Paris, France, 1982.
22. Analytica-EBC. *European Brewery Convention*; Fachverlag Hans Carl: Nürnberg, Germany, 1998.
23. Fisher, E.H.; Stein, E.A. Dns colorimetric determination of available carbohydrates in foods. *Biochem. Prep.* **1961**, *8*, 30–37.
24. Fisher, E.H.; Stein, E.A. *Enzymes*, 2nd ed.; Academic Press: New York, NY, USA, 1960; Volume 4, p. 343.
25. Quettier-Deleu, C.; Gressier, B.; Vasseur, J.; Dine, T.; Brunet, J.; Luyck, M.; Cazin, M.; Cazin, J.C.; Bailleul, F.; Trotin, F. Phenolic compounds and antioxidant activities of buckwheat (*Fagopyrum esculentum* moench) hulls and flour. *J. Ethnopharmacol.* **2000**, *72*, 35–40. [CrossRef]
26. Oluwalana, I.B. Fruit cultivation and processing improvement in nigeria. *Agric. J.* **2006**, *1*, 307–310.
27. Oluwalana, I.B. Minimizing fruit wastages in nigeria. *Int. J. Agric. Food Sci.* **2010**, *1*, 77–87.
28. Oluwalana, I.B.; Oluwamukomi, M.O. Changes in qualities of ripening plantain fruits stored at tropical ambient conditions. *Int. J. Agric. Food Sci.* **2010**, *1*, 203–207.
29. Oluwalana, I.B.; Oluwamukomi, M.O.; Olajide, S.T. Physicochemical changes in ripening plantain stored at tropical ambient conditions. *J. Food Technol.* **2006**, *4*, 253–254.
30. Lœsecke, H.V. *Bananas*, 2nd ed.; InterScience: New York, NY, USA, 1950.
31. Palmer, J.K. The banana. In *The Biochemistry of Fruits and Their Products*; Hulme, A.C., Ed.; Academic Press: London, UK, 1971; Volume 2, pp. 65–105.
32. Marriott, J.; Robinson, M.; Karikari, S.K. Starch and sugar transformation during ripening of plantains and bananas. *Trop. Sci.* **1981**, *32*, 1021–1026. [CrossRef]
33. George, J.B.; Marriott, J. The effect of humidity in plantain ripening. *Sci. Holtic.* **1983**, *5*, 37–48. [CrossRef]
34. Pantastico, B.E. *Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables*; AVI Publishing Co. Inc.: Westport, CT, USA, 1975.
35. Egbebi, A.O.; Bademosi, T.A. Chemical compositions of ripe and unripe banana and plantain. *Int. J. Trop. Med. Public Health* **2012**, *1*, 1–5.
36. Patil, S.K.; Shanmugasundaram, S. Physicochemical changes during ripening of monthan banana. *Int. J. Technol. Enhanc. Emerg. Eng. Res.* **2015**, *3*, 18–21.
37. Ross, T. Indices for performance evaluation of predictive models in food microbiology. *J. Appl. Bacteriol.* **1996**, *81*, 501–508. [PubMed]
38. Baranyi, J.; Pin, C.; Ross, T. Validating and comparing predictive models. *Int. J. Food Microbiol.* **1999**, *48*, 159–166. [CrossRef]
39. Dadzie, B.K. Cooking qualities of black sigatoka resistant plantain hybrids. *Infomusa* **1995**, *4*, 7–9.
40. Ngalani, J.A.; Tchango-Tchango, J. Cooking qualities and physicochemical changes during ripening in some banana and plantain hybrids and cultivars. *Acta Hortic.* **1998**, *490*, 571–576. [CrossRef]
41. Wang, S.; Copeland, L. Molecular disassembly of starch granules during gelatinization and its effect on starch digestibility: A review. *Food Funct.* **2013**, *4*, 1564–1580. [CrossRef] [PubMed]
42. Donovan, J.W. Phase transitions of the starch–water system. *Biopolymers* **1979**, *18*, 263–275. [CrossRef]
43. BeMiller, J.N. Pasting, paste, and gel properties of starch–hydrocolloid combinations. *Carbohydr. Polym.* **2011**, *86*, 386–423. [CrossRef]

44. Slade, L.; Levine, H. Non-equilibrium melting of native granular starch: Part i. Temperature location of the glass transition associated with gelatinization of a-type cereal starches. *Carbohydr. Polym.* **1988**, *8*, 183–208. [CrossRef]
45. Sreenath, H.K.; Frey, M.D.; Scherz, H.; Radola, B.J. Degradation of a washed carrot preparation by cellulases and pectinases. *Biotechnol. Bioeng.* **1984**, *26*, 788–796. [CrossRef] [PubMed]
46. Akin, H. *Evolution Du Ph Pendant La Fermentation Alcoolique De Moûts De Raisins: Modélisation Et Interprétation Métabolique*; Institut National Polytechnique de Toulouse Toulouse: Toulouse, France, 2008.
47. Adetuyi, F.O.; Ibrahim, T.A. Effect of fermentation time on the phenolic, flavonoid and vitamin C contents and antioxidant activities of okra (*abelmoschus esculentus*) seeds. *Niger. Food J.* **2014**, *32*, 128–137. [CrossRef]
48. Shrestha, A.K.; Dahal, N.R.; Ndungustse, V. Bacillus fermentation of soybean: A review. *J. Food Sci. Technol. Nepal* **2010**, *6*, 1–9. [CrossRef]
49. Ademiluyi, A.O.; Oboh, G. Antioxidant properties of condiment produced from fermented bambara groundnut (*Vigna subterranean* L. Verdc). *J. Food Biochem.* **2011**, *35*, 1145–1160. [CrossRef]
50. Morata, A.; Gomez-Cordoves, M.C.; Colomo, B.; Suarez, J.A. Pyruvic acid and acetaldehyde production by different strains of saccharomyces: Relationship with vitisin a and b formation in red wines. *J. Agric. Food Chem.* **2003**, *51*, 7402–7409. [CrossRef] [PubMed]
51. Jiranek, V.; Langridge, P.; Henschke, P.A. Amino acid and ammonium utilization by saccharomyces cerevisiae wine yeasts from a chemically defined medium. *Am. J. Enol. Vitic.* **1995**, *46*, 75–83.
52. Beltran, G.; Novo, M.; Rozès, N.; Mas, A.; Guillamón, J.M. Nitrogen catabolite repression in saccharomyces cerevisiae during wine fermentations. *FEMS Yeast Res.* **2004**, *4*, 625–632. [CrossRef] [PubMed]
53. Taillandier, P.; Ramon-Portugal, F.; Fuster, A.; Strehaiano, P. Effect of ammonium concentration on alcoholic fermentation kinetics by wine yeasts for high sugar content. *Food Microbiol.* **2007**, *24*, 95–100. [CrossRef] [PubMed]

© 2017 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).

Résumé de l’article

Optimization of the Juice Extraction Process and Investigation on Must Fermentation of Overripe Giant Horn Plantains

C. W. Makebe, **Z. S. C. Desobgo***, and E. J. Nso

Abstract

The study was initiated to optimize the enzymatic extraction process of plantain pulp using response surface methodology. Weight loss of plantain decreased until it became stable at an over-ripe stage. The significant regression model describing the changes of extraction yield and Brix with respect to hydrolysis parameters was established. Temperature contributed to reducing the yield from 53.52% down to 49.43%, and the dilution factor increased the yield from 53.52% to 92.97%. On the contrary, the dilution factor significantly reduced Brix from 21.74 ◦Bx down to 0.15 ◦Bx, while the enzyme concentration increased Brix from 21.73 ◦Bx to 26.16 ◦Bx. The optimum conditions for juice extraction from plantain pulp were: temperature: 25 ◦C; enzyme concentration: 5%; dilution ratio: 1.10; and extraction time: 24 h. The implementation of these conditions led to (resulted in obtaining) obtaining a must yield of more than 70% and Brix between 10 ◦Bx and 15 ◦Bx. The total polyphenols and flavonoids were 7.70 ± 0.99 mg GAE /100 g and 0.4 ± 0.01 µg rutin/g for must and 17.01 ± 0.34 mg GAE/100 g and 4 ± 0.12 µg rutin/g and 7.70 ± 0.99 for wine, indicated the presence of antioxidant activity in the produced wine. On the other hand, the total soluble solids were between 16.06 ± 0.58 ◦Bx and 1.5 ± 0.10 ◦Bx, which permitted obtaining a wine with low alcohol content.

Keywords: plantains; losses; extraction; response surface methodology; wine

IV.4.9) Modeling of Dimethyl Sulfide Stripping Behavior When Applying Delayed Onset of Boiling During Wort Boiling

Titre de la revue

American Society of Brewing Chemists
FREE ACCESS

Comité de lecture

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, pleas
contact our customer service department to purchase a subscription.

Journal

Journal of the American Society of Brewing Chemists ›
The Science of Beer

This journal

Editorial board

Editor-in-Chief
Inge Russell

Editorial Board
G. Aerts
R. Agu
P. Aldred
M. Andersen
P. Aron
C. Boulton
S. Britton
D. Cook
C. Curtin
S. Deckers
J. De Clippeleer
S. Duke
A. Egi
R. Foster
L. Garbe
C. Henson

A. Hill
J. Hort
N. Kageyama
M. Kanauchi
S. Lawrence
Q. Li
B. Lodolo
A. Macintosh
D. Maskell
C. Powell
G. Sanchez
D. Sedin
S. Serna-Saldivar
T. Shellhammer
J. Sheppard
A. Speers
D. Stewart
E. Storgards
L. Van Nedervelde
K. Verstrepen
D. Vollmer
G. Walker
D. Wang
H. Wedler
X. Yin
M. Zarnkow
B. Ziola

Publisher

Amy L. Hope

Director of Publications

Greg Grahek

Technical Editor

Carol Duling

Circulation Coordinator

Dawn Wuest

Table des matières

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, please contact our customer service department to purchase a subscription.

Journal of the American Society of Brewing Chemists

The Science of Beer

2017 Impact Factor
0.880

Publish open access in this journal

Advanced search

Submit an article | New content alerts | RSS | Citation search

Current issue | Browse list of issues

Official Journal of the American Society of Brewing Chemists

This journal

Havlik et al.
Published online: 6 Jul 2018

Investigations into the Transfer Rate of Volatile Compounds in y in tanol-Water Partitior Coefficient Model

Kirkendall et al.
Published online: 11 Jun 2018

Control of Fermentation By-Products and Aroma Features of Beer Pr ed with Sc Ale Yeast by Variation of Fermentation Temperature and Wort Aeration Rate

Vanbeneden et al.
Published online: 7 Jun 2018

Pan et al.
Published online: 29 Mar 2018

Analysis of Physicochemical Indices, Volatile Flavor Components, and Microbial Community of a Light-Flavor *Daqu*

See all volumes and issues

Volume 75, 2017 | Vol 74, 2016 | Vol 73,

Issue 4 | Issue 3 | Issue 2 | Issue 1

Review

Review

The Bitter, Twisted Truth of the Hop: 50 Years of Hop Chemistry

Patrick L. Ting & David S. Ryder

Pages: 161-180

Published online: 05 Feb 2018

42 Views | 0 CrossRef citations | 0 Altmetric

Original Articles

Article

Fusarium Profiling and Barley Malt Gushing Propensity

Vertti Virkajärvi, Tuija Sarlin & Arja Laitila

Pages: 181-192

Published online: 05 Feb 2018

5 Views | 0 CrossRef citations | 0 Altmetric

Article

Analyzing Differences in Freshness of SA-1 Hops by Headspace Solid-Phase Microextraction Gas Chromatography–Mass Spectrometry Combined with Chemometrics

Zechang Liu, Liping Wang & Yumei Liu

Pages: 193-200

Published online: 05 Feb 2018

6 Views | 0 CrossRef citations | 0 Altmetric

Article

Flavor Contribution of Esters in Lager Beers and an Analysis of Their Flavor Thresholds ›

Yang Xu, Deliang Wang, Hon g Li, JianQin Hao, Wei Jiang, Zhushui Liu & Qian Qin

Pages: 201-206

Published online: 05 Feb 2018

22 Views | 0 CrossRef citations | 0 Altmetric

Article

Sour Brewing: Impact of *Lactobacillus Amylovorus* FST2.11 on Technological and Quality Attributes of Acid Beers ›

Lorenzo C. Peyer, Martin Zarnkow, Fritz Jacob, David P. De Schutter & Elke K. Arendt

Pages: 207-216

Published online: 05 Feb 2018

19 Views | 0 CrossRef citations | 0 Altmetric

Article

Model Solution as a Beer Foam Standard Should Contain Fatty Acids ›

Petr Kosin, Jan Savel, Tomas Branyik & Filip Ulmann

Pages: 217-220

Published online: 05 Feb 2018

5 Views	1 CrossRef citations	0 Altmetric

Article

Ethanol Content Has Little Effect on the Sensory Orthonasal Detection Threshold of Hop Compounds in Beer ›

Meghan Peltz & Thomas Shellhammer

Pages: 221-227

Published online: 05 Feb 2018

13 Views	0 CrossRef citations	0 Altmetric

Article

Investigation of 2-Sulfanylethyl Acetate Cysteine-*S*-Conjugate as a Potential Precursor of Free Thiols in Beer ›

Marie-Lucie Kankolongo Cibaka, Thi Thu Hang Tran, Jacques Gros, Raphaël Robiette & Sonia Collin

Pages: 228-235

Published online: 05 Feb 2018

5 Views	0 CrossRef citations	0 Altmetric

Article

Mechanical Characterization of Individual Brewing Yeast Cells Using Microelectromechanical Systems (MEMS): Cell Rupture Force and Stiffness ›

Bruno Barazani, Stephan Warnat, Ted Hubbard & Andrew J. MacIntosh

Pages: 236-243

Published online: 05 Feb 2018

6 Views	0 CrossRef citations	0 Altmetric

Article

Impact of Extracellular Osmolality on *Saccharomyces* Yeast Populations during Brewing Fermentations ›

Shiwen Zhuang, Katherine Smart & Chris Powell

Pages: 244-254

Published online: 05 Feb 2018

9 Views | 0 CrossRef citations | 0 Altmetric

Article

Comparative Study of Limit Dextrinase Potential of Three Sorghum Cultivars (Safrari, Madjeru, and S.35) ›

A. C. Nguemogne, Z. S. C. Desobgo & E. J. Nso

Pages: 255-261

Published online: 05 Feb 2018

3 Views | 0 CrossRef citations | 0 Altmetric

Article

Reduction of Hordein Content in Beer by Applying Prolyl Endoprotease to the Malting Process ›

Joshua P. Taylor, Fritz Jacob, Emanuele Zannini & Elke K. Arendt

Pages: 262-268

Published online: 05 Feb 2018

5 Views | 0 CrossRef citations | 0 Altmetric

Article

Modeling of Dimethyl Sulfide Stripping Behavior When Applying Delayed Onset of Boiling during Wort Boiling ›

Z. S. C. Desobgo, R. A. Stafford & D. J. A. Metcalfe

Pages: 269-275

Published online: 05 Feb 2018

4 Views | 0 CrossRef citations | 0 Altmetric

Article

Profiling of Hop-Derived Flavan-3-ols from Lager Beer in Relation to Hopping Technology ›

Patricia M. Aron & Thomas H. Shellhammer

Pages: 276-282

Published online: 05 Feb 2018

8 Views | 0 CrossRef citations | 0 Altmetric

Explore

Most read articles | Most cited articles | Open access articles

Review article
Hop Aroma and Hoppy Beer Flavor: Chemical Backgrounds and Analytical Tools—A Review ›
Rettberg et al.

Article
The Freshening Power of Centennial Hops ›
Kirkendall et al.

Article
Impacts of Copper, Iron, and Manganese Metal Ions on the EPR Assessment of Beer Oxidative Stability ›
Jenkins et al.

Article
Use of Sorbents to Increase Beer Foam Stability ›
Kosin et al.

Pages de l’article

Modeling of Dimethyl Sulfide Stripping Behavior When Applying Delayed Onset of Boiling During Wort Boiling

Z. S. C. Desobgo,[1] R. A. Stafford, and D. J. A. Metcalfe, *Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein, Johannesburg 2028, South Africa*

ABSTRACT

J. Am. Soc. Brew. Chem. 75(3):269-275, 2017

The response surface methodology, using the central composite design as a tool for modeling, was used to study the impact of two parameters (power supply and boiling time) and their effect on dimethyl sulfide (DMS) removal during wort boiling, when applying delayed onset of boiling. It was observed that the two parameters were significantly impacting the DMS removal with a 21% contribution for power supply and a 58% contribution for the boiling time ($P = 0.000$ for both). The interaction of the two factors was also significant ($P = 0.008$) with a contribution of 7%. With the *S*-methyl methionine conversion to DMS following the pseudo first-order kinetics reaction, k_1 was computed as 0.0054 min^{-1}, and the values of k_2 were between 0.0151 and 0.407 min^{-1}. After several statistical analyses, we learned that the results coming from the theoretical equations for DMS removal at each studied power supply were not significantly different from the experimental value obtained in the laboratory, validated by the use of these equations. The time spent to reach the residual DMS target of 30, 50, and 100 ppb was 141–377, 94–295, and 60–197 min, respectively, and the energy used to reach the same target was 11.31–12.69, 8.46–8.85, and 5.40–5.91 MJ, respectively.

Keywords: Power supply, Boiling time, Dimethyl sulfide, Wort boiling, Central composite design (CCD), Response surface methodology (RSM)

Beer making, which is a complex process, generates some flavor during several treatments such as malting, mashing, boiling, and fermentation. During the malting process, a chemical named *S*-methyl methionine (SMM), whose level increases during germination, is responsible for dimethyl sulfide (DMS) formation (3,34). A portion of SMM is transformed into DMS during mashing and boiling and, because the DMS itself is very volatile, it is removed during the boiling stage, and sulfur components occurring from that process are mainly sources of off-flavors, which are globally linked to DMS (1–3,6,11,18,22,33). The high volatility of DMS and the lower concentration obtained after boiling permit the use of multiple techniques such as chromatography to estimate its residual concentration (6,9–11,14,18). Previous work demonstrated the importance of wort boiling on DMS removal, and kinetics models were presented (12,28). But in all these papers, the boiling process was continuous (12,32), apart from the Shoko process system, which used a heated holding time (26). In fact, during normal wort boiling, a batch of wort is heated continuously to reach the boiling point, and the boiling process is realized at a target evaporation rate for the duration of the boil. The target evaporation rate is intended to produce all of the classical wort boiling functions such as volatile formation, volatile stripping, sterilization, hop isomerization, hot break formation, and so on. Typical evaporation rates have gradually been reduced over the years from 10–15% per hour (volumetric % per hour) in the 1980s to currently 4–7% per hour. The primary driver behind this reduction has been the imperative to save energy and consequently reduce production costs and the environmental footprint of the brewing process. In this study, using the same energy-saving purpose, the delayed onset of boiling (DOOBOIL) was implemented and the impact of power supply and boiling time using response surface methodology was studied on the DMS removal and kinetic reaction coefficients.

[1] Corresponding author. Phone: +27725061322. E-mail: desobgo.zangue@gmail.com

http://dx.doi.org/10.1094/ASBCJ-2017-3198-01

© 2017 American Society of Brewing Chemists, Inc.

EXPERIMENTAL

Chemicals

The chemicals utilized here were DMS solution (99% purity, Sigma-Aldrich) and dichloromethane (DCM) solution (99.8% for HPLC, Chromasolv).

Boiling Procedure and Preparation of Samples

The wort at pH 5.4 and 10°P was obtained using an all-in-one, electric all-grain brewing unit system (Braumeister, Speidel, Germany), in which 10 kg of malt (obtained from SABMiller) and 50 L of water were mashed during 1 h at 65°C. The quantity of wort obtained was 45 L per brew. Many brews were done and mixed together to obtain 200 L of wort. The wort was then divided into 10 L batches for boiling trials and placed in buckets. Each bucket containing wort was placed in a deep freezer at –25°C for future use. The wort-boiling unit comprised a voltage regulator (phases, 1; input, 220 V, 50–60 Hz; output, 0–250 V; capacity, 2,000 W; max., 8 amp; model TDGC2-2kVA, AC-DC Dynamics, Johannesburg, South Africa), which was linked to a Lutron DW-6060 watt meter. The watt meter was attached to the boiling kettle. A thermometer from Therma 3 Thermometer (manufactured in the United Kingdom by ETI Ltd.) was utilized to measure the wort temperature during the boiling process (12). To realize the boiling trials, a singular power supply (1,500 W) was utilized to reduce the preheating time of 10 L of wort and permitted it to reach the boiling point (95°C). After that, the power supply using the voltage regulator was stopped, and the wort was allowed to rest (DOOBOIL) in an insulated and closed bucket (to maintain the temperature of 95°C) for a period between 0 and 60 min according to the experimental design. This resting period was to create the conditions for SMM conversion into DMS. After the targeted resting period, the cover of the bucket was removed and the wort was then boiled according to a specific power supply (using the voltage regulator) and time. The samples (50 mL, collected using a 250 mL Schott Duran glass with screw top and cooled in cold water) were taken at specific points in the process (before preheating, at the end of preheating, at the end of the resting period, and at the end of boiling). After chilling the wort, 50 mL of dichloromethane (DCM) was added, and the DMS removal from the wort was executed at 450 rpm utilizing a centrifuge (HT Infors, Bottmingen, Switzerland) for 1 h. The DCM phase containing DMS was brought into 2 mL vials and crimped for GC-MS analysis. The standard curve was done using pure DMS from Sigma-Aldrich from 0 to 1,000 ppb.

Conditions for Wort Analysis

For the analysis executed in triplicate, 2 mL crimped vials composed of the DMS drawn out from wort were analyzed and, after designating the parameters presented in Table I, 1 µL of the solu-

tion from the vials was automatically reflected in the inlet of a LECO Pegasus 4D GC×GC-TOFMS. Data were acquired using LECO's ChromaTOF software.

The Pegasus 4D GC×GC-TOFMS (LECO Corporation, U.S.A.) was utilized to estimate the concentration of DMS in every step of the study in respect of the standard curve utilizing DMS solution (Sigma-Aldrich, 99% purity). Peak identification, signal deconvolution, and computation for distinctive analytes inside the sample were attained with automated data processing. Wiley and NIST libraries were used for peak identification with signal to noise (S/N) > 200, eliminating low similarity compounds (less than 650).

Modeling

The response surface methodology (RSM) with central composite design (CCD) was adapted to the study to model and optimize the DMS removal from wort during boiling. The RSM theory provided the conditions for which the best accuracy was achieved with minimal testing and therefore the minimum cost (17). In statistics, a CCD is an experimental design, appropriate in RSM, for constructing a quadratic model for the response variable without demanding a full three-level factorial experiment. After the designed experiment is achieved, linear regression is applied, sometimes iteratively, to have results. Coded variables are usually utilized when building this design. The independent variables were the power supply (x_1) and boiling time (x_2). The intervals of variables were, respectively, 500–1,500 W and 0–60 min (Table II). The gaps were taken according to the literature (12).

From the CCD matrix, the transformation into real variables for laboratory purposes was done and the equations used were as follows:

$$X_i = X_{0i} + x_i \times \Delta X_i \quad (1)$$

$$N = k^2 + 2k + k_0 \quad (2)$$

where X_i is the real variable, X_{0i} is the center of the real variable, x_i is the coded variable given by the CCD, ΔX_i is the increment, k is the number of variables, k_0 is the number of center points, and N is the number of experiments.

With a total of 13 experiments (five replicates at the central point), the value of α was estimated for the sake of the respect orthogonality criterion (24) using the following formula:

$$\alpha = \left(\frac{2^k \left(\sqrt{2^k + 2k + k_0} + \sqrt{2^k} \right)^2}{4} \right)^{\frac{1}{4}} \quad (3)$$

where k is the number of variables and k_0 is the number of center points.

The statistical model illustrating the relation among the response and independent variables were established as a second-order polynomial equation as stated in the literature (16) as follows:

TABLE I
Conditions of LECO Pegasus Equipment for Dimethyl Sulfide Detection

Equipment	Specifications
Detector	LECO Pegasus
Rate of acquisition	200 spectra/s
Delay of acquisition	3 min
Range of mass stored	29–500 u
Temperature of transfer line	250°C
Temperature of the source	250°C
Voltage of the detector	–1,800 V
Mass defect settling	0 mu/100 u
Column 1 type	Rtx-WAX, 30 m length × 0.25 mm internal diameter, 0.25 µm film thickness
Column 2 type	DB-1, 1.0 m length × 0.1 mm internal diameter, 0.10 µm film thickness
Oven of column 1	1 min at 35°C, 4°C/min from 35 to 250°C, 10 min hold at 250°C
Oven of column 2	1 min at 45°C, 4°C/min from 45 to 360°C, 10 min hold at 360°C
Period of modulation	10 s
Offset temperature of the modulator	30°C
Inlet	Splitless at 230°C
Injection volume	1 µL
Gas	He, 1.0 mL/min constant flow

TABLE II
Central Composite Design Matrixes and Model Validation Tools (R^2, AAD, B_f, A_{f1})[a]

	Variables				Response		
	Coded variables		Real variables		Residual DMS (ppb)		
Number	Power supply, x_1	Boiling time, x_2	Power supply, X_1	Boiling time, X_2	Experimental	Theoretical	Residue
1	1	1	1,354	51	124.55 ± 2.90	123.15	1.40
2	0	0	1,000	30	360.31 ± 4.29	360.45	–0.14
3	1	–1	1,354	9	520.66 ± 2.72	519.13	1.53
4	1.414	0	1,500	30	245.7 ± 3.91	250.51	–4.81
5	0	0	1,000	30	355.24 ± 5.18	360.45	–5.21
6	0	0	1,000	30	354.44 ± 4.04	360.45	–6.01
7	0	–1.414	1,000	0	685.21 ± 3.50	678.71	6.50
8	–1	–1	646	9	590.67 ± 5.37	605.13	–14.46
9	–1	1	646	51	282.49 ± 2.60	297.07	–14.58
10	0	1.414	1,000	60	187.54 ± 2.15	180.95	6.59
11	–1.414	0	500	30	452.12 ± 2.81	434.28	17.84
12	0	0	1,000	30	371.08 ± 3.47	360.45	10.63
13	0	0	1,000	30	361.18 ± 1.50	360.45	0.73
				R^2	0.996		
				AAD	0.020		
				B_f	1.000		
				A_{f1}	1.018		

[a] AAD = absolute average deviation; B_f = bias factor; A_f = accuracy factor; and DMS = dimethyl sulfide.

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum \sum_{i<j}^{k} \beta_{ij} x_i x_j + \varepsilon \quad (4)$$

where y is response, x_i and x_j are variables, β_0 is the constant, β_i is the linear term coefficient, β_{ii} is the quadratic term coefficient, and β_{ij} is the interaction term coefficient.

The model and statistics were accessed utilizing Minitab 16 software (Minitab, Coventry, U.K.), and graphs were plotted by applying Sigmaplot version 13, build 13.0.0.83 (Dundas Software, Wpcubed GmbH, Germany).

The validation of the model was done by estimating the absolute average deviation (AAD), the bias factor (B_f), and accuracy factor (A_f) (4,31), which were asserted as follows:

$$\mathrm{AAD} = \frac{\left[\sum_{i=1}^{N} \left(\frac{\left| y_{i,\exp} - y_{i,cal} \right|}{y_{i,\exp}} \right)\right]}{N} \quad (5)$$

$$B_f = 10^{\frac{1}{N}\sum_{i=1}^{N} \log\left(\frac{y_{i,cal}}{y_{i,\exp}} \right)} \quad (6)$$

$$A_{f1} = 10^{\frac{1}{N}\sum_{i=1}^{N} \left| \log\left(\frac{y_{i,cal}}{y_{i,\exp}} \right) \right|} \quad (7)$$

where $y_{i,\exp}$ and $y_{i,cal}$ are experimental and theoretical responses, respectively, and N is the number of trials.

The contributions of the linear, quadratic, and interaction terms for each variable were estimated as follows:

$$\text{linear } (\%) = \frac{\left|\beta_i\right|}{\sum_{i=1}^{k}\left|\beta_i\right| + \sum_{i=1}^{k}\left|\beta_{ii}\right| + \sum\sum_{i<j}^{k}\left|\beta_{ij}\right|} \quad (8)$$

$$\text{quadratic } (\%) = \frac{\left|\beta_{ii}\right|}{\sum_{i=1}^{k}\left|\beta_i\right| + \sum_{i=1}^{k}\left|\beta_{ii}\right| + \sum\sum_{i<j}^{k}\left|\beta_{ij}\right|} \quad (9)$$

$$\text{interaction } (\%) = \frac{\left|\beta_{ij}\right|}{\sum_{i=1}^{k}\left|\beta_i\right| + \sum_{i=1}^{k}\left|\beta_{ii}\right| + \sum\sum_{i<j}^{k}\left|\beta_{ij}\right|} \quad (10)$$

Evaluation of Reaction Rate Coefficient of SMM Conversion to DMS (k_1)

Taking into consideration that the reaction was assumed to be of first-order reaction kinetics, and also that it could be simultaneous, the estimation k_1 was executed during the resting period. This was done at that stage as the DMS stripping was weak because of no boiling and a closed bucket. The insulated bucket allowed maintenance of the temperature in the system at the boiling point (95°C), and thus the conversion of SMM was the main reaction. At the end of each resting period (0, 9, 30, 51, and 60 min), samples were taken for DMS analysis. Because the reaction kinetic rate of DMS generated was considered equal to the SMM elimination, the values of DMS obtained were used and, considering the reaction as stoichiometric, the value of $[A]_0$ was calculated.

The values of DMS obtained were plotted in a graph, and a regression using the first-order kinetics reaction equation was implemented to determine the value of k_1. That first-order kinetic reaction equation was expressed as follows:

$$[A] = [A]_0 \exp(-k_1 t) \quad (11)$$

where $[A]$ is SMM concentration at any time t, $[A]_0$ is the initial concentration of SMM, and k_1 is the reaction rate coefficient of SMM conversion to DMS.

Evaluation of Volatility Rate Coefficient of DMS (k_2) and Other Constant Terms

The validated polynomial multivariable model was used at each fixed value power supply, and the DMS model, which was remaining as a function of time, was correlated to the theoretical established model to determine k_2 and other constant coefficients. That model was as follows:

$$[DMS]_T = \frac{k_1 [A]_0}{k_2 - k_1}\left(e^{-k_1 t} - e^{-k_2 t}\right) + [B]_0 e^{-k_2 t} \quad (12)$$

where $[DMS]_T$ is residual DMS in the wort after boiling, k_2 is the volatility rate coefficient of DMS, and $[B]_0$ is the initial concentration of DMS.

To obtain the value of k_2, the theoretical equation was introduced in Sigmaplot 13.0 (regression wizard) in order to plot and determine all the constant terms of that equation. This was done by introducing the obtained value of $[A]_0$ and k_1 because the SMM conversion to DMS was considered temperature dependent and the boiling process was done at atmospheric pressure with that temperature remaining at 95°C.

Statistical analysis was performed to compare the value obtained from the theoretical established equation and the experimental results. This was done to validate the theoretical equations obtained.

Optimization

Lastly, optimization was realized by fixing three targets of residual DMS concentration in the wort (30, 50, and 100 ppb). The time was calculated using Scientific WorkPlace 5.5 software, build 2890 (MacKichan Software) to solve the equations. The graphs were executed with Sigmaplot 13.0, build 13.0.0.83 (Dundas Software).

Energy Calculation

The calculation of the energy depends on the power of the device and its usage time. Thus, the energy consumed during the boiling of the wort is estimated by the following formula:

$$E = P_i t \quad (13)$$

where E is the energy consumed (J), P_i is the power supply, and t is the boiling time.

RESULTS AND DISCUSSION

RSM for Residual Wort DMS Modeling

RSM was used to assess the model for DMS removal during wort boiling unit operation after DOOBOIL, and ANOVA was utilized for statistical analysis on the model (Table II). DMS was detected using the LECO GC-MS (Fig. 1), and the model acquired was as follows:

$$y(x_1, x_2) = 360.45 - 64.98x_1 - 176.01x_2 - 21.98x_1x_2 - 9.03x_1^2 + 34.7x_2^2 \quad (14)$$

where $y(x_1,x_2)$ is the model for residual DMS, x_1 is the power supply, and x_2 is the boiling time.

The obtained model was polynomial multivariable, with a correlation coefficient (R^2) of 0.996. The model was validated by determining AAD, B_f, and A_{f1}. The values of 0.020, 1.000, and 1.018 were obtained, respectively (Table II). Also, a nonsignificant value of the lack-of-fit (0.052) confirmed that the model was adequate.

In Table II, values of $P < 0.050$ designated that model terms were significant. In this case, x_1, x_2, x_1x_2, and x_2^2 were significant model terms. Values higher than 0.050 indicated the model terms were not significant (x_1^2). With the certification of the model validation accomplished, the simulation of the impact of each singular and interaction factor was then assessed.

Impact of power supply. The influence of power supply (x_1) on DMS removal was significant ($P = 0.000$, Table III). Its contribution to DMS removal was estimated at 21% (Table III). Its effect is shown in Figure 2A when fixing the boiling time (x_2) at 30 min. In fact, DMS decreased from 434.28 ppb at 500 W to 250.51 ppb at 1,500 W. An increase in power supply (and in turn, energy load and evaporation rate) raised DMS removal and reduced residual DMS in wort. This could be seen because the DMS, which derived from SMM by heat during wort boiling (1), was dissipated and whisked away with the steam (36).

Impact of boiling time. The effect of the boiling time (x_2) on DMS elimination was significant ($P = 0.000$, Table III). Its impact is shown in Figure 2B when adjusting the power supply (x_1) at 500 W. It was therefore observed that DMS declined from 708.59 ppb initially (at $t = 0$ min) to 298.72 ppb at 60 min. In fact, because the half-life of DMS was between 30 and 70 min (1,13, 29,37), the longer the boiling time, the higher the DMS that was discarded from wort (5,8,12,15,19,20,23,25,27,30). Its contribution to DMS removal was calculated at 58% (Table III).

Impact of power supply/boiling time interaction. The impact of power supply/boiling time (x_1x_2) on DMS discharge was significant ($P = 0.008$, Table III). It was observed (Fig. 3) that there was a synergistic effect between the two factors on the discharge of DMS during wort boiling. This can be seen because, when increasing the power supply, the evaporation rate increased, and with an increase of the boiling time, a significant amount of DMS was removed from wort (12). Its contribution was yielded at 7%.

Determination of Reaction Rate Coefficient of SMM Conversion to DMS (k_1)

During the trials, the DOOBOIL was between 0 and 60 min. It was used to obtain the data in Figure 4. Because the kinetic energy of discharge of SMM was considered equal to the kinetic energy of generation of DMS, the value of k_1, which was 0.0054

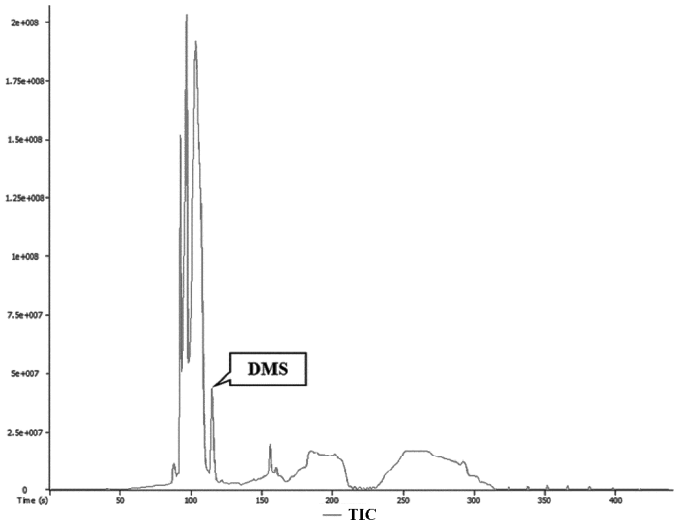


Fig. 1. Chromatogram of wort for dimethyl sulfide (DMS) detection.

TABLE III
Analysis of Variance for Dimethyl Sulfide Model

Source	DF	Seq SS	Adj SS	Adj MS	*F*	*P*
Regression	5	293,237	293,237	58,647	398.96	0.000
Linear	2	281,627	281,627	140,814	957.92	0.000
x_1	1	33,783	33,783	33,783	229.82	0.000
x_2	1	247,844	247,844	247,844	1,686.01	0.000
Square	2	9,677	9,677	4,839	32.92	0.000
x_1^2	1	1,301	568	568	3.86	0.090
x_2^2	1	8,376	8,376	8,376	56.98	0.000
Interaction	1	1,933	1,933	1,933	13.15	0.008
$x_1 x_2$	1	1,933	1,933	1,933	13.15	0.008
Residual error	7	1,029	1,029	147		
Lack-of-fit	3	852	852	284	6.43	0.052
Pure error	4	177	177	44		
Total	12	294,266				

[a] DF = degrees of freedom; Seq SS = sequential sum of squares; Adj SS = adjusted sum of squares; and Adj MS = adjusted mean squares.

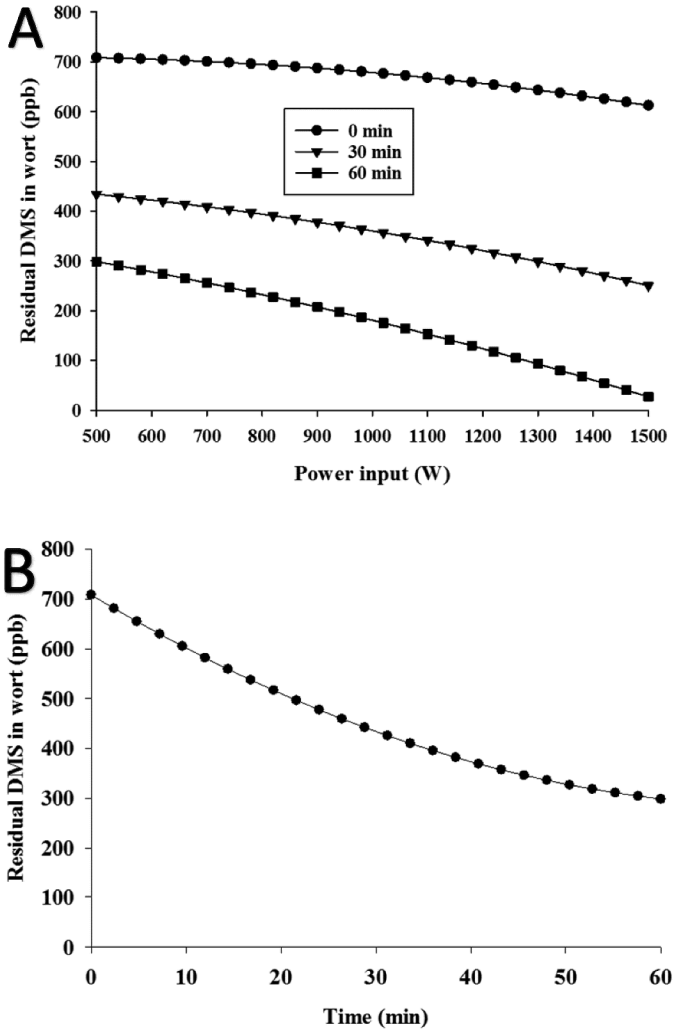


Fig. 2. Residual dimethyl sulfide (DMS) evolution: **A,** at fixed boiling times, and **B,** at a 500 W fixed value of power supply.

min^{-1}, was estimated using the DMS generation (Fig. 4). The stoichiometric relation between SMM and DMS was used and calculated the value of $[A]_0$, which was 390.54 ppb. The equation was written as follows:

$$[A] = 390.54 \times \exp(-0.0054t) \quad (15)$$

where S is residual concentration of SMM in the wort and t is time.

The estimated value of k_1 was about 1.85 times lower than the values (0.01 min^{-1} at 95°C) obtained by the literature (32). In fact, this could be explained by the fact that a reaction rate coefficient could vary depending on the operating conditions (13,35). For the Mitani case, after exploiting the data, the calculated power supply for their operating system was 11,850 W for a type 1 vessel and 4,900 W for a type 2 vessel. These conditions were obviously far more severe than the conditions used for this work. In fact, an increase in power supply for a specified time generated a global energy that contributed to increase the final temperature of the wort and thus an increase of k_1. The consequence was a weaker efficiency of SMM conversion to DMS, meaning a lower value of k_1.

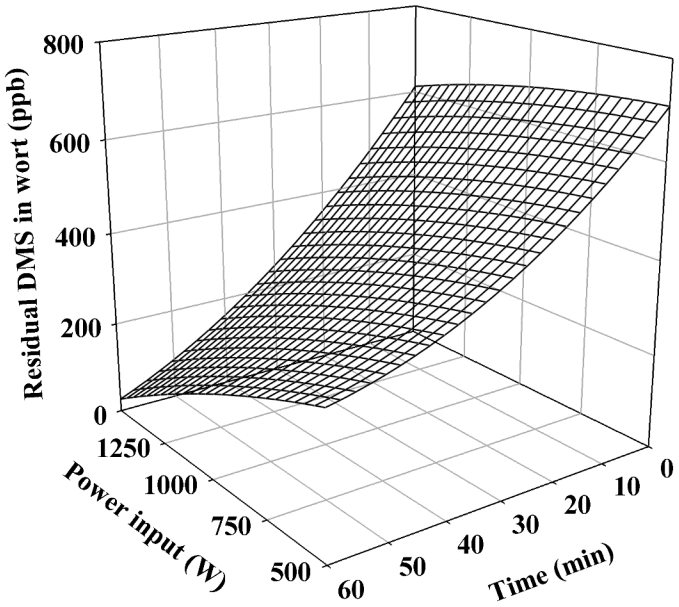


Fig. 3. Effect of power supply (power input)/boiling time interaction on the residual dimethyl sulfide (DMS) content of wort.

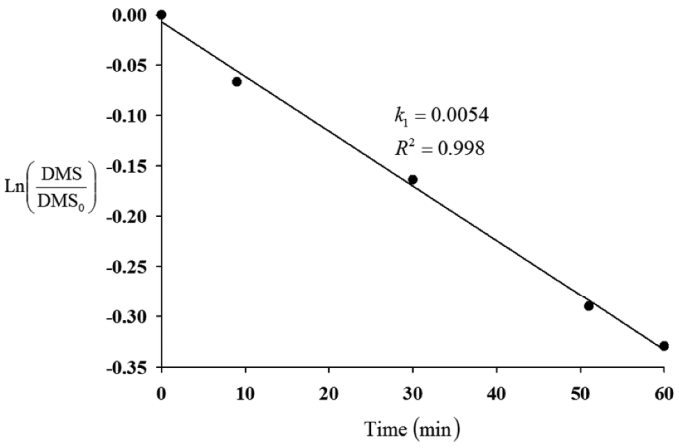


Fig. 4. Estimation of reaction rate coefficient of *S*-methyl methionine conversion to dimethyl sulfide (DMS) (k_1).

Determination Volatility Rate Coefficient of DMS (k_2) and Other Constants

After estimating the reaction rate k_1 and $[A]_0$ obtained after the DOOBOIL, the introduction of the theoretical model in Sigmaplot 13.0, taking into account the previous value calculated for SMM conversion kinetics, permitted us to obtain the complete equations for DMS stripping as follows for each power supply:

$$[DMS]_{T500} = \frac{0.0054}{0.0151 - 0.0054} \times 390.54\left[\exp(-0.0054t) - \exp(-0.0151t)\right] + 696.35\exp(-0.0151t) \quad (16)$$

$$[DMS]_{T646} = \frac{0.0054}{0.0168 - 0.0054} \times 390.54\left[\exp(-0.0054t) - \exp(-0.0168t)\right] + 697.39\exp(-0.0168t) \quad (17)$$

$$[DMS]_{T1000} = \frac{0.0054}{0.0222 - 0.0054} \times 390.54\left[\exp(-0.0054t) - \exp(-0.0222t)\right] + 693.45\exp(-0.0222t) \quad (18)$$

$$[DMS]_{T1354} = \frac{0.0054}{0.0322 - 0.0054} \times 390.54\left[\exp(-0.0054t) - \exp(-0.0322t)\right] + 691.46\exp(-0.0322t) \quad (19)$$

$$[DMS]_{T1500} = \frac{0.0054}{0.0407 - 0.0054} \times 390.54\left[\exp(-0.0054t) - \exp(-0.0407t)\right] + 706.56\exp(-0.0407t) \quad (20)$$

where $[DMS]_{T500}$, $[DMS]_{T646}$, $[DMS]_{T1000}$, $[DMS]_{T1354}$, and $[DMS]_{T1500}$ are the equations for DMS volatility when boiling was realized at 500, 646, 1,000, 1,354, and 1,500 W, respectively.

The value of k_1 remained constant because the heating process until boiling was executed using the same power supply (1,500 W), whereas the increase of k_2 observed with the increase of power supply could be interpreted by the fact that the modification of operating conditions changed the volatility rate coefficient value, as observed in the literature (1,12,13,28). The values obtained were similar to those of Mitani (28) and of the substitute wort water/DMS/sugar (12), which used the same boiling unit equipment.

A simulation was done to estimate the value of residual DMS in wort using the global equations (Mitani equation) to compare the values with experimental data. All the data were summarized in Table III. Three statistical analyses (ANOVA, variance check, and Kruskal–Wallis test) were executed to see whether there was a statistical difference or not between the data. The ANOVA table broke up the variance of the data into two constituents, the between-group constituent and the within-group constituent. The P values of the F test were greater than 0.05 (Table IV); there was not a statistically significant difference between the means of the two compared variables. For the variance check, the statistic dis-

played the null hypothesis that the standard deviations within both groups of data were the same. Considering that the *P* values were greater than 0.05 (Table IV), there was not a statistically significant difference among the standard deviations of the compared variables. The Kruskal–Wallis test tested the null hypothesis that the medians within each of the two variables were the same. The data from all the samples were first combined and ranked from smallest to largest. The average rank was then calculated for the data in each sample. Because the *P* values were greater than 0.05 (Table IV), there was not a statistically significant difference among the medians.

The different statistical analyses confirmed that the equations established (Mitani equation) followed the effective DMS removal during wort boiling. Therefore, the theoretical equations were used for the optimization process because the RSM could not allow investigations out of the intervals studied.

Optimization

The target values of residual DMS in wort were fixed at 30, 50, and 100 ppb because the supported values in the literature were from 30 to 100 ppb (7,8,19,21). Using Scientific Workplace 5.5 and Sigmaplot 13.0 software, the Mitani equations were solved and the different times to reach the targets were assessed. These targets were chosen to examine the efficiency of the laboratory boiling conditions when applying DOOBOIL on the removal of DMS.

The boiling times estimated for 30, 50, and 100 ppb were then 141–377, 94–295, and 60–197 min, respectively, as observed in Figure 5. These data suggested that the boiling conditions (DOOBOIL) executed were not suitable to reach a low level (30 ppb) and medium level (50 ppb) of DMS unless the boiling stage was realized for a very long period. This aspect implied high energy to spend, meaning 11.31–12.69 and 8.46–8.85 MJ, respectively, to reach 30 and 50 ppb. It was therefore suitable to reach a residual value of 100 ppb because the boiling time was 60–197 min and the energy spent was 5.40–5.91 MJ.

The values of energy spent to reach the target of 50 ppb were higher than the one spent to reach the same target using wort substitutes, which was between 3.66 and 6.42 MJ (12). This could be explained by the presence of SMM and its low value of k_1, which were the elements that could be responsible for the longer boiling time estimated to reach the targets. In fact, the low value of k_1 enabled a slower conversion of SMM into DMS and then a longer period of DMS removal.

TABLE IV
Statistical Analysis (Probability Values, *P*) Comparison Between Mitani Equation Theoretical Data and Response Surface Methodology Model at Each Power Supply

Power supply (W)	ANOVA	Variance check	Kruskal–Wallis test
500	0.404	0.519	0.317
646	0.453	0.577	0.369
1,000	0.543	0.703	0.457
1,354	0.655	0.875	0.555
1,500	0.747	0.973	0.738

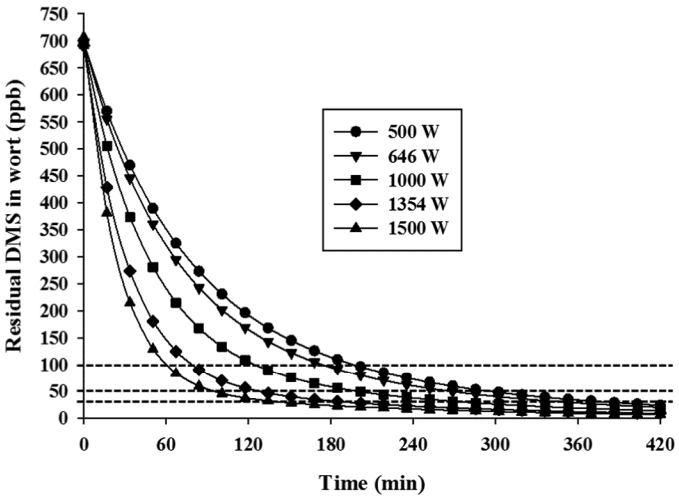


Fig. 5. Estimation of boiling time necessary to reach the targets of 30, 50, and 100 ppb of dimethyl sulfide (DMS).

CONCLUSIONS

Impacts of boiling time and power supply on DMS stripping from wort were investigated. The influence of these variables and the interaction between them were significant. When applying the DOOBOIL during wort boiling, it was found that the value of reaction rate coefficient of SMM conversion to DMS (k_1) was lower than the volatility rate coefficient of DMS (k_2). That situation generated very long boiling times and high energy spent to reach some targets (30 and 50 ppb). It then became obvious that DOOBOIL was not suitable for these targets at laboratory-scale wort boiling with nonpressure vessels. It would be therefore relevant to investigate a combination of gas sparging and DOOBOIL effects.

ACKNOWLEDGMENTS

Our acknowledgements go to the Faculty of Science (Department of Biotechnology and Food Technology and Department of Applied Chemistry) of the University of Johannesburg, Doornfontein Campus, for support of this study and to SABMiller for supplying malt.

LITERATURE CITED

1. Anness, B. J., and Bamforth, C. W. Dimethyl sulfide—A review. *J. Inst. Brew.* 88:244-252, 1982.
2. Arfi, K., Spinnler, H. E., Tache, R., and Bonnarme, P. Production of volatile compounds by cheese-ripening yeasts: Requirement for a methanethiol donor for *S*-methyl thioacetate synthesis by *Kluyveromyces lactis*. *Appl. Microbiol. Biotechnol.* 58:503-510, 2002.
3. Bamforth, C. W. Dimethyl sulfide—Significance, origins, and control. *J. Am. Soc. Brew. Chem.* 72:165-168, 2014.
4. Baranyi, J., Pin, C., and Ross, T. Validating and comparing predictive models. *Int. J. Food Microbiol.* 48:159-166, 1999.
5. Barnes, Z. C. Brewing process control. In: *Handbook of Brewing*, F. G. Priest and G. G. Stewart, eds. CRC Press, Boca Raton, FL, 2006.
6. Berger, C., Martin, N., Collin, S., Gijs, L., Khan, J. A., Piraprez, G., Spinnler, H. E., and Vulfson, E. N. Combinatorial approach to flavor analysis. 2. Olfactory investigation of a library of *S*-methyl thioesters and sensory evaluation of selected components. *J. Agric. Food Chem.* 47:3274-3279, 1999.
7. Briggs, D. E. *Malts and Malting*. Springer, London, 1998.
8. Briggs, D. E., Boulton, C. A., Brookes, P. A., and Stevens, R. *Brewing Science and Practice*. Woodhead and CRC Press, Cambridge, U.K., 2004.
9. Burmeister, M. S., Drummond, C. J., Pfisterer, E. A., Hysert, D. W., Sin, Y. O., Sime, K. J., and Hawthorne, D. B. Measurement of volatile sulfur compounds in beer using gas chromatography with a sulfur chemiluminescence detector. *J. Am. Soc. Brew. Chem.* 50:53-58, 1992.
10. De Schutter, D. P., Saison, D., Delvaux, F., Derdelinckx, G., Rock, J.-M., Neven, H., and Delvaux, F. R. Optimisation of wort volatile analysis by headspace solid-phase microextraction in combination with gas chromatography and mass spectrometry. *J. Chromatogr. A* 1179:75-80, 2008.

11. Dercksen, A., Laurens, J., Torline, P., Axcell, B. C., and Rohwer, E. Quantitative analysis of volatile sulfur compounds in beer using a membrane extraction interface. *J. Am. Soc. Brew. Chem.* 54:228-233, 1996.
12. Desobgo, Z. S. C., Stafford, R. A., and Metcalfe, D. J. A. Dimethyl sulfide stripping behavior during wort boiling using response surface methodology. *J. Am. Soc. Brew. Chem.* 73:84-89, 2015.
13. Dickenson, C. J. The relationship of dimethyl sulphide levels in malt, wort and beer. *J. Inst. Brew.* 85:235-239, 1978.
14. Firor, R. L., and Quimby, B. D. A comparison of sulfur selective detectors for low level analysis in gaseous streams. In: *Application Note*, Agilent Technologies, 2001.
15. Fix, G. Sulfur flavors in beer. *Zymurgy* 15:40-44, 1992.
16. Giovanni, M. Response surface methodology and product optimization. *Food Technol.* 37:41-45, 1983.
17. Goupy, J., and Creighton, L. *Introduction aux plans d'expériences*. Dunod, Paris, 2006.
18. Hill, P. G., and Smith, R. M. Determination of sulphur compounds in beer using headspace solid-phase microextraction and gas chromatographic analysis with pulsed flame photometric detection. *J. Chromatogr. A* 872:203-213, 2000.
19. Hough, J. S., Briggs, D. E., Stevens, R., and Young, T. W. *Malting and Brewing Science.* Chapman and Hall, London, 1982.
20. Krottenthaler, M., Rübsam, H., and Becker, T. Optimizing brewhouse technology with reference to dimethylsulfide. *Brauwelt Int.* 28:138-145, 2010.
21. Kunze, W. *Technology Brewing and Malting*. VLB, Berlin, 2004.
22. Leppänen, O. A., Denslow, J., and Ronkainen, P. P. Determination of thioacetates and some other volatile sulfur compounds in alcoholic beverages. *J. Agric. Food Chem.* 28:359-362, 1980.
23. Lewis, M. J., and Bamforth, C. W. *Essays in Brewing Science*. Springer, New York, 2006.
24. Louvet, F., and Delplanque, L. *Design of experiments: The French touch/Les plans d'expériences: Une approche pragmatique et illustrée*. Expérimentique, 2005.
25. Meilgaard, M. Effects on flavour of innovations in brewery equipment and processing: A review. *J. Inst. Brew.* 107:271-286, 2001.
26. Mezger, R. Betrachtung moderner Würzekochsysteme bezüglich ihres Einflusses auf technologisch und physiologisch bedeutende Würzeinhaltsstoffe. In: *Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt*. Technische Universität München, München, Germany, 2006.
27. Miracle, R. E., Ebeler, S. E., and Bamforth, C. W. The measurement of sulfur-containing aroma compounds in samples from production-scale brewery operations *J. Am. Soc. Brew. Chem.* 63:129-134, 2005.
28. Mitani, Y., Suzuki, H., Abe, T., Nomura, M., and Shinotsuka, K. Performance of wort boiling with inert gas sparging for the energy reduction. Pages 619-626 in: *Proceedings of the EBC Congress*, 1999.
29. Narziss, L., Miedaner, H., and Schneider, F. Some aspects of the technology of wort boiling today. *Brauwelt Int.* 4:346-355, 1992.
30. Poreda, A., Czarnik, A., Zdaniewicz, M., Jakubowski, M., and Antkiewicz, P. Corn grist adjunct—Application and influence on the brewing process and beer quality. *J. Inst. Brew.* 120:77-81, 2014.
31. Ross, T. Indices for performance evaluation of predictive models in food microbiology. *J. Appl. Bacteriol.* 81:501-508, 1996.
32. Scheuren, H., Tippmann, J., Methner, F. J., and Sommer, K. Decomposition kinetics of dimethyl sulphide. *J. Inst. Brew.* 120:474-476, 2014.
33. Seaton, J. C. Special malt types and beer quality. Pages 29-30 in: *Proceedings of the International Symposium-Malting and Brewing Technology: Progress Through Increased Knowledge*, Brussels, Belgium, 1993.
34. Ullrich, S. E. *Barley: Production, Improvement, and Uses*. Wiley-Blackwell, London, 2011.
35. Vavilin, V. A., Fernandez, B., Palatsi, J., and Flotats, X. Hydrolysis kinetics in anaerobic degradation of particulate organic material: An overview. *Waste Manag.* 28:939-951, 2008.
36. White, F. H., and Wainwright, T. The measurement of dimethyl sulphide precursor in malts, adjuncts, worts and beers. *J. Inst. Brew.* 82:46-48, 1976.
37. Wilson, R. J. H., and Booer, C. D. Control of the dimethyl sulphide content of beer by regulation of the copper boil. *J. Inst. Brew.* 85:144-148, 1978.

Résumé de l’article

Modeling of Dimethyl Sulfide Stripping Behavior When Applying Delayed Onset of Boiling During Wort Boiling

Z. S. C. Desobgo*, R. A. Stafford, and D. J. A. Metcalfe

Abstract

The response surface methodology, using the central composite design as a tool for modeling, was used to study the impact of two parameters (power supply and boiling time) and their effect on dimethyl sulphide (DMS) removal during wort boiling, when applying delayed onset of boiling. It was observed that the two parameters were significantly impacting the DMS removal with a 21% contribution for power supply and a 58% contribution for the boiling time ($P = 0.000$ for both). The interaction of the two factors was also significant ($P = 0.008$) with a contribution of 7%. With the S-methyl methionine conversion to DMS following the pseudo first-order kinetics reaction, k_1 was computed as 0.0054 min^{-1}, and the values of k_2 were between 0.0151 and 0.407 min^{-1}. After several statistical analyses, we learned that the results coming from the theoretical equations for DMS removal at each studied power supply were not significantly different from the experimental value obtained in the laboratory, validated by the use of these equations. The time spent to reach the residual DMS target of 30, 50, and 100 ppb was 141–377, 94–295, and 60–197 min, respectively, and the energy used to reach the same target was 11.31–12.69, 8.46–8.85, and 5.40–5.91 MJ, respectively.

Keywords: Power supply, Boiling time, Dimethyl sulfide, Wort boiling, Central composite design (CCD), Response surface methodology (RSM)

IV.4.10) Impact of Gaseous Carbon Dioxide and Boiling Power on Dimethyl Sulfide Stripping Behavior During Wort Boiling

Titre de la revue

American Society of Brewing Chemists
FREE ACCESS

Comité de lecture

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, pleas
contact our customer service department to purchase a subscription.

Journal

Journal of the American Society of Brewing Chemists ›
The Science of Beer

This journal

Editorial board

Editor-in-Chief
Inge Russell

Editorial Board
G. Aerts
R. Agu
P. Aldred
M. Andersen
P. Aron
C. Boulton
S. Britton
D. Cook
C. Curtin
S. Deckers
J. De Clippeleer
S. Duke
A. Egi
R. Foster
L. Garbe
C. Henson

A. Hill
J. Hort
N. Kageyama
M. Kanauchi
S. Lawrence
Q. Li
B. Lodolo
A. Macintosh
D. Maskell
C. Powell
G. Sanchez
D. Sedin
S. Serna-Saldivar
T. Shellhammer
J. Sheppard
A. Speers
D. Stewart
E. Storgards
L. Van Nedervelde
K. Verstrepen
D. Vollmer
G. Walker
D. Wang
H. Wedler
X. Yin
M. Zarnkow
B. Ziola

Publisher
Amy L. Hope

Director of Publications
Greg Grahek

Technical Editor

Carol Duling

Circulation Coordinator

Dawn Wuest

Table des matières

Taylor & Francis Online

Log in | Register

Due to a technical issue, we are unable to display some subscription pricing. In the meantime, please contact our customer service department to purchase a subscription.

Journal of the American Society of Brewing Chemists

The Science of Beer

2017 Impact Factor
0.880

Publish open access in this journal

Advanced search

Submit an article New content alerts RSS Citation search

Current issue Browse list of issues

Official Journal of the American Society of Brewing Chemists

This journal

Investigations into the Transfer Rate of Volatile Compounds in Hopping

Published online: 6 Jul 2018

Kirkendall et al.

Published online: 11 Jun 2018

Control of Fermentation By-Products and Aroma Features of Beer Pr ed with Sc Ale Yeast by Variation of Fermentation Temperature and Wort Aeration Rate

Published online: 7 Jun 2018

Pan et al.

Published online: 29 Mar 2018

Analysis of Physicoche mical Indices, Volatile Flavor Components , and Microbial Community of a Light-Flavor *Daqu*

See all volumes and issues

Vol 76, 2018 Volume 75, 2017 Vol 74, 2

Issue 4 Issue 3 Issue 2 Issue 1

ing an t Water Coefficient Model

Biographical Review

Review

A Happy, Hoppy Odyssey: From a Flavorsome Hobby to a Dream Job

Denis De Keukeleire

Pages: 283-301

Published online: 05 Feb 2018

17 Views	0 CrossRef citations	0 Altmetric

Original Articles

Article

Comparison of Diastatic Power Enzyme Release and Persistence during Modified Institute of Brewing 65°C and Congress Programmed Mashes

D. Evan Evans & Glen P. Fox

Pages: 302-311

Published online: 05 Feb 2018

11 Views	0 CrossRef citations	0 Altmetric

Article

Distribution of *Lactobacillus* and *Pediococcus* in a Brewery Environment ›

Jorge Hugo Garcia-Garcia, Luis J. Galán-Wong, Benito Pereyra-Alférez, Luis C. Damas-Buenrostro, Esmeralda Pérez & Juan Carlos Cabada

Pages: 312-317

Published online: 05 Feb 2018

25 Views | 0 CrossRef citations | 0 Altmetric

Article

Rapid Screening Method for Phenolic Off-Flavor (POF) Production in Yeast ›

Stijn Mertens, Jan Steensels, Brigida Gallone, Ben Souffriau, Philippe Malcorps & Kevin J. Verstrepen

Pages: 318-323

Published online: 05 Feb 2018

31 Views | 0 CrossRef citations | 0 Altmetric

Article

Impact of Gaseous Carbon Dioxide and Boiling Power on Dimethyl Sulfide Stripping Behavior during Wort Boiling ›

Z. S. C. Desobgo, R. A. Stafford, D. T. Ndinteh, D. J. A. Metcalfe & R. Meijboom

Pages: 324-332

Published online: 05 Feb 2018

10 Views | 0 CrossRef citations | 0 Altmetric

Article

Rapid Determination of Humulones and Isohumulones in Beers Using MISER LC-MS Analysis ›

Bruce C. Hamper, Kerstin Zawatzky, Vivian Zhang & Christopher J. Welch

Pages: 333-338

Published online: 05 Feb 2018

13 Views | 0 CrossRef citations | 0 Altmetric

Article

Detection of a Hop-Tolerance Gene *horA* Insertion Variant in Lactic Acid Bacteria That Results in a Truncated HorA Lacking the Walker B Motif Necessary for Transport Function ›

Jordyn Bergsveinson, Ilkka Kajala, Scott Goerzen & Barry Ziola

Pages: 339-344

Published online: 05 Feb 2018

7 Views | 0 CrossRef citations | 0 Altmetric

Article

Effects of Barley (*Hordeum Vulgare* L.) Variety and Growing Environment on Beer Flavor ›

Dustin Herb, Tanya Filichkin, Scott Fisk, Laura Helgerson, Patrick Hayes, Brigid Meints, Rebecca Jennings, Robert Monsour, Sean Tynan, Kristi Vinkemeier, Ignacio Romagosa, Matthew Moscou, Daniel Carey, Randy Thiel, Luis Cistue, Christopher Martens & William Thomas

Pages: 345-353

Published online: 05 Feb 2018

68 Views | 1 CrossRef citations | 18 Altmetric

Article

Malt Modification and its Effects on the Contributions of Barley Genotype to Beer Flavor ›

Dustin Herb, Tanya Filichkin, Scott Fisk, Laura Helgerson, Patrick Hayes, Amanda Benson, Veronica Vega, Daniel Carey, Randy Thiel, Luis Cistue, Rebecca Jennings, Robert Monsour, Sean Tynan, Kristi Vinkemeier, Yueshu Li, Andrew Nguygen, Aaron Onio, Brigid Meints, Matthew Moscou, Ignacio Romagosa & William Thomas

Pages: 354-362

Published online: 05 Feb 2018

33 Views | 1 CrossRef citations | 0 Altmetric

Article

Toward Understanding the Bitterness of Dry-Hopped Beer ›

Ellen Parkin & Thomas Shellhammer

Pages: 363-368

Published online: 05 Feb 2018

41 Views | 0 CrossRef citations | 0 Altmetric

Article

Effect of Dilute Alkaline Steeping on Mold Contamination, Toxicity, and Nutritive Value of Maize Malt ›

Marko M. Jauković, Veselinka M. Zečević, Slavica Ž. Stanković, Vesna S. Krnjaja, Tanja S. Nikić, Stanislava M. Bailović & Jelena I. Tadić

Pages: 369-373

Published online: 05 Feb 2018

5 Views | 0 CrossRef citations | 0 Altmetric

Technical Committee and Subcommittee Reports

Report

2016–2017 Report of the Technical Committee ›

Pages: S375-S386

Published online: 06 Mar 2018

4 Views | 0 CrossRef citations | 0 Altmetric

Pages de l’article

Impact of Gaseous Carbon Dioxide and Boiling Power on Dimethyl Sulfide Stripping Behavior During Wort Boiling

Z. S. C. Desobgo[1] and R. A. Stafford, *Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein, Johannesburg 2028, South Africa;* **D. T. Ndinteh,** *Department of Applied Chemistry, University of Johannesburg, P.O. Box 17011, Doornfontein, Johannesburg 2028, South Africa;* **D. J. A. Metcalfe,** *Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein, Johannesburg 2028, South Africa;* **and R. Meijboom,** *Department of Chemistry, Faculty of Science, University of Johannesburg, P.O. Box 17011, Auckland Park Kingsway, Johannesburg 2028, South Africa*

ABSTRACT

J. Am. Soc. Brew. Chem. 75(4):324-332, 2017

The impact of carbon dioxide (CO_2) supply flow rate on dimethyl sulfide (DMS) removal during wort boiling was studied when applying a 1 h hold between the end of preheating and the beginning of boiling. This was done during wort boiling by varying the boiling power (from 500 to 1,500 W), aiming to reduce energy consumption to reach the target of an end-of-boil DMS concentration of 100 ppb (w/v). When using the Mitani equation, which describes *S*-methyl methionine (SMM) conversion into DMS and DMS stripping, the preboiling step allowed a reaction rate coefficient of SMM conversion (k_1) value of 0.0099 min^{-1} to be obtained. The values of volatilization rate coefficient of DMS (k_2) during the provision of CO_2 at a flow rate between 5 and 11 L/min and boiling power between 500 and 1,500 W were between 0.02049 and 0.07882 min^{-1}. It was found that the coefficient k_2 increased with the increase of CO_2 supply flow rate and the increase of boiling power. At a fixed boiling power of 1,500 W, the use of CO_2 supply flow rate permitted the target of 100 ppb to be attained in an interval of 39.21 min for 11 L/min to 62.31 min for 5 L/min. The energy saved in the boiling process when applying CO_2 supply flow rate between 5 and 11 L/min was 2.49–4.57 MJ.

Keywords: Boiling power, Boiling time, Dimethyl sulfide, Wort boiling, CO_2 supply flow rate

Reducing energy production costs is a major concern for food industries in general and breweries in particular. One major target is the reduction of process time in energy-intensive steps (37–39,43, 47,54). This reduction in process time must not impact negatively on the quality of the product, allowing good qualitative and physicochemical characteristics of the product to develop. In the brewing process, wort boiling is one of the most energy-intensive steps (25,26,51), and it is one of the last processing steps in which wort physicochemical characteristics are fixed before fermentation. During the boiling step, wort profile characteristics are developed, including the development of numerous undesirable flavors (off-flavors). Among the multitude of off-flavor components, dimethyl sulfide (DMS) is a major concern (1,3,4,7,18,27,35,49). DMS develops from *S*-methyl methionine (SMM) and increases during the malting process (4,53). The thermal conversion of SMM to DMS, the oxidation of DMS to dimethyl sulfoxide (DMSO) (1,2), and the fact that DMS is volatile allow the wort boiling step to potentially be a method of eliminating this off-flavor. Many efficient chromatographic protocols reported in the literature enable the evaluation of residual concentrations of DMS after malting, wort boiling, and fermentation (7,14,17,18,23,27). The wort boiling procedures in the brewhouse (and research on it) consist of executing a continuous boil and applying theoretical model to estimate some parameters linked to DMS stripping (8–10,17,31, 32,43,44,50,52) or, more recently, a polynomial model using the response surface methodology (19); also, a derived equation and application of a simultaneous volatile formation and stripping kinetics for wort boiling was developed (20). Some studies reported using CO_2 supply flow rate (16,43) to accelerate DMS stripping, but none of them studied the simultaneous impact of CO_2 supply flow rate and boiling power variation, as energy reduction factors, on DMS-stripping behavior.

[1] Corresponding author. Phone: +27725061322. E-mail: desobgo.zangue@gmail.com

http://dx.doi.org/10.1094/ASBCJ-2017-4458-01

© 2017 American Society of Brewing Chemists, Inc.

EXPERIMENTAL

Chemicals

The chemicals used for this study were DMS solution (Sigma-Aldrich, 99% purity), dichloromethane (DCM) solution (Chromasolv, 99.8% for HPLC), and CO_2 in a pressure bottle (35 kg), chemically pure (99.0%) (material number 514202-SE-C, Afrox, South Africa).

Brewing

The brewing was done using a Braumeister all-in-one electric all-grain brewing unit (Speidel, Germany). In the unit were first placed the malt pipe, the first filter plate, and the first fine sieve. It was then filled with water (50 L) to reach a notch on the center post. The temperature was initially set to 65°C, and when the water reached the correct temperature, 10 kg of the milled malt (milled using a two-roller mill with the gap of the drill drive grain mill adjusted to 0.7 mm) was added, and the mixture was stirred and allowed to swell for a few minutes. Then, the second fine sieve was positioned onto the malt, followed by the second filter plate, and finished with the hold-down notch, which was installed and fixed well by utilizing a wing nut. The pump was then switched on, and the mashing was conducted at that temperature (65°C) for 1 h. During that period, the liquid wort was circulated through the mash and then cascaded down between the malt pipe and the outer wall of the Braumeister unit. The pH and the degrees Brix of the wort obtained after the mashing process were 5.4 and 10.5°B, respectively. The wort was then stored in a deep-freezer at –20°C in 25 L closed plastic buckets.

Wort Boiling Unit

The wort boiling unit consisted of a 25 L insulated vessel equipped with an electrical heating element. It was connected to a voltage regulator (phases, 1; input, 220 V and 50–60 Hz; output, 0–250 V; capacity, 2,000 VA max.; 8 amp; TDGC2-2kVA, AC-DC Dynamics, South Africa), which itself was connected to a Lutron DW-6060 watt meter. A Therma 3 thermometer (ETI, U.K.) was used to determine the wort temperature during the boiling process.

The CO_2 distribution system consisted of a compressed gas cylinder fitted with a flow regulation valve and volumetric flow meter (Afrox Saffire ArC 20L) capable of metering gas flow rate up to 20 L/min. The sparger was a sintered metal porous cylindrical metal device that permitted sparging the gas in all the directions in the vessel.

Boiling and Preparation of Samples

The boiling trials were done utilizing a single boiling power (2,000 W) for preheating 10 L wort batches to reach 97°C, which is the boiling point of the wort at the atmospheric pressure of the site (altitude above sea level for Johannesburg, South Africa, 1,753 m). After reaching the boiling point, the heating element was de-energized, wort boiling was arrested, and the insulated vessel was closed for 60 min, during which time the temperature dropped from 97 to 94°C. During this 60 min period, conversion of SMM to DMS was undertaken. Loss of DMS from the boiler was considered negligible owing to the closure of the vessel. This 60 min period was considered as part of a laboratory method only to allow the rate constant of DMS formation to be empirically determined, in the absence of stripping. Any impact of this period on other wort quality parameters or kettle cycle time was not considered. Samples (50 mL, collected into a 250 mL Schott Duran glass with a screw top and cooled in cold water to about 1–2°C) were collected through this 60 min period after 0, 15, 30, 45, and 60 min. After this 60 min period had elapsed, the vessel was opened, the CO_2 distribution system was switched on at an adequate flow rate (0, 5, 6, 8, 10, and 11 L/min), and the wort was then boiled at a specific boiling power (500, 1,000, and 1,500 W) for 90 min (Fig. 1). The samples, for each boiling power and CO_2 supply flow rate, were collected after 0, 15, 30, 45, 60, 75, and 90 min during the boiling stage (50 mL, collected using a 250 mL Schott Duran glass with a screw top and cooled in an ice-water mixture to about 1–2°C). Once the wort was cooled, 50 mL of dichloromethane (DCM) was added, and the mixture was shaken at 450 rpm using a lab shaker (HT Infors, Switzerland) for 2 h, to enhance DMS extraction by the solvent phase (DCM). That solvent phase (1.5 mL) was transferred into 2 mL vials and crimped for GC-MS analysis. The standard curve (0–1,000 ppb) was prepared using DMS solution (Sigma-Aldrich, 99% purity).

Conditions for Wort Analysis

The Pegasus 4D GC×GC time-of-flight mass spectrometer (TOFMS) (Leco, U.S.A.) was used to determine the concentration of DMS in each step of the study with reference to the standard curve using DMS solution (Sigma-Aldrich, 99% purity). Identification of peak, signal deconvolution, and computation for distinctive analytes inside the sample were achieved with automated data processing. Wiley and National Institute of Standards and Technology libraries were utilized for peak identification with signal-to-noise ratio > 200, eliminating low similarity compounds (less than 650).

For the analysis, conducted in triplicate, 2 mL crimped vials containing the DMS extracted from wort were analyzed, and after defining the parameters shown in Table I, 1 µL of the solution from the vials was automatically redirected into the inlet of the Leco Pegasus 4D GC×GC-TOFMS. Data were obtained with Leco's ChromaTOF software.

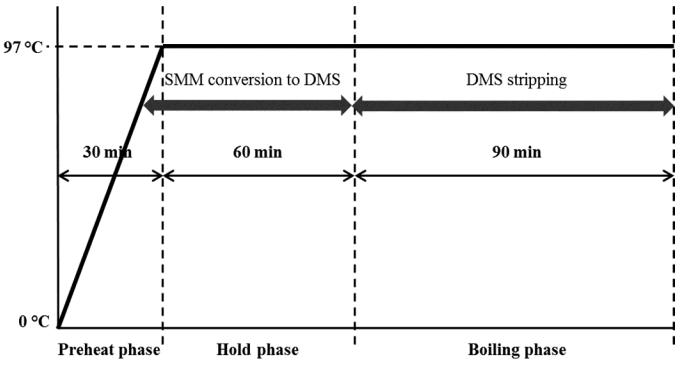


Fig. 1. Wort boiling diagram.

Evaluation of Reaction Rate Coefficient of SMM Conversion to DMS (k_1)

Taking into consideration the fact that the SMM conversion to DMS reaction was considered to be represented as a first-order reaction kinetic equation (43) and also that it could be simultaneous with the DMS stripping, the estimation of k_1 was determined during the 60 min holding period prior to the boil. This was done at that stage because the DMS removal was assumed to be weak because boiling was not present. Once the wort had reached boiling temperature achieved by turning the heating element off and closing the vessel, the insulated vessel permitted the temperature (during 1 h) to be maintained in the system to within 3°C of the boiling point. Considering the mass balance principle between the SMM converted and the DMS formed, the experimental DMS values were correlated to an exponential equation expressed as follows:

$$[DMS] = [DMS]_0 \exp(k_1 t) \quad (1)$$

where $[DMS]$ is the concentration of DMS at any time t, $[DMS]_0$ is the initial concentration of DMS at the beginning of the arrested boiling period, and k_1 is the reaction rate coefficient of SMM conversion to DMS.

The DMS value at the end of the 1 h holding period was used to calculate the initial SMM concentration ($[SMM]_0$) as DMS equivalent and k_1.

Evaluation of Volatilization Rate Coefficient of DMS (k_2) and Other Constant Terms

To obtain the value of k_2, the data considered were obtained on analysis of the samples taken during wort boiling, and the Mitani theoretical equation (which express DMS stripping during wort

TABLE I
Conditions of LECO Pegasus Equipment for DMS Detection

Equipment	Specifications
Detector	Pegasus 4D GC×GC-TOFMS (Leco)
Rate of acquisition	200 spectra/s
Delay of acquisition	3 min
Range of mass stored	29–500 u
Temperature of transfer line	250°C
Temperature of the source	250°C
Voltage of the detector	–1,800 V
Mass defect settling	0 mu/100 u
Column 1 type	Rtx-WAX, 30 m length × 0.25 mm internal diameter, 0.25 µm film thickness
Column 2 type	DB-1, 1.0 m length × 0.1 mm internal diameter, 0.10 µm film thickness
Oven of column 1	1 min at 35°C, 4°C/min from 35 to 250°C, 10 min hold at 250°C
Oven of column 2	1 min at 45°C, 4°C/min from 45 to 360°C, 10 min hold at 360°C
Period of modulation	10 s
Offset temperature of the modulator	30°C
Inlet	Splitless at 230°C
Injection volume	1 µL
Gas	He, 1.0 mL/min constant flow

boiling) was computed using Matlab R2014a software (8.3.0.532, The Mathworks, U.S.A.) to correlate it with the experimental data and determine all the constant terms of that equation. This was done by introducing the obtained values of $[SMM]_0$ and k_1 because the SMM conversion to DMS was considered temperature dependent and the boiling process was done at atmospheric pressure with the temperature remaining at 97°C. The Mitani model was expressed as follows:

$$[DMS] = \frac{k_1[SMM]_0}{k_2 - k_1}\left[\exp(-k_1 t) - \exp(-k_2 t)\right] + [DMS]_0 \exp(-k_2 t) \quad (2)$$

where $[DMS]$ is the residual DMS in wort at time t during boiling, $[SMM]_0$ is the initial concentration of SMM, k_1 is the reaction rate coefficient of SMM conversion to DMS, k_2 is the volatilization rate coefficient of DMS, and $[DMS]_0$ is the initial concentration of DMS.

Statistical Analysis

The multiple sample comparison tool of Statgraphics Centurion XVI software (build 16.1.11, Statpoint Technologies, U.S.A.) was utilized for data analysis including analysis of variance (ANOVA) and the multiple range tests, which used Fisher's least significant difference (LSD) procedure. Fisher's LSD method was utilized as a part of ANOVA to generate confidence intervals for all pairwise variation between variable levels means while controlling the individual error rate to a significance level that was indicated. Fisher's LSD technique then utilized the individual error rate and number of correlations to estimate the simultaneous confidence level for all confidence intervals. This concurrent confidence level was the probability that all confidence intervals contained the true difference.

For each batch of analysis, the data were arranged into four columns. These columns were sample labels, sample sizes, sample means, and sample standard deviations. The labels were assigned for the different boiling conditions by assigning codes to the samples, and each measurement of DMS was done in triplicate. The column reflecting the means contained the mean value of each sample (each measurement was done in triplicate), as did the standard deviations column, which reflected the standard deviation obtained for each sample.

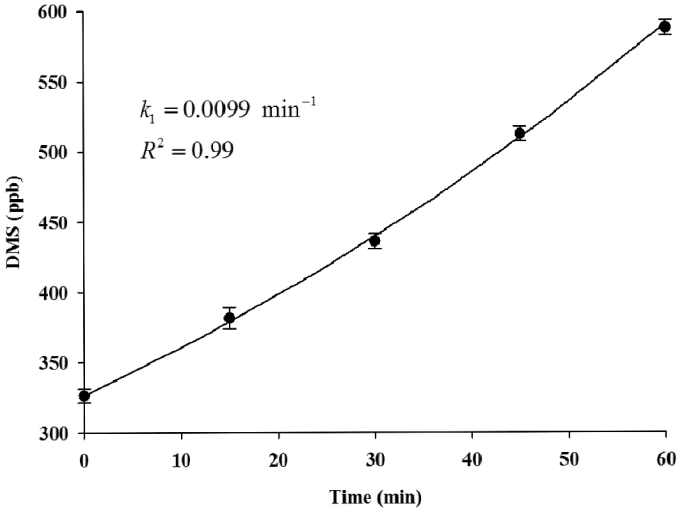


Fig. 2. Evolution of DMS during the holding phase.

Optimization

Optimization was realized by fixing a target of residual DMS concentration in the wort (100 ppb) and a maximum acceptable time to reach the target (90 min). A boiling time of 90 min allowed a value of residual DMS ≤ 100 ppb to be obtained, and the time to reach 100 ppb was then calculated using Scientific WorkPlace 5.5 software, build 2890 (MacKichan Software, U.S.A.) to solve the Mitani equation.

Energy Calculation

The calculation of energy depends on the power of the device and its usage time. Thus, the energy consumed during the boiling of the wort was estimated by the following formula:

$$E = P_i t \quad (3)$$

where E is the energy consumed (J), P_i is the boiling power (W), and t is the boiling time (s).

RESULTS AND DISCUSSION

Estimation of Reaction Rate Coefficient (k_1) of SMM Conversion to DMS

The first-order equation (equation 1) was fitted to experimental data (Fig. 2) during the arrested boiling step (at 0, 15, 30, 45, and 60 min), and a value of k_1 = 0.0099 min^{-1} was elicited. After determining the amount of DMS produced, the initial concentration of SMM was estimated at 807 ppb as DMS equivalent. There was a possibility during wort boiling that a part of DMSO was reduced to DMS by sulfhydryl compounds at the same time that DMS produced was oxidized to DMSO (2). According to the literature, these reactions are balanced or insignificant (1). By considering the conversion of SMM to DMS, with no loss of either from the system owing to the absence of boiling and hence stripping, the quantity of DMS produced could be equated to SMM consumed at any time t and expressed as a rate equation as follows:

$$[SMM] = 807 \times \exp(-0.0099t) \quad (4)$$

where $[SMM]$ is the concentration of SMM in the wort and t is the time.

The elicited k_1 value was about 34% lower than the value obtained by Mitani et al. (43), and it was about 41% lower than the value obtained when exploiting data from Dickenson (21). This could be interpreted by the reaction rate coefficient, which could change, being dependent upon on the running settings (1,19,21, 43,55). The reason why k_1 was lower than the one obtained by Mitani et al. (43) and Dickenson (21) could be explained also by the fact that it is a known function of temperature, and the SMM was converted to DMS at significantly lower temperatures than Mitani et al. and Dickenson used, owing to the holding phase and the low energy involved. Mitani et al. (43) reported the energy use for their operating system was 160 MJ·m^3·h^{-1} for a type 1 vessel (0.4 m^3) and 150 MJ·m^3·h^{-1} for a type 2 vessel (6 m^3). These conditions were undoubtedly more severe than our study conditions (0.075–0.225 MJ·m^3·h^{-1}).

Impact of Boiling Conditions on Wort Residual DMS

For the boiling conditions with no CO_2 supply flow rate applied (Fig. 3A), it was observed that, from the initial DMS concentration around 587 ppb, the DMS concentration decreased to 378.3 ± 7.34, 253 ± 4.36, and 109.6 ± 2.87 ppb, respectively, for 500, 1,000, and 1,500 W. The decrease of DMS in wort during the boiling stage was also observed by many authors (5,13,19,22,46, 48,57,58). The values obtained at the end of the boiling process

were statistically different (Table II). The increasing rate of DMS removal with boiling power was owing to the increase in the liberated flow rate of steam because of the increased boiling power (12,15,24,29,33,36,40–42,45,50,56). It was also mentioned in the literature that DMS could be oxidized to DMSO during wort boiling (2).

For boiling conditions using 500 W with a CO_2 supply flow rate of 5, 6, 8, 10, and 11 L/min (Fig. 3B), a DMS concentration

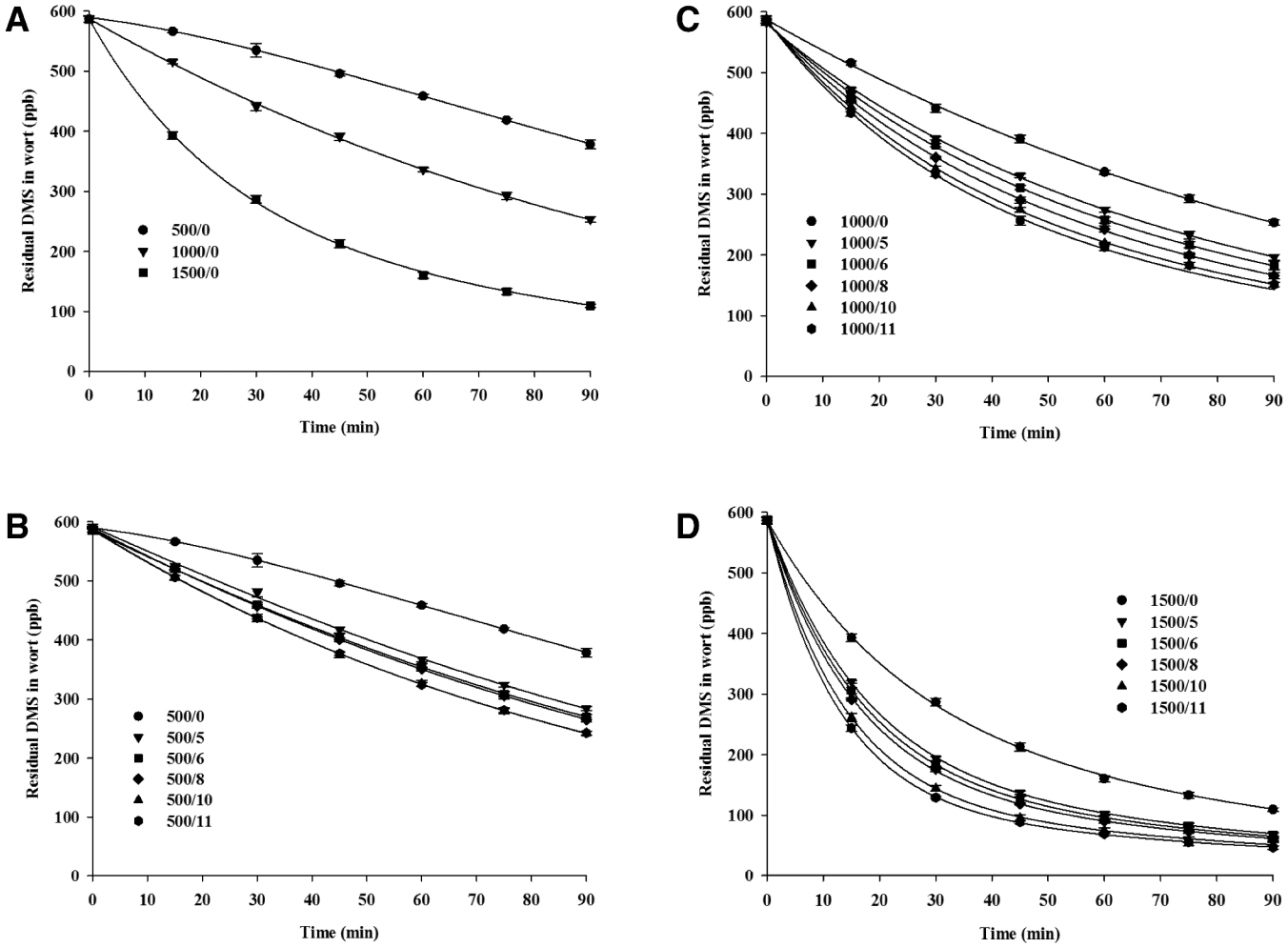


Fig. 3. Evolution of DMS during boiling: **A,** at each boiling power and with no CO_2 supply flow rate; **B,** 500 W, when applying different CO_2 supply flow rates (0, 5, 6, 8, 10 and 11 L/min); **C,** 1,000 W, when applying different CO_2 supply flow rates; and **D,** 1,500 W, when applying different CO_2 supply flow rates. Sample designations list power level followed by flow rate.

TABLE II
Statistical Comparison Between Power Input Impact on Residual DMS After 90 min Boiling Time and No CO_2 Supply Flow Rate[a]

ANOVA

Source	Sum of squares	df	Mean square	*F* ratio	*P* value
Between groups	108,438.7	2	54,219.1	2,003.75	0.0000
Within groups	162.353	6	27.0589		
Total (corr.)	108,601.0	8			

Method: 95.0% LSD

Power (W)/flow rate (L/min)	Count	Mean	Homogeneous groups
1,500/0	3	109.6	X
1,000/0	3	253.033	X
500/0	3	378.267	X

Contrast	Significance	Difference	+/– Limits
500/0 vs. 1,000/0	*	125.233	10.3927
500/0 vs. 1,500/0	*	268.667	10.3927
1,000/0 vs. 1,500/0	*	143.433	10.3927

[a] Asterisk (*) denotes a statistically significant difference. Placement of "X" indicates homogeneous groups.

decrease was noticed for all the CO_2 supply flow rates, from a start-of-boil value around 570 ppb to an end-of-boil value around 242.5 ± 3.35 ppb obtained (at 11 L/min) after 90 min of boiling. At the end of that boiling process, when comparing the residual DMS in the wort, it was statistically demonstrated that there was no significant difference when applying 6 and 8 L/min and when applying 10 and 11 L/min sparging rate, whereas for the other combinations there were significant differences when using the 95% Fisher's LSD method (Table III). The decrease of DMS concentration for all the CO_2 supply flow rates could be owing to the contribution of CO_2 on DMS stripping. The increased removal rate of DMS with an increase of CO_2 supply flow rate was also observed by Mitani et al. The boiling conditions utilizing 1,000 W with a CO_2 supply flow rate of 5, 6, 8, 10, and 11 L/min (Fig. 3C) showed that the DMS concentration also decreased to a minimum (end-of-boil) value of 151.4 ± 3.80 ppb at a CO_2 supply flow rate of 11 L/min. For this case, statistical analysis exhibited for the residual DMS concentration that there was no significant difference when implementing CO_2 supply flow rates of 8 and 10 L/min, whereas all the other pairwise comparisons were significantly different when using the 95% Fisher's LSD method (Table IV). As with the previous case (500 W), an increase of CO_2 supply flow rate generated an increased rate of DMS stripping (43).

When boiling at 1,500 W with a CO_2 supply flow rate of 5, 6, 8, 10, and 11 L/min (Fig. 3D), the decrease of DMS in wort after 90 min reached a minimum (end-of-boil) value of 47.3 ± 2.50 ppb when using a CO_2 supply flow rate of 11 L/min. Statistical analysis revealed that there was no significant difference when comparing 5 and 6 L/min, 6 and 8 L/min, and 10 and 11 L/min (Table V). For other pairwise comparisons, there was significant difference observed (Table V), and greater DMS stripping was exhibited when raising the CO_2 supply flow rate.

Volatilization Rate Coefficient (k_2) and Initial DMS Concentration ($[DMS]_0$)

The reaction rate coefficient k_1 and $[SMM]_0$ were elicited using the arrested boiling period data and were introduced into the Mitani equation (equation 2). After fitting that equation to boiling-stage data, volatilization rate coefficient (k_2) and initial DMS concentration ($[DMS]_0$) were obtained as presented in Table VI. The values of $[DMS]_0$ were between 580.9 and 591.2 ppb, and the values of k_2 varied from 0.01544 to 0.07882 min^{-1} (Table VI). These values of k_2 obtained for this study were not of the same order of magnitude as that sourced from Mitani et al. in 1999 (43), owing in part to the energy involved. In this case, the heat supply was between 0.075 and 0.225 $MJ/m^3 \cdot h$. In addition, the scale (400 L pilot and 6,000 L commercial scale) and the type of kettles (technology) were different compared with the 25 L kettle used in this study.

Impact of CO_2 Supply Flow Rate on Volatilization Rate Coefficient k_2

An analysis of Figure 4 shows that the volatilization rate coefficient k_2 increased with CO_2 flow rate, increasing at higher boiling powers. The CO_2 sparging disturbed the equilibrium condition (liquid/vapor interface equilibrium) (6) of DMS in the wort matrix. Thus, the gas absorbed and carried the contaminant (DMS) with it as it progressed to the surface and was vented away from the process stream and vessel. In fact, sparging produced a condition in which a large surface area of the wort to be treated was exposed to CO_2, which promoted transfer of the contaminant (DMS) from the liquid phase to the gaseous phase (30,43). This occurred because under normal conditions the concentration of contaminant in ambient air was much lower than the concentration in aqueous solution (wort) (30). The result of that phenomenon

TABLE III
Statistical Comparison Between CO_2 Supply Flow Rate Impact on Residual DMS After 90 min Boiling Time and 500 W[a]

ANOVA

Source	Sum of squares	df	Mean square	*F* ratio	*P* value
Between groups	38,584.6	5	7,716.92	374.00	0.0000
Within groups	247.6	12	20.6333		
Total (corr.)	38,832.2	17			

Method: 95.0% LSD

Power (W)/flow rate (L/min)	Count	Mean	Homogeneous groups
500/11	3	242.467	X
500/10	3	242.033	X
500/8	3	264.8	X
500/6	3	269.6	X
500/5	3	284.0	X
500/0	3	378.267	X

Contrast	Significance	Difference	+/– Limits
500/0 vs. 500/5	*	94.2667	8.0809
500/0 vs. 500/6	*	108.667	8.0809
500/0 vs. 500/8	*	113.467	8.0809
500/0 vs. 500/10	*	136.233	8.0809
500/0 vs. 500/11	*	135.8	8.0809
500/5 vs. 500/6	*	14.4	8.0809
500/5 vs. 500/8	*	19.2	8.0809
500/5 vs. 500/10	*	41.9667	8.0809
500/5 vs. 500/11	*	41.5333	8.0809
500/6 vs. 500/8		**4.8**	8.0809
500/6 vs. 500/10	*	27.5667	8.0809
500/6 vs. 500/11	*	27.1333	8.0809
500/8 vs. 500/10	*	22.7667	8.0809
500/8 vs. 500/11	*	22.3333	8.0809
500/10 vs. 500/11		**–0.43333**	8.0809

[a] Asterisk (*) denotes a statistically significant difference. Boldface differences were not statistically significant. Placement of "X" indicates homogeneous groups.

TABLE IV
Statistical Comparison Between CO_2 Supply Flow Rate Impact on Residual DMS After 90 min Boiling Time and 1,000 W[a]

ANOVA

Source	Sum of squares	df	Mean square	*F* ratio	*P* value
Between groups	19,820.6	5	3,964.12	153.48	0.0000
Within groups	309.933	12	25.8278		
Total (corr.)	20,130.6	17			

Method: 95.0% LSD

Power (W)/flow rate (L/min)	Count	Mean	Homogeneous groups
1,000/11	3	151.4	X
1,000/10	3	165.933	X
1,000/8	3	165.967	X
1,000/6	3	182.367	X
1,000/5	3	195.967	X
1,000/0	3	253.033	X

Contrast	Significance	Difference	+/– Limits
1,000/0 vs. 1,000/5	*	57.0667	9.04105
1,000/0 vs. 1,000/6	*	70.6667	9.04105
1,000/0 vs. 1,000/8	*	87.0667	9.04105
1,000/0 vs. 1,000/10	*	87.1	9.04105
1,000/0 vs. 1,000/11	*	101.633	9.04105
1,000/5 vs. 1,000/6	*	13.6	9.04105
1,000/5 vs. 1,000/8	*	30.0	9.04105
1,000/5 vs. 1,000/10	*	30.0333	9.04105
1,000/5 vs. 1,000/11	*	44.5667	9.04105
1,000/6 vs. 1,000/8	*	16.4	9.04105
1,000/6 vs. 1,000/10	*	16.4333	9.04105
1,000/6 vs. 1,000/11	*	30.9667	9.04105
1,000/8 vs. 1,000/10		**0.03333**	9.04105
1,000/8 vs. 1,000/11	*	14.5667	9.04105
1,000/10 vs. 1,000/11	*	14.5333	9.04105

[a] Asterisk (*) denotes a statistically significant difference. Boldface differences were not statistically significant. Placement of "X" indicates homogeneous groups.

TABLE V
Statistical Comparison Between CO_2 Supply Flow Rate Impact on Residual DMS After 90 min Boiling Time and 1,500 W[a]

ANOVA

Source	Sum of squares	df	Mean square	*F* ratio	*P* value
Between groups	7,327.05	5	1,465.41	162.71	0.0000
Within groups	108.073	12	9.00611		
Total (corr.)	7,435.12	17			

Method: 95.0% LSD

Power (W)/flow rate (L/min)	Count	Mean	Homogeneous groups
1,500/11	3	47.333	X
1,500/10	3	52.6	X
1,500/8	3	61.3	X
1,500/6	3	66.5667	XX
1,500/5	3	69.0	X
1,500/0	3	109.6	X

Contrast	Significance	Difference	+/– Limits
1,500/0 vs. 1,500/5	*	40.6	5.3388
1,500/0 vs. 1,500/6	*	43.0333	5.3388
1,500/0 vs. 1,500/8	*	48.3	5.3388
1,500/0 vs. 1,500/10	*	57.0	5.3388
1,500/0 vs. 1,500/11	*	62.2667	5.3388
1,500/5 vs. 1,500/6		**2.4333**	5.3388
1,500/5 vs. 1,500/8	*	7.7	5.3388
1,500/5 vs. 1,500/10	*	16.4	5.3388
1,500/5 vs. 1,500/11	*	21.6667	5.3388
1,500/6 vs. 1,500/8		**5.26667**	5.3388
1,500/6 vs. 1,500/10	*	13.9667	5.3388
1,500/6 vs. 1,500/11	*	19.2333	5.3388
1,500/8 vs. 1,500/10	*	8.7	5.3388
1,500/8 vs. 1,500/11	*	13.9667	5.3388
1,500/10 vs. 1,500/11		**5.26667**	5.3388

[a] Asterisk (*) denotes a statistically significant difference. Boldface differences were not statistically significant. Placement of "X" indicates homogeneous groups.

combined with the power of boiling was an increase of the volatilization rate coefficient (k_2).

Optimization

In this section, the parameters of CO_2 flow rate and boiling power were manipulated to optimize end-of-boil DMS against energy utilized during boiling. Any energy associated with the production or provision of the differing quantities of carbon dioxide was not considered in this optimization process. The optimization method used consisted of minimizing the boiling time (which must be less than the baseline of 90 min), thus reducing energy consumed, to attain 100 ppb, which was the established target for residual DMS (1,11,12,28,34). The results presented in Table VII for that purpose showed that it was impossible to attain the target of 100 ppb in less than 90 min boiling time when using 500 and 1,000 W of boiling power, whatever the CO_2 supply flow rate utilized. Therefore, there was no energy reduction to consider in this case. This could be explained by the fact that the enhancement of the volatilization rate coefficients owing to the presence of gaseous CO_2 was not sufficient to achieve an end-of-boil DMS

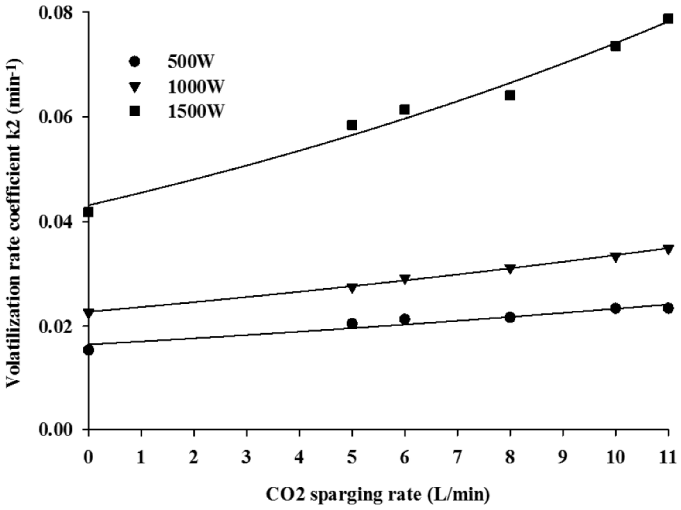


Fig. 4. Effect of CO_2 supply flow rate on volatilization rate coefficient k_2.

TABLE VI
Estimation of Mitani Equation Parameters at 500, 1,000, and 1,500 W Power Input and 5–11 L/min CO_2 Supply Flow Rate, and No CO_2 Supply[a]

Power input	CO_2 (L/min)	R^2	k_2 (min^{-1})	$[DMS]_0$ (ppb)	Mitani equations
500 W					
	0	0.99	0.01544	589.6	$[0.0099/(0.01544 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.01544t)] + 589.6 \times \exp(-0.01544t)$
	5	0.99	0.02049	591.2	$[0.0099/(0.02049 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02049t)] + 591.2 \times \exp(-0.02049t)$
	6	0.99	0.02133	585.2	$[0.0099/(0.02133 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02133t)] + 585.2 \times \exp(-0.02133t)$
	8	0.99	0.02165	588.4	$[0.0099/(0.02165 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02165t)] + 588.4 \times \exp(-0.02165t)$
	10	0.99	0.02341	585.9	$[0.0099/(0.02341 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02341t)] + 585.9 \times \exp(-0.02341t)$
	11	0.99	0.02343	586.8	$[0.0099/(0.02343 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02343t)] + 586.8 \times \exp(-0.02343t)$
1,000 W					
	0	0.99	0.02260	587.5	$[0.0099/(0.02260 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02260t)] + 587.5 \times \exp(-0.02260t)$
	5	0.99	0.02751	580.9	$[0.0099/(0.02751 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02751t)] + 580.9 \times \exp(-0.02751t)$
	6	0.99	0.02920	583.6	$[0.0099/(0.02920 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.02920t)] + 583.6 \times \exp(-0.02920t)$
	8	0.99	0.03118	584.9	$[0.0099/(0.03118 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.03118t)] + 584.9 \times \exp(-0.03118t)$
	10	0.99	0.03342	586.8	$[0.0099/(0.03342 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.03342t)] + 586.8 \times \exp(-0.03342t)$
	11	0.99	0.03487	587.5	$[0.0099/(0.03487 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.03487t)] + 587.5 \times \exp(-0.03487t)$
1,500 W					
	0	0.99	0.04180	586.3	$[0.0099/(0.04180 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.04180t)] + 586.3 \times \exp(-0.04180t)$
	5	0.99	0.05842	589.4	$[0.0099/(0.05842 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.05842t)] + 589.4 \times \exp(-0.05842t)$
	6	0.99	0.06141	587.8	$[0.0099/(0.06141 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.06141t)] + 587.8 \times \exp(-0.06141t)$
	8	0.99	0.06415	585.8	$[0.0099/(0.06415 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.06415t)] + 585.8 \times \exp(-0.06415t)$
	10	0.99	0.07358	586.7	$[0.0099/(0.07358 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.07358t)] + 586.7 \times \exp(-0.07358t)$
	11	0.99	0.07882	586.0	$[0.0099/(0.07882 - 0.0099)] \times 807 \times [\exp(-0.0099t) - \exp(-0.07882t)] + 586.0 \times \exp(-0.07882t)$

[a] The Mitani equation calculates [*DMS*], the residual DMS in wort at time t during boiling (equation 2). k_2 = volatilization rate coefficient of DMS; and $[DMS]_0$ = the initial concentration of DMS at the beginning of the arrested boiling period.

TABLE VII
Impact of CO_2 Supply Flow Rate on the Residual DMS Concentration and Energy Saved (Targeted DMS Concentration is 100 ppb)

		CO_2 supply flow rate (L/min)					
Power input (W)	Parameter	0	5	6	8	10	11
500	[*DMS*] reached in 90 min (ppb)	378.3 ± 7.34	284.0 ± 3.46	269.6 ± 4.27	264.8 ± 4.06	242.0 ± 3.45	242.5 ± 3.35
	Time to reach target (min)[a]	/	/	/	/	/	/
	Energy spent (MJ)	2.7	2.7	2.7	2.7	2.7	2.7
	Energy saved (MJ)	/	/	/	/	/	/
1,000	[*DMS*] reached in 90 min (ppb)	253.0 ± 4.36	196 ± 4.81	182.4 ± 7.20	166.0 ± 4.74	165.9 ± 4.89	151.4 ± 3.80
	Time to reach target (min)[a]	/	/	/	/	/	/
	Energy spent (MJ)	5.4	5.4	5.4	5.4	5.4	5.4
	Energy saved (MJ)	/	/	/	/	/	/
1,500	[*DMS*] reached in 90 min (ppb)	109.6 ± 2.87	69 ± 2.88	66.6 ± 3.22	61.3 ± 3.48	52.6 ± 2.98	47.3 ± 2.50
	Time to reach target (min)[a]	90	62.31	57.77	54.00	43.66	39.21
	Energy spent (MJ)	**8.1**	**5.61**	**5.20**	**4.86**	**3.93**	**3.53**
	Time saved (min)	**0**	**27.69**	**32.23**	**36.00**	**46.34**	**50.79**
	Energy saved (MJ)	**0**	**2.49**	**2.90**	**3.24**	**4.17**	**4.57**

[a] Only times < 90 min are considered. Slash (/) indicates not applicable. Boldface listings highlight the savings achieved at 1,500 W.

target of 100 ppb to be reached in 90 min. However, the energy spent when using 500 and 1,000 W during 90 min of boiling was 2.7 and 5.4 MJ, respectively (Table VII). Furthermore, it was also observed in Table VII for 1,500 W of boiling power that the use of CO_2 supply flow rate permitted reaching 100 ppb at maximum and minimum boiling times of 62.31 and 39.21 min, respectively. This trend was observed in the literature, in which the use of gas sparging (nitrogen) reduced a conventional boil from 50 to 25 min duration for an equivalent end-of-boil DMS concentration (43). These reduced boiling times equated to utilized energy values ranging from 3.53 to 5.61 MJ. This represented a reduction of 31–56% in utilized energy, because the energy required to boil for 90 min at 1,500 W was calculated at 8.1 MJ (Table VII). That boiling time reduction could therefore provoke incomplete progress or completion of other important reactions and processes occurring during wort boiling.

CONCLUSIONS

The boiling power and the CO_2 supply flow rate effects on DMS removal from wort were studied when applied to a constant arrested boiling time of 1 h. The boiling power combined with the CO_2 supply flow rate permitted an increase of the volatilization coefficient rate of DMS. The CO_2 supply flow rate allowed also significant boiling time reduction and associated energy reductions (the energy required to produce the CO_2 was not considered), with the minimum utilized boiling energy arising from maximizing boiling power and CO_2 flow rate. As indicated in the discussion of the results, the impact of the scale of the wort kettle on the stripping behavior and any associated energy benefit would need to be considered if extrapolating up to and including industrial-scale wort kettles. Practical implementation of such a gas stripping technique into a production brewery would require consideration of the impact of the energy and financial cost of CO_2 together with the safety aspects of using CO_2 in the brewhouse.

ACKNOWLEDGMENTS

The authors acknowledge SAB Maltings for provision of malted barley, the Braumeister unit via financial support, and Witness Qaku of University of Johannesburg for technical support.

LITERATURE CITED

1. Anness, B. J., and Bamforth, C. W. Dimethyl sulfide—A review. *J. Inst. Brew.* 88:244-252, 1982.
2. Anness, B. J., Bamforth, C. W., and Wainwright, H. The measurement of dimethyl sulphoxide in barley and malt and its reduction to dimethyl sulphide by yeast. *J. Inst. Brew.* 85:346-349, 1979.
3. Arfi, K., Spinnler, H. E., Tache, R., and Bonnarme, P. Production of volatile compounds by cheese-ripening yeasts: Requirement for a methanethiol donor for *S*-methyl thioacetate synthesis by *Kluyveromyces lactis*. *Appl. Microbiol. Biotechnol.* 58:503-510, 2002.
4. Bamforth, C. W. Dimethyl sulfide and significance, origins and control. *J. Am. Soc. Brew. Chem.* 72:165-168, 2014.
5. Barnes, Z. C. Brewing process control. In: *Handbook of Brewing*. F. G. Priest and G. G. Stewart, eds. CRC Press, Boca Raton, FL, pp. 447-486, 2006.
6. Barrera, J. A. Air sparging and vapour extraction as a means of removing chlorinated and BTEX compounds in complex groundwater conditions. In: *Superfund XIV Conference and Exhibition Conference Proceedings, Washington D.C.* Vol. 1, 1994.
7. Berger, C., Martin, N., Collin, S., Gijs, L., Khan, J. A., Piraprez, G., Spinnler, H. E., and Vulfson, E. N. Combinatorial approach to flavor analysis. 2. Olfactory investigation of a library of *S*-methyl thioesters and sensory evaluation of selected components. *J. Agric. Food Chem.* 47:3274-3279, 1999.
8. Bonachelli, B., De-Brackeleire, C., and Harmegnies, F. Wort boiling—The Meura's concept with wort stripping. In: *Proc. Eur. Brew. Conv. Congr., Venice*, 2007.
9. Bonachelli, B., Harmegnies, F., and Gil, R. T. Continuous wort boiling and hot trub separation. In: *Proc. Eur. Brew. Conv. Congr., Dublin,* 2003.
10. Braekeleirs, R., and Bauduin, C. L. In: *Proc. 8th Brew. Conv., Institute of Brewing (Central and Southern Africa Section), Sun City,* p. 36, 2001.
11. Briggs, D. E. *Malts and Malting*. Blackie Academic & Professional, London, U.K., 1998.
12. Briggs, D. E., Boulton, C. A., Brookes, P. A., and Stevens, R. *Brewing Science and Practice*. Woodhead, Cambridge, U.K., 2004.
13. Buckee, G. K., Malcolm, P. T., and Peppard, T. L. Evolution of volatile compounds during wort-boiling. *J. Inst. Brew.* 88:175-181, 1982.
14. Burmeister, M. S., Drummond, C. J., Pfisterer, E. A., Hysert, D. W., Sin, Y. O., Sime, K. J., and Hawthorne, D. B. Measurement of volatile sulfur compounds in beer using gas chromatography with a sulfur chemiluminescence detector. *J. Am. Soc. Brew. Chem.* 50:53-58, 1992.
15. Clarke, B. J., Burmeister, M. S., Krynicki, L., Pfisterer, E. A., Sime, K. J., and Hawthorne, D. B. Sulfur compounds in brewing. In: *Proceedings of the 1991 European Brewing Convention Congress*, pp. 217-224, 1991.
16. De Schutter, D. Method for treating a wort in a boiling kettle. Patent application EP20130191922, 2015.
17. De Schutter, D. P., Saison, D., Delvaux, F., Derdelinckx, G., Rock, J. M., Neven, H., and Delvaux, F. R. Optimisation of wort volatile analysis by headspace solid-phase microextraction in combination with gas chromatography and mass spectrometry. *J. Chromatogr. A* 1179:75-80, 2008.
18. Dercksen, A., Laurens, J., Torline, P., Axcell, B. C., and Rohwer, E. Quantitative analysis of volatile sulfur compounds in beer using a membrane extraction interface. *J. Am. Soc. Brew. Chem.* 54:228-233, 1996.
19. Desobgo, Z. S. C., Stafford, R. A., and Metcalfe, D. J. A. Dimethyl sulfide stripping behavior during wort boiling using response surface methodology. *J. Am. Soc. Brew. Chem.* 73:84-89, 2015.
20. Desobgo, Z. S. C., Stafford, R. A., and Metcalfe, D. J. A. Derivation and application of a simultaneous volatile formation and stripping kinetics equation for wort boiling. *J. Am. Soc. Brew. Chem.* 75:11-21, 2017.
21. Dickenson, C. J. The relationship of dimethyl sulphide levels in malt, wort and beer. *J. Inst. Brew.* 85:235-239, 1978.
22. Eßlinger, H. M., and Narziß, L. Beer. In: *Ullmann's Encyclopedia of Industrial Chemistry*. Wiley-VCH Verlag, Weinheim, Germany, 2012.
23. Firor, R. L., and Quimby, B. D. A comparison of sulfur selective detectors for low level analysis in gaseous streams. Agilent Technologies, Wilmington, DE, 2001.
24. Fix, G. Sulfur flavors in beer. *Zymurgy* 15:40-44, 1992.
25. Galitsky, C., Martin, N., Worrell, E., and Lehman, B. Energy efficiency improvement and cost saving opportunities for breweries: An ENERGY STAR guide for energy and plant managers. Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA, 2003.
26. Hackensellner, T. *Efficient Energy Use in the Brewhouse*. The Huppman Group, Kitzingen, Germany, 2000.
27. Hill, P. G., and Smith, R. M. Determination of sulphur compounds in beer using headspace solid-phase microextraction and gas chromatographic analysis with pulsed flame photometric detection. *J. Chromatogr. A* 872:203-213, 2000.
28. Hough, J. S., Briggs, D. E., Stevens, R., and Young, T. W. *Malting and Brewing Science*. Chapman and Hall, London, U.K., 1982.
29. Hough, J. S., Briggs, D. E., Stevens, R., and Young, T. W. *Malting and Brewing Science: Hopped Wort and Beer*. Aspen, Gaithersburg, MD, p. 526, 1999.
30. Ju-Chang, H., and Chii, S. Air stripping. In: *Advanced Physicochemical Treatment Processes*. L. K. Wang, Y.-T. Hung, and N. K. Shammas, eds. Humana Press/Springer, New York, NY, 2006.
31. Krottenthaler, M., and Back, W. The effects of wort precooling during cast-out. *Brew. Distill. Int.* 14-15, 2001.
32. Krottenthaler, M., Hartmann, K., and Back, W. Einsatz eines Entspannungsverdampfers zur Wurzebehandelung. *Brauwelt* 39:1690-1693, 2001.
33. Krottenthaler, M., Rübsam, H., and Becker, T. Optimizing brewhouse technology with reference to dimethylsulfide. *Brauwelt Int.* 28:138-

145, 2010.
34. Kunze, W. *Technology Brewing and Malting*. VLB, Berlin, Germany, 2004.
35. Leppänen, O. A., Denslow, J., and Ronkainen, P. P. Determination of thioacetates and some other volatile sulfur compounds in alcoholic beverages. *J. Agric. Food Chem.* 28:359-362, 1980.
36. Lewis, M. J., and Bamforth, C. W. *Essays in Brewing Science*. Springer, New York, NY, 2006.
37. Lustig, S., Kunst, T., and Hill, P. *Proc. 21st Congr. Eur. Brew. Conv., Maastricht*, p. 341, 1997.
38. Manger, H.-J. *Brauwelt Int.* 16:320, 1998.
39. Maule, D. R., and Clark, B. E. *Proc. 20th Congr. Eur. Brew. Conv., Helsinki*, p. 379, 1985.
40. Meilgaard, M. *Beer Flavour*. Dissertation, Technical University of Denmark, Copenhagen, Denmark, 1981.
41. Meilgaard, M. Effects on flavour of innovations in brewery equipment and processing: A review. *J. Inst. Brew.* 107:271-286, 2001.
42. Miracle, R. E., Ebeler, S. E., and Bamforth, C. W. The measurement of sulfur-containing aroma compounds in samples from production-scale brewery operations. *J. Am. Soc. Brew. Chem.* 63:129-134, 2005.
43. Mitani, Y., Suzuki, H., Abe, T., Nomura, M., and Shinotsuka, K. Performance of wort boiling with inert gas sparging for the energy reduction. In: *Proceedings of the EBC Congress*, 1999, pp. 619-626.
44. Mitani, Y., Suzuki, H., Ohshima, T., Kobayashi, M., Kurihara, T., Akiyama, H., and Ishida, F. Method of boiling wort and wort boiler used therefor. Patent application EP0875560 A1, 1998.
45. O'Rourke, T. The function of wort boiling. *Brewer Int.* 17-19, 2002.
46. Poreda, A., Czarnik, A., Zdaniewicz, M., Jakubowski, M., and Antkiewicz, P. Corn grist adjunct—Application and influence on the brewing process and beer quality. *J. Inst. Brew.* 120:77-81, 2014.
47. Schu, G. F. The balance of energy and warm water in the brewhouse. *Brauwelt Int.* 4:316-330, 1995.
48. Schulbach, K. F., Rouseff, R. L., and Sims, C. A. Changes in volatile sulfur compounds in strawberry puree during heating. *J. Food Sci.* 69:C268-C272, 2004.
49. Seaton, J. C. Special malt types and beer quality. In: *Proceedings of the International Symposium—Malting and Brewing Technology: Progress Through Increased Knowledge, Brussels, Belgium*, pp. 29-30, 1993.
50. Seldeslachts, D., Van Den Eynde, E., and Degelin, L. Wort stripping. In: *Proc. Eur. Brew. Conv. Congr., Maastricht,* 1997.
51. Sorrell, S. Barriers to energy efficiency in the UK brewing sector. In: *Science and Technology Policy Research (SPRU)*. University of Sussex, U.K., 2000.
52. Stippler, K. The Merlin wort boiling system. *Ferment* 13:34-36, 2000.
53. Ullrich, S. E. *Barley: Production, Improvement, and Uses*. Blackwell Publishing, Hoboken, NJ, 2011.
54. Unterstein, K. Energy and water go to make beer. *Brauwelt Int.* 18:368-370, 2000.
55. Vavilin, V. A., Fernandez, B., Palatsi, J., and Flotats, X. Hydrolysis kinetics in anaerobic degradation of particulate organic material: An overview. *Waste Manage.* 28:939-951, 2008.
56. Walker, M. D. Formation and fate of sulphur volatiles in brewing. In: *Proceedings of the 1991 European Brewing Convention Congress*, pp. 521-528, 1991.
57. White, F. H., and Wainwright, T. The measurement of dimethyl sulphide precursor in malts, adjuncts, worts and beers. *J. Inst. Brew.* 82:46-48, 1976.
58. Wilson, R. J. H., and Booer, C. D. Control of the dimethyl sulphide content of beer by regulation of the copper boil. *J. Inst. Brew.* 85:144-148, 1978.

Résumé de l’article

Impact of Gaseous Carbon Dioxide and Boiling Power on Dimethyl Sulfide Stripping Behavior during Wort Boiling

Z. S. C. Desobgo*, R. A. Stafford, D. T. Ndinteh, D. J. A. Metcalfe & R. Meijboom

Abstract

The impact of carbon dioxide (CO_2) supply flow rate on dimethyl sulfide (DMS) removal during wort boiling was studied when applying a 1 h hold between the end of preheating and the beginning of boiling. This was done during wort boiling by varying the boiling power (from 500 to 1,500 W), aiming to reduce energy consumption to reach the target of an end-of-boil DMS concentration of 100 ppb (w/v). When using the Mitani equation, which describes S-methyl methionine (SMM) conversion into DMS and DMS stripping, the preboiling step allowed a reaction rate coefficient of SMM conversion (k1) value of 0.0099 min^{-1} to be obtained. The values of volatilization rate coefficient of DMS (k2) during the provision of CO_2 at a flow rate between 5 and 11 L/min and boiling power between 500 and 1,500 W were between 0.02049 and 0.07882 min^{-1}. It was found that the coefficient k2 increased with the increase of CO_2 supply flow rate and the increase of boiling power. At a fixed boiling power of 1,500 W, the use of CO_2 supply flow rate permitted the target of 100 ppb to be attained in an interval of 39.21 min for 11 L/min to 62.31 min for 5 L/min. The energy saved in the boiling process when applying CO_2 supply flow rate between 5 and 11 L/min was 2.49–4.57 MJ.

Keywords: Boiling power, Boiling time, Dimethyl sulfide, Wort boiling, CO_2 supply flow rate

IV.4.11) Optimization of fermentation conditions for ting production using response surface methodology

Titre de la revue

Journal of
Food Processing and Preservation
Institute of Food Science + Technology ifst

Edited By: Charles Brennan and Brijesh K. Tiwari
Impact factor:1.51
ISI Journal Citation Reports @ Ranking: 2017:77/133 (Food Science & Technology)
Online ISSN:1745-4549
© Wiley Periodicals Inc.

Comité de lecture

Wiley Online Library

Advertisement

Journal Articles Actions

EDITORS-IN-CHIEF

Charles Brennan, Lincoln University, Christchurch, New Zealand, Charles.brennan@lincoln.ac.nz
Brijesh K. Tiwari, Teagasc Food Research Centre, Dublin, Ireland, brijesh.tiwari@teagasc.ie

ASSOCIATE EDITORS

Ozlem Tokusoglu, Celal Bayar University, Manisa, Turkey, tokusogluozlem@yahoo.com
Xin'an Zeng, South China University of Technology, Guangzhou, China, xazeng@scut.edu.cn
Francisco J. Barba, University of Valencia, Burjassot, Valencia, Spain, francisco.barba@uv.es
Fabiano Andre Narciso Fernandes, Universidade Federal do Ceara, Fortaleza, Brazil, fabiano@ufc.br
Yuthana Phimolsiripol, Chiang Mai University, Thailand, yuthana.p@cmu.ac.th
Anet Rezek Jambrak, University of Zagreb, Croatia, arezek@pbf.hr

EDITORIAL BOARD

William E. Artz, University of Illinois, Urbana, IL, United States, wartz@uiuc.edu
K.C. 'Sam' Chang, Mississippi State University, Mississippi State, MS, United States, sc1690@msstate.edu
Haiqiang Chen, University of Delaware, Newark, DE, United States, haiqiang@udel.edu
Ming-Ju Chen, National Taiwan University, Taipei, Taiwan, cmj@ntu.edu.tw
Harold Corke, Shanghai Jiao Tong University, China, hcorke@sjtu.edu.cn
Binosha Fernando, Edith Cowan University, Western Australia, w.fernando@ecu.edu.au
Vincenza Ferraro, Catholic University of Portugal, Portugal, ferraro@porto.ucp.pt

Wiley Online Library

Navam Hettiarachchy, University of Arkansas, Fayetteville, AR, United States, nhettiar@uark.edu
Dr. Bernd Hitzmann, University Hohenheim, Germany, bernd.hitzmann@uni-hohenheim.de
Xinzhong Hu, Shaanxi Normal University, China, hxinzhong@snnu.edu.cn
Dejian Huang, National University of Singapore, Singapore, chmhdj@nus.edu.sg
Anastasios (Tassos) Koidis, Queen's University Belfast, Northern Ireland, UK, T.Koidis@qub.ac.uk
Kathiravan Krishnamurthy, Illinois Institute of Technology, Summit-Argo, IL, United States,

Journal Articles Actions

Fatih Oz, Ataturk University, Erzurum, Turkey, fatihoz@atauni.edu.tr
Steven Pao, Department of Food Science and Nutrition, California State University, Fresno, CA, spao@csufresno.edu
Jitu Patel, USDA-ARS, ANRI, BARC-EastBeltsville, MD, United States, jitu.patel@ars.usda.gov
Donatella Peressini, Università di Udine, Italy, donatella.peressini@uniud.it
Cristina Sabliov, Louisiana State University, Baton Rouge, LA, United States, csabliov@agcenter.lsu.edu
M.Teresa Sancho, University of Burgos, Burgos, Castilla-León, Spain, mtsancho@ubu.es
Cangliang Shen, Western Kentucky University, Bowling Green, KY, United States, cangliang.shen@wku.edu
Dongxiao Sun-Waterhouse, University of Auckland, Auckland, New Zealand, dx.sun-waterhouse@auckland.ac.nz
Juming Tang, Washington State University, Pullman, WA, United States, jtang@wsu.edu
Xiaoyuan Wang, Jiangnan University, China, xwang@jiangnan.edu.cn
Wen-Hsin 'Cindy' Wu, Food and Drug Administration, Bothell, WA, United States, cindy.wu@fda.hhs.gov
Zhuohong 'Kenny' Xie, International Chemistry Testing, Milford, MA, United States, kxie@ichemtesting.com
Yanyun Zhao, Oregon State University, Corvallis, OR, United States, yanyun.zhao@orst.edu
Qixin Zhong, University of Tennessee, Knoxville, TN, United States, qzhong1@utk.edu

Tools

Submit an Article
Browse free sample issue
Get content alerts
Recommend to a librarian
Subscribe to this journal

Table des matières

Wiley Online Library

Journal Articles Actions

Advertisement

Volume 42, Issue 1

January 2018

GO TO SECTION

ISSUE INFORMATION

Free Access

Issue Information

First Published: 05 January 2018

PDF | Request permissions

ORIGINAL ARTICLES

Free Access

Selected characteristics of dry fermented sausages prepared with quick-dry-slice (QDS process) technology and their comparison with traditional products

Wiley Online Library

First Published: 17 March 2017

Free Access

Effects of drying and sterilization on the quality and shelf life of semimanufactured soybeans

Shengmin Lu, Daoqiang Yang, Zhongxiang Fang, Jieli Guo

First Published: 24 March 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of different moisture equilibration process on the quality of apple chips dried by instant controlled pressure drop (dic)-assisted hot air drying

Linyan Zhou, Xueyuan Wang, Jinfeng Bi, Xuan Liu, Jianyong Yi, Xinye Wu

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Physicochemical and volatile profile alterations in pasteurized and frozen strawberry pulp during storage

Gilma A. S. Gonçalves, Nathane S. Resende, Elisângela E. N. Carvalho, Jaime V. de Resende, Eduardo V. de B. Vilas Boas

First Published: 29 March 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Promoting *Lactobacillus casei* and *Bifidobacterium adolescentis* survival by microencapsulation with different starches and chitosan and poly L-lysine coatings in ice cream

Mohammad Ali Khosravi Zanjani, Mohammad Reza Ehsani, Babak Ghiassi Tarzi, Anousheh Sharifan

Wiley Online Library

Statistical optimization of ethanol fermentation parameters for processing local grape cultivars to wines

Pooja Nikhanj, G. S. Kocher

First Published: 24 March 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Forced-air precooling treatment enhanced antioxidant capacities of apricots

Jiaqi Yan, Yan Song, Jian Li, Weibo Jiang

First Published: 21 March 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Key hurdles in the Mediterranean-style dry fermented sausage “Salsiccia Sarda” as influenced by different ingredients related to product safety

Riccardo Consigliere, Domenico Meloni, Rina Mazzette

First Published: 31 March 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Discussion between alternative processing and preservation technologies and their application in beverages: A review

Luis Felipe Rascon Escajeda, Mario Cruz Hernandez, Rosa María Rodriguez Jasso, Ana Veronica Charles Rodriguez, Armando Robledo Olivo, Juan Carlos Contreras Esquivel, Ruth Belmares Cerda

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Wiley Online Library

Volatiles, polysaccharides and total polyphenols in Chinese rose tea infusions and their

Journal Articles Actions

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effects of chitosan coating containing lysozyme or natamycin on shelf-life, microbial quality, and sensory properties of Halloumi cheese brined in normal and reduced salt solutions

Ghadeer F. Mehyar, Anas A. Al Nabulsi, Mohammed Saleh, Amin N. Olaimat, Richard A. Holley

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

The analysis of phenolic compounds in daylily using UHPLC-HRMS^n and evaluation of drying processing method by fingerprinting and metabolomic approaches

Jianghao Sun, Wei Liu, Mengliang Zhang, Ping Geng, Yang Shan, Gaoyang Li, Yang Zhao, Pei Chen

First Published: 11 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

The nutraceutical quality of tomato fruit during domestic storage is affected by chitosan coating

Carlos Henrique Pagno, Antonella Castagna, Alice Trivellini, Anna Mensuali-Sodi, Annamaria Ranieri, Ester Alice Ferreira, Alessandro de Oliveira Rios, Simone Hickmann Flôres

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Wiley Online Library

First Published: 31 March 2017

Free Access

A comparative study of the nutritional values, volatiles compounds, and sensory qualities of pea pastes cooked in iron pot and clay pot

Qinhui Xing, Xiaohui Xing, Zhengmao Zhang, Xinjuan Hu, Fangliang Liu

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Determination of antibiotic susceptibility and decarboxylase activity of coagulase-negative *Staphylococcus* and *Macrococcus caseolyticus* strains isolated from fermented Turkish sausage (sucuk)

Burak Geniş, Yasin Tuncer

First Published: 28 April 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Evaluation of the robustness of the enzymatic hydrolysis in batch and continuous mode by a central composite design

N. Abdi, O. Kitous, H. Grib, M. Drouiche, H. Lounici, N. Drouiche, N. Mameri

First Published: 05 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Phytochemical profiles and antioxidant capacities of white and red ginseng as affected by marinating media (vinegar, yellow wine, and Chinese liquor)

X. C. Zhang, B. J. Xu

Wiley Online Library

Effects of using combined essential oils on quality parameters of bio-yogurt

Filiz Yangilar, Pinar Oguzhan Yildiz

First Published: 11 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Lignin accumulation and biosynthetic enzyme activities in relation to postharvest firmness of fresh waxy corn

Kuijie Gong, Lirong Chen, Xiaoyue Li, Kaichang Liu

First Published: 09 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effectiveness of electron beam irradiation for microbial decontamination of turmeric powder (*Curcuma longa* Linne) and analysis of curcuminoid degradation

Rumi Yamaoki, Shojiro Kimura

First Published: 09 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

The effect of preultrasonic process on oil content and fatty acid composition of hazelnut, peanut and black cumin seeds

Fahad Al Juhaimi, Nurhan Uslu, Mehmet Musa Özcan

First Published: 11 May 2017

Abstract | Full text | PDF | References | Request permissions

quality of refrigerated chicken fillet

First Published: 09 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Water dynamics of turbot flesh during frying, boiling, and stewing processes and its relationship with color and texture properties: Low-field NMR and MRI studies

Kexin Xia, Wei Xu, Linlin Huang, Yukun Song, Bei-Wei Zhu, Mingqian Tan

First Published: 19 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Antifungal activity of water-soluble chitosan against *Colletotrichum capsici* in postharvest chili pepper

Le Thanh Long, Le Van Tan, Vu Ngoc Boi, Trang Si Trung

First Published: 19 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Industrial and artisanal fresh filled pasta: Quality evaluation

Stefania Maria Marotta, Filippo Giarratana, Giovanni Raffaele, Daniele Muscolino, Alessandro Giuffrida, Antonio Panebianco, Graziella Ziino

First Published: 11 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Optimization of simultaneous recovery of oil and protein from sesame (*Sesamum indicum*) seed

Wiley Online Library

Abstract | Full text | PDF | References | Request permissions

Journal Articles Actions

Free Access

High-pressure recovery of anthocyanins from grape skin pomace (*Vitis vinifera* cv. Teran) at moderate temperature

Predrag Putnik, Danijela Bursać Kovačević, Damir Ježek, Ivana Šustić, Zoran Zorić, Verica Dragović-Uzelac

First Published: 19 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

The use of grape, pomegranate and rosehip seed flours in Turkish noodle (erişte) production

Ilkay Koca, Belkis Tekguler, Volkan Arif Yilmaz, Incinur Hasbay, Ahmet Faik Koca

First Published: 16 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Separation, purification of anthocyanin and vitis linn polysaccharide from grape juice by the two-step extraction and dialysis

Xu Tang, Yun Wang, Juan Han, Lei Wang, Cheng Li, Liang Ni

First Published: 25 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Electro activated water mechanism on *Escherichia coli* and *Enterococcus faecalis* and optimization of operating parameters

Ozge Turkay, Mine G. Seker, Salim S. Ramadhan, Anatoli Dimoglo

First Published: 16 May 2017

Abstract | Full text | PDF | References | Request permissions

Wiley Online Library

Optimal blending of differently refined fish proteins based on their functional properties

Journal Articles Actions

First Published: 22 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Analysis of the effects of thermal protein denaturation on the quality attributes of sous-vide cooked tuna

Yvan Llave, Naomi Shibata-Ishiwatari, Mai Watanabe, Mika Fukuoka, Naoko Hamada-Sato, Noboru Sakai

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Monitoring black tea fermentation using a colorimetric sensor array-based artificial olfaction system

Huanhuan Li, Bin Zhang, Weiwei Hu, Yan Liu, Chunwang Dong, Quansheng Chen

First Published: 17 May 2017

Abstract | PDF | References | Request permissions

Free Access

Combined treatment of ultraviolet-C and *L. plantarum* on *Salmonella enteritidis* and quality control of fresh-cut apple

An-Jun Chen, Wei Luo, Yun-Bo Luo, Ben-Zhong Zhu

First Published: 31 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Storage study and quality evaluation of fresh coconut grating

Archana Gopalrao Lamdande, Maya Prakash, Raghavarao KSMS

Wiley Online Library

Isolation and identification of exopolysaccharide producer lactic acid bacteria from Turkish yogurt

Hümeyra İspirli, Enes Dertli

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of pretreatments and drying methods on physico-chemical, sensory characteristics and nutritional value of oyster mushroom

Ahmed R. M. Maray, Mostafa K. Mostafa, Alaa El-Din M. A. El-Fakhrany

First Published: 09 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Quality differences of hamburger patties incorporated with encapsulated β carotene both as an additive and edible coating

Emin Burcin Ozvural, Qingrong Huang

First Published: 23 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Neutral electrolyzed water (NEW), chlorine dioxide, organic acid based product, and ultraviolet-C for inactivation of microbes in fresh-cut vegetable washing waters

Marja Lehto, Risto Kuisma, Hanna-Riitta Kymäläinen, Maarit Mäki

First Published: 25 May 2017

Abstract | Full text | PDF | References | Request permissions

phytochemicals content and multivariate chemometrics

First Published: 22 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Quality characteristics of centrifuged broth from blanched *Pleurotus eryngii* and its application as instant drink

Sheng-Dun Lin, Yu-Ting Wu, Yu-Chang Lo, Jeng-Leun Mau

First Published: 19 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Changes of amino acid and fatty acid profile in freshwater fish after smoking

Iwona Cieślik, Władysław Migdał, Kinga Topolska, Barbara Mickowska, Ewa Cieślik

First Published: 26 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Prolonged preservation of corn oil via gold nanoparticles

Al-Sayed Al-Sherbini, Mostafa M. H. Khalil, Hanaa Hussein El-Sayed, Amira Fawzy Soliman

First Published: 31 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Physical properties of infrared (IR) assisted hot air dried nutmeg (*Myristica fragrans*) seeds

Anandu PS, Sangeetha K, Sanjana Potluri, Santhosh R, Mahendran R

First Published: 08 June 2017

Wiley Online Library

fungal incidence and patulin biosynthesis

Weili Li, Ting Zhou, Tao Wu, Xihong Li

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Rheological and nutritional studies of amaranth enriched wheat *chapatti* (Indian flat bread)

Anamika Banerji, Laxmi Ananthanarayan, Smita Lele

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Evaluation of PLA nanocomposite films on physicochemical and microbiological properties of refrigerated cottage cheese

Wenhui Li, Lin Li, Heng Zhang, Minglong Yuan, Yuyue Qin

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of severing skeletal muscle at different stage of rigor on the quality of pacific white shrimp (*Litopenaeus vannamei*)

Tariq Hussain Bhat, Mithlesh Kumar Chouksey, Amjad Khansaheb Balange, Binaya Bhusan Nayak

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

(*Castanea mollissima*) prepared by autoclaving treatment and pullulanase hydrolysis

First Published: 31 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Using chromatography and mass spectrometry to monitor isomerization of catechin in alkaline aqueous with thermal processing

Liang-Yü Chen, Jun-Yun Wu, Ji-yuan Liang

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of storage temperature and packaging on quality and shelf-life of high pressure processed black tiger shrimp (*Penaeus monodon*)

Barjinder Pal Kaur, P. Srinivasa Rao

First Published: 24 May 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Protopectinase production by *Paenibacillus polymyxa* Z6 and its application in pectin extraction from apple pomace

Jian Zhang, Li Zhao, Bei Gao, Wei Wei, Hualei Wang, Jingli Xie

First Published: 09 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Changes of bioactive components in berry seed oils during supercritical CO_2 extraction

Wiley Online Library

First Published: 08 June 2017

Free Access

Optimization of mechanochemical-assisted extraction and decoloration by resins of polysaccharides from petals of *Crocus sativus* L

Jun Yang, Yingpeng Tong, Kunming Zhu, Yu Jiang, Yongqiu Yan, Suhong Chen, Ping Wang

First Published: 09 June 2017

Abstract | PDF | References | Request permissions

Open Access

Antimicrobial packaging based on ε-polylysine bioactive film for the control of mycotoxigenic fungi in vitro and in bread

C. Luz, J. Calpe, F. Saladino, Fernando B. Luciano, M. Fernandez-Franzón, J. Mañes, G. Meca

First Published: 09 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Improving quality of cumin powder through cryogenic grinding technology

Vivekkumar Saxena, Bhaumik B. Patel, R. F. Sutar, D. C. Joshi

First Published: 09 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Grinding characteristics, physical, and flow specific properties of roasted maize and soybean flour

Rakesh Kumar Raigar, Hari Niwas Mishra

First Published: 08 June 2017

Abstract | Full text | PDF | References | Request permissions

Polysaccharides from *Enteromorpha tubulosa*: Optimization of extraction and cytotoxicity

First Published: 08 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Development of moisture-absorbing and antioxidant active packaging film based on poly(vinyl alcohol) incorporated with green tea extract and its effect on the quality of dried eel

Chen-Wei Chen, Jing Xie, Fu-Xin Yang, Hai-Lin Zhang, Zhe-Wei Xu, Jin-Liang Liu, You-Ji Chen

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Composition, digestibility, and functional properties of yellow pea as affected by processing

Sabine Ribéreau, Alberta N. A. Aryee, Siriane Tanvier, Jay Han, Joyce I. Boye

First Published: 30 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Ultrasound-assisted extraction and characterization of anthocyanins from purple corn bran

Liyuan Chen, Min Yang, Haijin Mou, Qing Kong

First Published: 08 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Free Access

Determination of physicochemical properties of multifloral honeys stored in different containers

Fahad Aljuhaimi, Mehmet Musa Özcan, Kashif Ghafoor, Elfadil E. Babiker

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of banana and plasticizer types on mechanical, water barrier, and heat sealability of plasticized banana-based films

Aungkana Orsuwan, Rungsinee Sothornvit

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Optimization of fermentation conditions for *ting* production using response surface methodology

Oluwafemi Ayodeji Adebo, Patrick Berka Njobeh, Antoine Floribert Mulaba-Bafubiandi, Janet Adeyinka Adebiyi, Zangué Steve Carly Desobgo, Eugenie Kayitesi

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Analysis of main physicochemical parameters in purple wheat with different milling technology

Shuang-Qi Tian, Zhi-Cheng Chen, Yong-Feng Qiao

Wiley Online Library

The impact of cooking method on the phenolic composition, total antioxidant activity and starch digestibility of rice (*Oryza sativa* L.)

T. Chmiel, I. E. Saputro, B. Kusznierewicz, A. Bartoszek

First Published: 22 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Application of magnetic polymethacrylate-based microspheres for the isolation of DNA from raw vegetables and processed foods of plant origin

Zdeněk Trojánek, Aleš Kovařík, Alena Španová, Kristýna Marošiová, Daniel Horák, Bohuslav Rittich

First Published: 23 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Towards the development of peanut–wheat flour composite dough: Influence of reduced-fat peanut flour on bread quality

A. S. Adeboye, O. E. Fayemi, A. Bamgbose, A. Adewunmi, S. S. Sobowale

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Evaluation of bioactive compounds content and antioxidant properties of soil-growing and wood-growing edible mushrooms

Monika Gąsecka, Marek Siwulski, Mirosław Mleczek

First Published: 14 June 2017

Abstract | Full text | PDF | References | Request permissions

(*Solanum lycopersicum*) fruit

First Published: 04 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of cooking and germination on antioxidant activity, total polyphenols and flavonoids, fiber content, and digestibility of lentils (*Lens culinaris* L.)

Zuzana Bubelová, Daniela Sumczynski, Richardos Nikolaos Salek

First Published: 22 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Quality changes and microbiological spoilage analysis of air-packed and vacuum-packed silver carp (*Hypophthalmichthys molitrix*) fillets during chilled storage

Dongping Li, Qian Li, Yuemei Zhang, Xiaochang Liu, Hui Hong, Yongkang Luo

First Published: 06 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

The quality of pork and the shelf life of the chosen carcass elements during storage depending on the method of carcass chilling

Piotr Janiszewski, Karol Borzuta, Dariusz Lisiak, Beata Bartodziejska, Eugenia Grześkowiak, Joanna Królasik, Ewa Poławska

First Published: 30 August 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Free Access

Effects of pretreatment ultrasound bath and ultrasonic probe, in osmotic dehydration, in the kinetics of oven drying and the physicochemical properties of beet snacks

Marcela Bromberger Soquetta, Silvana Schmaltz, Fabiana Wesz Righes, Renata Salvalaggio, Lisiane de Marsillac Terra

First Published: 22 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Processing of Xoconostle fruit (*Opuntia joconostle*) juice for improving its commercialization using membrane filtration

Roberto Castro-Muñoz, Vlastimil Fíla, Blanca E. Barragán-Huerta, Jorge Yáñez-Fernández, José A. Piña-Rosas, Jaime Arboleda-Mejía

First Published: 28 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Evaluation of debittered and germinated fenugreek (*Trigonella foenum graecum* L.) seed flour on the chemical characteristics, biological activities, and sensory profile of fortified bread

Pravesh S. Chaubey, Gauresh Somani, Divya Kanchan, Sadhana Sathaye, Sadineni Varakumar, Rekha S. Singhal

First Published: 28 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Wiley Online Library

First Published: 07 July 2017

Free Access

Antioxidant effect of olive leaf powder on fresh Atlantic horse mackerel (*Trachurus trachurus*) minced muscle

Irene Albertos, Ana B. Martín-Diana, Isabel Jaime, Roberto J. Avena-Bustillos, Tara H. McHugh, Gary R. Takeoka, Lan Dao, Daniel Rico

First Published: 12 July 2017

Abstract | PDF | References | Request permissions

Free Access

An efficient and innovative method to preserve the harvested plums during storage

Anca Peter, Camelia Nicula, Leonard Mihaly-Cozmuta, Anca Mihaly-Cozmuta

First Published: 28 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Modification of insoluble dietary fiber from garlic straw with ultrasonic treatment

Liurong Huang, Xiaona Ding, Yunshu Zhao, Yuxiang Li, Haile Ma

First Published: 28 June 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Synergistic antifungal effects of thyme essential oil and *Lactobacillus plantarum* cell-free supernatant against *Penicillium* spp. and in situ effects

Suphamid Sriwattanachai, Muhammad Bilal Sadiq, Anil Kumar Anal

First Published: 05 July 2017

Abstract | Full text | PDF | References | Request permissions

Wiley Online Library

Journal Articles Actions

Evaluation of the quality of fresh and frozen wheatgrass juices depending on the time of

Łukasz Skoczylas, Anna Korus, Małgorzata Tabaszewska, Katarzyna Gędoś, Edyta Szczepańska

First Published: 30 June 2017

Abstract | PDF | References | Request permissions

Free Access

Inhibitory effect of acid concentration, aging, and different packaging on *Escherichia coli* O157:H7 and on color stability of beef

Ana Paula A. A. Salim, Anna C. V. C. S. Canto, Bruno R. C. Costa-Lima, Julia S. Simoes, Pedro H. N. Panzenhagen, Marion P. Costa, Robson M. Franco, Teófilo J. P. Silva, Carlos A. Conte-Junior

First Published: 05 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Bioactive compounds of cold pressed spice paprika seeds oils

Arnold Koncsek, Lajos Helyes, Hussein G. Daood

First Published: 05 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

The effects of ozonated water on the microbial counts and the shelf life attributes of fresh-cut spinach

Michalis Papachristodoulou, Athanasios Koukounaras, Anastasios S. Siomos, Aglaia Liakou, Dimitrios Gerasopoulos

First Published: 04 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Free Access

The influence of natural sweetener (*Stevia rebaudiana* Bertoni) on bioactive compounds content in chokeberry juice

Jana Šic Žlabur, Nadica Dobričević, Ante Galić, Stjepan Pliestić, Sandra Voća

First Published: 04 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of high pressure processing on sugar-snap cookie dough preservation and cookie quality

A. Aguirre, M. V. Karwe, R. Borneo

First Published: 18 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Extraction optimization and profile analysis of oligosaccharides in banana pulp and peel

Gustavo Araujo Pereira, Henrique Silvano Arruda, Gustavo Molina, Gláucia Maria Pastore

First Published: 12 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of different cleaning processes on saponins' loss rate and total ash clearance rate of Notoginseng and heavy metal health risk assessment

Yang Ye, Tian Mengyuan, Guo Lan-Ping, Liu Dahui, Qu Yu, Cui Xiu-Ming

First Published: 14 July 2017

Wiley Online Library

of heat penetration of a food simulant processed in a pouch

Mollye S. MacNaughton, William S. Whiteside, James R. Rieck, Ronald L. Thomas

First Published: 01 August 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Extraction and characterization of pectin from pomelo peel and its impact on nutritional properties of carrot jam during storage

Manik Chandra Roy, Majbaul Alam, Abu Saeid, Bijoy Chandra Das, Md. Biplob Mia, Md. Atikur Rahman, Jong Bang Eun, Maruf Ahmed

First Published: 12 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Synergistic bacterio-myco soyabean co-fermentation methodology for harnessing the unexhausted

Li Xiang, Judy Gopal, Sechul Chun, Si-Kyung Lee, Ki-Cheol Son

First Published: 12 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Influence of top spray fluidized bed agglomeration conditions on the reconstitution property and structure modification of skim yoghurt powder

Ilyas Atalar, Fehmi Yazici

First Published: 13 July 2017

Abstract | Full text | PDF | References | Request permissions

sweet potato and bambara groundnut-based snacks

First Published: 13 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Fabrication of chia (*Salvia hispanica* L.) seed oil nanoemulsions using different emulsifiers

Jing Teng, Xiaoqian Hu, Mingfu Wang, Ningping Tao

First Published: 13 July 2017

Abstract | Full text | PDF | References | Request permissions

Free Access

Effect of cold press and soxhlet extraction systems on fatty acid, tocopherol contents, and phenolic compounds of various grape seed oils

Fahad Al Juhaimi, Mehmet Musa Özcan

First Published: 13 July 2017

Abstract | Full text | PDF | References | Request permissions

Copyright © 1999-2018 John Wiley & Sons, Inc. All rights reserved

Pages de l’article

Received: 13 January 2017 | Revised: 14 March 2017 | Accepted: 23 April 2017

DOI: 10.1111/jfpp.13381

ORIGINAL ARTICLE

WILEY Journal of Food Processing and Preservation Institute of Food Science + Technology ifst

Optimization of fermentation conditions for *ting* production using response surface methodology

Oluwafemi Ayodeji Adebo[1] | Patrick Berka Njobeh[1] | Antoine Floribert Mulaba-Bafubiandi[2] | Janet Adeyinka Adebiyi[1] | Zangué Steve Carly Desobgo[1] | Eugenie Kayitesi[1]

[1]Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, Gauteng, South Africa

[2]Department of Metallurgy, Mineral Processing and Technology Research Centre, Faculty of Engineering and The Built Environment, University of Johannesburg, Gauteng, South Africa

Correspondence
Oluwafemi Ayodeji Adebo, Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein Campus, Gauteng, South Africa.
Email: oluwafemiadebo@gmail.com
or
Eugenie Kayitesi, Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, P.O. Box 17011, Doornfontein Campus, Gauteng, South Africa.
Email: eugeniek@uj.ac.za

Funding information
University of Johannesburg (Global Excellence and Stature Fellowship to OAA); National Research Foundation (NRF) Center of Excellence (CoE) in Food Security co-hosted by the University of Pretoria (UP) and the University of the Western Cape (UWC), South Africa

Abstract

This study investigated the effect of fermentation conditions (time and temperature) of sorghum on the composition of *ting*, using the Doehlert design of response surface methodology (RSM). Fermentation temperature and time were optimized and pH, titratable acidity (TTA), total viable bacteria count (TBC), total lactic acid bacteria count (TLABC), total fungal and yeast count (TFYC), tannin content (TNC), total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activities (AA) were determined. Experimental and predicted values obtained were similar, with statistical indices indicating the validity of the models generated (R^2 between 93.45 and 99.71%, AAD values close to 0, B_f and A_f values close to 1). Numerical multi-response optimization of parameters suggested optimal fermentation conditions to be 34 °C for 24 hr. Physicochemical characterization of *ting* samples using scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier Transform Infrared Spectroscopy (FTIR) showed slight changes in morphology, similarity in diffraction patterns and presence of different functional groups, respectively. Results of this study could provide information for the commercialization of quality *ting*.

Practical applications

Response surface methodology was used to study the influence of fermentation conditions on the quality of *ting* and optimal fermentation conditions were obtained at 34 °C for 24 hr. The findings in this study will be useful for *ting* processors to obtain a product with maximal beneficial composition and traits.

1 | INTRODUCTION

Sorghum is an important cereal crop and major source of food for millions of people. Sorghum like other cereals is transformed into edible forms using fermentation, known to enhance nutritional qualities, shelf life, bioavailability of nutrients, palatability, beneficial health promoting components, and consumer appeal (Adebiyi, Obadina, Adebo, & Kayitesi, in press; Taylor & Duodu, 2015).

Ting, is a fermented sorghum product commonly consumed in Botswana, South Africa, and other neighboring countries. It is known for its sour taste and unique flavor and it is used as a weaning food for infants as well as consumed during ceremonies (Sekwati-Monang & Gänzle, 2011). Different fermentation conditions for the preparation of *ting* have been reported in the literature (Madoroba et al., 2009; Sekwati-Monang & Gänzle, 2011), with variations in their fermentation process, which have no available standardized or optimized conditions.

A widely accepted optimization procedure is response surface methodology (RSM), which is a collection of statistical and mathematical methods for obtaining the optimum conditions of factors for desirable responses. The Doehlert design of RSM are easily applied to

 © 2017 Wiley Periodicals, Inc.

optimize variables more effectively as they have the ability to explore the whole of an experimental domain (Ferreira, dos Santos, Quintella, Neto, & Bosque-Sendra, 2004).

Scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared spectroscopy (FTIR) are techniques that can be used to study and understand the morphology, composition and possible structural changes during food processing. The use of such techniques can provide substantial information and have been used for fermented foods (Adebiyi, Obadina, Mulaba-Bafubiandi, Adebo, & Kayitesi, 2016; Amadou, Gounga, Shi, & Le, 2014). Few studies have been presented in the literature on characterizing the microbiota and selected chemical properties of *ting* (Madoroba et al., 2009, 2011; Sekwati-Monang & Gänzle, 2011). To our knowledge, none of these studies have optimized fermentation variables and subsequently investigated their effects on the composition and physicochemical properties of *ting*. Hence, this study focused on optimizing fermentation parameters (time and temperature) of *ting* and evaluating their physicochemical properties and microstructure.

2 | MATERIALS AND METHODS

2.1 | Raw material and sample preparation

Sorghum (*Sorghum bicolor* L.) grain cultivar (Titan) was purchased from Agricol (Pty) Ltd., Potchefstroom, South Africa. The sorghum grains were milled using a Perten Laboratory Mill 3600 (Perten Instruments, Sweden) and passed through a 2 mm aperture size sieve (Analysette 3 Spartan, Fritsch, Germany) to obtain the flour.

2.2 | Fermentation of *ting*

Sorghum flour was processed into *ting* by mixing sterile distilled water (40 °C) and the sorghum flour (1:1, w/v). The mixture was subsequently allowed to spontaneously ferment by endogenous microflora. For each experimental run, the fermentation process was done in triplicate.

2.3 | Optimization of *ting* production process

A response surface methodology (RSM) using the Doehlert design was used to model and optimize the effect of fermentation parameters on the parameters investigated. The independent variables were fermentation time (X_1) and fermentation temperature (X_2), with intervals of 24–72 hr and 20–34 °C respectively. The selection of the parameter levels was based on other studies in the literature on the production of *ting* (Madoroba et al., 2009; Sekwati-Monang & Gänzle, 2011). The two-factor Doehlert design gave a total of eight experimental runs (Supporting Information Table 1). Nine parameters including pH (Y_1), total titratable acidity (TTA, Y_2), total bacteria count (TBC, Y_3), total lactic acid bacteria count (TLABC, Y_4), total fungal and yeast count (TFYC, Y_5), tannin content (TNC, Y_6), total phenolic content (TPC, Y_7), total flavonoid content (TFC, Y_8), and antioxidant activity (AA, Y_9) were investigated.

Mathematical models describing the relationship between the process variables in terms of their linear, quadratic and interactive effects used were described by a second-order polynomial equation presented in Equation (1).

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum \sum_{i<j}^{k} \beta_{ii} x_i x_j \quad (1)$$

where Y is the response, x_i and x_j are factors, β_0 the constant, β_i, β_{ii}, and β_{ij} the coefficients of linear, quadratic and interaction terms, respectively. The response surfaces were subsequently represented with model equations and respective coefficients obtained using Minitab 16 statistical software (Minitab Lt. Coventry, UK).

2.4 | Model validation

The different statistical parameters utilized in validating the adequacy of the models generated, were average absolute deviation (AAD), bias factor (B_f), and accuracy factor (A_f) (Equations (2)–(4)), respectively, as well as the coefficient of determination (R^2).

$$\text{AAD} = \frac{\left[\sum_{i=1}^{N} \left(\frac{|Y_{i,\text{exp}} - Y_{i,\text{cal}}|}{Y_{i,\text{exp}}}\right)\right]}{N} \quad (2)$$

$$B_f = 10^{\frac{1}{N}\sum_{i=1}^{N} \log\left(\frac{Y_{i,\text{cal}}}{Y_{i,\text{exp}}}\right)} \quad (3)$$

$$A_f = 10^{\frac{1}{N}\sum_{i=1}^{N} \left|\log\left(\frac{Y_{i,\text{cal}}}{Y_{i,\text{exp}}}\right)\right|} \quad (4)$$

2.5 | pH and TTA

At the end of each fermentation process, pH of the *ting* was measured using a pH meter (pH 510, Eutech Pte Ltd, Singapore). Titratable acidity was determined by titrating a mixture of 2 g of *ting* sample and 20 ml distilled water against 0.1 N NaOH, using phenolphthalein as an indicator, the TTA was expressed in g of tartaric acid/kg sample.

2.6 | Estimation of viable microbial counts

For viable microbial counts, 1 g of the respective *ting* sample was added to 9 ml sterile distilled water and vortexed. Counts were determined by surface plating tenfold serial dilutions of *ting* sample on plate count agar (Oxoid, South Africa), potato dextrose agar (Merck, South Africa), and MRS agar (Sigma Aldrich, Germany) in petri dishes for bacterial (TBC), fungal and yeast (TFYC) and lactic acid bacteria (LAB) counts, respectively (Madoroba et al., 2011; Njobeh et al., 2009; Nyambane, Thari, Wangoh, & Njage, 2014). Plates were incubated (IncoShake, Labotec, South Africa) at 30 °C for 72 hr for TBC, 25 °C for 120 hr for TFYC, and anaerobically at 35 °C for 72 hr for TLABC.

2.7 | Tannin content, total phenolic content, total flavonoid content, and antioxidant activity assay

2.7.1 | Extraction

To a 0.3 g of freeze-dried milled *ting* sample, 10 ml of acidified methanol (1% HCl in methanol) was added in a centrifuge tube (Kayitesi, de Kock, Minnaar, & Duodu, 2012). The content was sealed with an

aluminum foil, stirred for 2 hr and centrifuged at 3,500 rpm for 10 min (Eppendorf 5702R, Merck South Africa). The supernatant was decanted and kept while the residue was re-extracted using 10 ml acidified methanol as earlier described. The extraction process was repeated until a total of 30 ml acidified methanol (1% HCl in methanol) was used. After extraction, the supernatants were pooled together and stored at −4 °C prior to analysis.

2.7.2 | Analytical procedure

Tannin content

Using the methods of Price, Van Scoyoc, and Butler (1978), 1 ml of extract was added to a test tube containing 5 ml of an equal volume of 8% HCl in methanol and 1% vanillin (Merck, South Africa). The resulting mixture was vortexed and incubated in a water bath (30 °C) for 20 min. A blank was also done repeating the earlier step but this time using 5 ml of 4% HCl. The absorbance of the mixture was read at 500 nm using a spectrophotometer (Biomate, Thermo Spectronic, Rochester). Catechin (Sigma Aldrich, Germany) was used as a standard and results obtained expressed in mg catechin equivalents (CE)/g.

Total phenolic content

The TPC of the *ting* sample was determined according to Folin–Ciocalteu method as described by Ainsworth and Gillespie (2007). To 500 μl of distilled water, 10 μl of the extract was added and reacted with 50 μl of the Folin–Ciocalteu phenol reagent (Sigma Aldrich, Germany). This was allowed to stand in the dark for 3 min followed by the addition of 200 μl of 20% Na_2CO_3 (g/v) and finally 245 μl of distilled water and mixed. The mixture (300 μl) was accurately pipetted into a 96-well microplate, wrapped in aluminum foil and further incubated in the dark for 30 min and absorbance read at 750 nm wavelength on a microplate reader (iMark, Biorad, South Africa). Gallic acid (Sigma Aldrich, Germany) was used as a standard and results obtained expressed in mg gallic acid equivalents (GAE)/g.

Total flavonoid content

Using the method of Ar-Farsi and Lee (2008), TFC was determined by mixing 30 μl of the extract with 20 μl of 36 mM $NaNO_2$ followed by incubation in the dark for 5 min. Thereafter, 20 μl of 94 mM $AlCl_3$ was added and after incubation for another 5 min (in the dark), 100 μl of NaOH was added. The absorbance of the mixture was read at 450 nm on a microplate reader (iMark, Biorad, South Africa). Catechin (Sigma Aldrich, Germany) was used as a standard and data obtained were expressed as mg CE/g.

Antioxidant activity

The free radical scavenging potential of *ting* sample was determined using the ABTS modified methods of Awika, Rooney, Wu, Prior, and Zevallos (2003) and Kayitesi et al. (2012). To 20 μl of the extract, 180 μl of ABTS free radical cation solution (equal volumes of 7 mM ABTS and 2.45 mM $K_2S_2O_8$ previously incubated for 12 hr) was added and incubated for 5 min in the dark. Absorbance of the solution was measured at 750 nm on a microplate reader (iMark, Biorad, South Africa). Trolox (Sigma Aldrich, Germany) was used as a standard solution and results obtained expressed as μM trolox equivalents (TE)/g sample).

2.8 | Physicochemical characterization

For both SEM and XRD, representative samples were obtained by vigorously homogenizing the freeze-dried *ting* samples obtained from each experimental run prior to analysis.

2.8.1 | SEM analysis of the ting samples

The *ting* samples were mounted on an aluminum stub and sprayed-coated in a carbon coater (Quorum Q150TE, Quorum Technologies, UK). The samples were then transferred to SEM specimen chamber, subjected to electron beam and viewed under a scanning electron microscope under vacuum.

2.8.2 | XRD analysis of the ting samples

The *ting* samples were loaded into the XRD sample holder and pressed down using a stainless steel weight. The XRD pattern of the samples were examined using an X-ray diffractometer (Rigaku-UltimaIV, Japan) equipped with a divergence slit, operating at 40 kV and 40 mA at a scan speed of 1°/min.

2.9 | FTIR spectroscopy and chemometric analysis

For analysis on FTIR, spectra of each triplicate fermented *ting* sample were obtained in duplicates giving six spectra for each *ting* sample. This was done using a FTIR spectrophotometer [Thermo Scientific Smart iTR, (Attenuated Total Reflectance), Thermo Fisher Scientific Inc., United States]. Respective spectra with characteristic peaks in wave numbers from 400 to 4,000 cm^{-1} at 32 runs per scan were subsequently recorded. All the FTIR spectra were respectively pre-treated using the following transformation techniques (i) baseline correction, (ii) normalization, (iii) standard normal variate (SNV), (iv) smoothing using Gaussian filter, (v) smoothing using Savitzky–Golay, and (vi) derivation using Savitzky–Golay first derivative on Unscrambler X statistical software version 10.4.2 (Camo software, Oslo, Norway). Principal Component Analysis (PCA) and Cluster Analysis (CA) were subsequently done on the same chemometric software.

2.10 | Statistical analysis

Except for FTIR, all other analyses were done in triplicate. To determine the significance of the generated models, an analysis of variance (ANOVA) was conducted on Minitab 16 (Minitab Lt. Coventry, UK) and differences were considered statistically significant if $p \leq .05$. Response surface plots were obtained using Sigmaplot 12.5 (Systat Software Inc., California).

3 | RESULTS AND DISCUSSION

3.1 | Statistical models and validation

This study investigated the effects of independent process variables [fermentation time (X_1) and fermentation temperature (X_2)] of sorghum on the production of *ting*. Parameters determined were pH (Y_1), TTA (Y_2), TBC (Y_3), TLABC (Y_4), TFYC (Y_5), TNC (Y_6), TPC (Y_7), TFC (Y_8), and

TABLE 1 Coefficient of regression for the different mathematical models obtained

Coefficient	pH	TTA	TBC	TLABC	TFYC	TNC	TPC	TFC	AA
β_0	6.18	0.565	2,240,000	1,415,000	706,000	9.965	16.06	8.695	1.145
β_1	−0.45*	0.27833	1,150,000	1,017,000*	268,333	−1.9917	−4.44*	−1.1967*	−0.03500*
β_2	−0.677552*	0.43014	2,881,062*	2,083,141*	680,716*	−5.5745*	−7.1132*	−1.9977*	−0.05485*
β_{11}	−0.075	0.34	1,110,000	450,000	126,500	−0.5450	1.12	1.2500	−0.02
β_{22}	−0.14834	0.36335	3,190,187*	1,391,415*	−16,168	−2.7552	0.7467	0.9567	0.01
β_{12}	−0.24249	−0.04042	438,799	1,557,737*	138,568	−1.0335	0.4157	0.5658	−0.00577
R^2 (%)	98.77	93.45	97.95	99.11	98.28	98.58	99.71	96.80	99.63
AAD	0.01	0.12	0.01	0.11	0.19	0.12	0.02	0.12	0.01
B_f	1.00	1.00	1.01	0.98	0.96	1.04	1.00	1.07	1.00
A_f	1.01	1.13	1.10	1.12	1.23	1.11	1.02	1.10	1.00

β represents the coefficients of equations of the different models with β_0 representing the constant term, β_1 and β_2 the linear effects of fermentation time and temperature, respectively, β_{11} and β_{22} their quadratic effects and β_{12} their interactions. TTA = titratable acidity; TBC = total bacteria count; TLABC = total lactic acid bacteria; TFYC = total fungal and yeast count; TNC = tannin content; TPC = total phenolic content; TFC = total flavonoid content; AA = antioxidant activity. *Significant at $p \leq .05$.

AA (Y_9) and the different models representing each provided in Equations (5)–(13).

$$Y_1 = 6.18 - 0.45x_1 - 0.67552x_2 - 0.07500x_{1^2} - 0.14834x_{2^2} - 0.24249x_1x_2 \quad (5)$$

$$Y_2 = 0.565 + 0.27833x_1 + 0.43014x_2 + 0.34x_{1^2} + 0.36335x_{2^2} - 0.04042x_1x_2 \quad (6)$$

$$Y_3 = 2,240,000 + 1,150,000x_1 + 2,881,062x_2 + 1,110,000x_{1^2} + 3,190,187x_{2^2} + 438,799x_1x_2 \quad (7)$$

$$Y_4 = 1,415,000 + 1,017,000x_1 + 2,083,141x_2 + 450,000x_{1^2} + 1,391,415x_{2^2} + 1,557,737x_1x_2 \quad (8)$$

$$Y_5 = 706,000 - 268,333x_1 + 680,716x_2 + 126,500x_{1^2} - 16,168x_{2^2} + 138,568x_1x_2 \quad (9)$$

$$Y_6 = 9.9650 - 1.9917x_1 - 5.5745x_2 - 0.5450x_{1^2} - 2.7552x_{2^2} - 1.0335x_1x_2 \quad (10)$$

$$Y_7 = 16.06 - 4.44x_1 - 7.1132x_2 + 1.12x_{1^2} + 0.7467x_{2^2} + 0.4157x_1x_2 \quad (11)$$

$$Y_8 = 8.695 - 1.1967x_1 - 1.9977x_2 + 1.2500x_{1^2} + 0.9567x_{2^2} + 0.5658x_1x_2 \quad (12)$$

$$Y_9 = 1.145 - 0.035x_1 - 0.05485x_2 - 0.02x_{1^2} + 0.01x_{2^2} - 0.00577x_1x_2 \quad (13)$$

All calculated R^2 values in this study were above 90 (93.45–99.71%) (Table 1). R^2 values should be at least 80% to have a good fit of the model and the closer it is to 100%, the better the empirical model fits the actual data (Filli, Nkama, Jideani, & Abubakar, 2011; Sobowale, Adebiyi, & Adebo, in press). Other parameters of predictive models in biological systems that measure the relative deviation from the observed (experimental) and predicted (calculated) parameters were determined and results presented in Table 1. As observed, the closeness of the B_f and A_f to unity Equation (1)) and that of AAD to zero indicates reasonable agreements between the predicted and observed parameters (Desobgo, Stafford, & Metcalfe, 2015; Sobowale et al., in press).

3.2 | pH and TTA

The pH and TTA are important biochemical parameters peculiar to fermented foods. With increasing time and temperature, pH decreased (increased acidity) with a corresponding increase in TTA (Figure 1a,b). pH values obtained in this study were relatively higher compared with those reported by Sekwati-Monang and Gänzle (2011). This may thus be attributed to difference in sample sources, fermentation conditions, and the use of nondecorticated sorghum grains in this study. A decrease in TTA indicates an accumulation of organic acids with increase in microbial activity and metabolism of the fermenting organisms. The regression model describing the effect of fermentation time and temperature on pH and TTA is given in Equations (5) and (6), respectively, with their corresponding regression coefficient of determination values provided in Table 1. The values of AAD (0.01 and 0.12) depicted an agreement between experimental and predicted values further showing that the models adequately described the pH and TTA values (Table 2). Results also showed that the linear factors of fermentation time (X_1) and temperature (X_2) had a significant ($p \leq .05$) effect on pH of *ting* samples, while the quadratic effects were not significant, meanwhile these variables had no significant ($p \leq .05$) effect on TTA. A negative correlation of 0.936 (Table 3) between these parameters suggested that increased acidity resulted in increased amount of organic acids. While relatively higher TTA values were observed in other samples, lower TTA values in others suggests that the metabolic activities of the fermenting organisms at such conditions were relatively low.

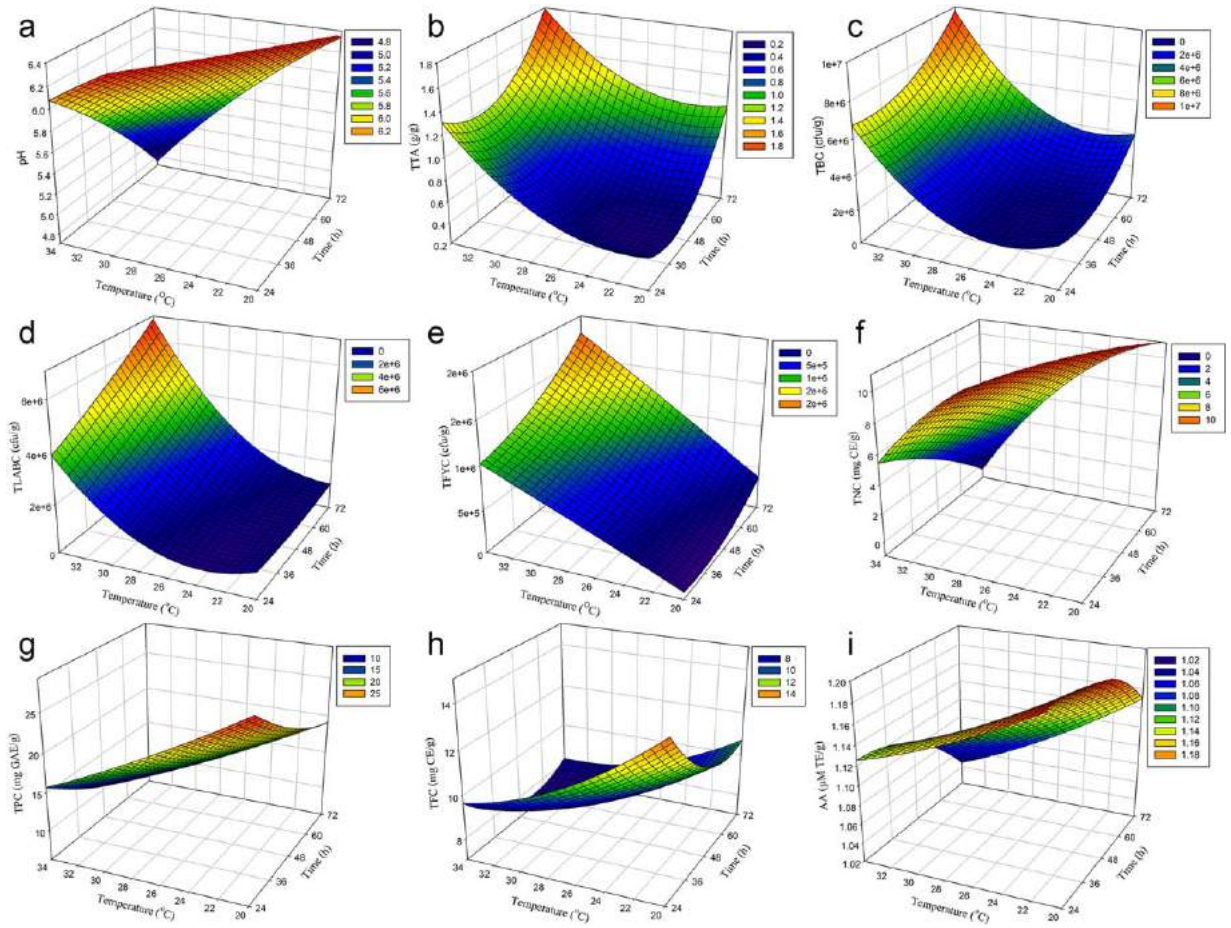


FIGURE 1 Response surface plots showing the effects of fermentation time and temperature on: (a) pH, (b) TTA, (c) TBC, (d) TLABC, (e) TFYC, (f) TNC, (g) TPC, (h) TFC, (i) AA of the ting samples

3.3 | Microbial load

Counts obtained on the different selective media used in this study (Table 2), suggested a diverse microbial flora on *ting* samples. LABs dominated the fermentation microbiota (Madoroba et al., 2011; Sekwati-Monang & Gänzle, 2011), while the relatively low counts of yeasts and fungi suggests that cereal fermentation favors the growth of LABs as compared with other group of microorganisms (Meroth, Hammes, & Hertel, 2003). As indicated by Adebiyi et al. (in press) spontaneous fermentation of cereals involves the competitive action of

TABLE 2 Experimental and predicted values obtained for the parameters investigated

Variables		pH		TTA (g/kg)		TBC ($\times 10^6$ cfu/g)		TLABC ($\times 10^5$ cfu/g)		TFYC ($\times 10^5$ cfu/g)		TNC (mg CE/g)		TPC (mg GAE/g)		TFC (mg CE/g)		AA (μM TE/g)	
X_1	X_2	Exp	Pre	Exp	Pre	Exp	Pre	Exp	Pre	Exp	Pre	Exp	Pre	Exp	Pre	Exp	Pre	Exp	Pre
48	27	6.18	6.18	0.56	0.57	2.25	2.24	14.3	14.2	7.07	7.06	9.96	9.97	16.07	16.06	8.71	8.70	1.15	1.15
48	27	6.18	6.18	0.57	0.57	2.23	2.24	14.0	14.2	7.09	7.06	9.97	9.97	16.05	16.06	8.68	8.70	1.14	1.15
72	27	5.59	5.66	1.29	1.18	4.87	4.50	27.1	28.8	11.7	11.0	7.95	7.43	12.42	12.74	8.43	8.74	1.09	1.09
60	34	5.20	5.14	1.31	1.42	7.80	8.17	57.3	55.6	14.4	15.1	0.97	1.49	9.02	8.70	7.96	7.64	1.08	1.08
24	27	6.62	6.56	0.52	0.63	1.83	2.20	10.2	8.48	4.95	5.64	10.89	11.41	21.94	21.62	11.46	11.14	1.16	1.16
36	20	6.69	6.76	0.50	0.39	2.40	2.03	7.61	9.33	1.31	0.62	13.66	13.14	25.14	25.46	11.98	12.30	1.21	1.21
60	20	6.58	6.52	0.60	0.71	2.43	2.80	7.73	6.01	1.41	2.10	11.52	12.04	20.98	20.66	10.93	10.61	1.18	1.17
36	34	5.73	5.79	1.28	1.17	7.01	6.64	30.2	31.9	11.9	11.2	4.90	4.38	12.46	12.78	8.03	13.18	1.12	1.11

X_1 = fermentation time (h); X_2 = fermentation temperature (°C). TTA = titratable acidity; TBC = total bacteria count; TLABC = total lactic acid bacteria; TFYC = total fungal and yeast count; TNC = tannin content; TPC = total phenolic content; TFC = total flavonoid content; AA = antioxidant activity; Exp = Experimental value; Pre = Predicted value.

TABLE 3 Pearson correlation between the investigated parameters

	pH	TTA	TBC	TLABC	TFYC	TNC	TPC	TFC	AA
pH		−0.914**	−0.889**	−0.934**	−0.966**	0.930**	0.968**	0.880**	0.950**
TTA	−0.914**		0.940**	0.849**	0.886**	−0.857*	−0.846**	−0.723*	−0.860**
TBC	−0.889**	0.940**		0.921**	0.852**	−0.928**	−0.812*	−0.682	−0.770*
TLABC	−0.934**	0.849**	0.921**		0.888**	−0.967**	−0.859**	−0.708*	−0.850**
TFYC	−0.966**	0.886**	0.852**	0.888**		−0.921**	−0.958**	−0.887**	−0.962**
TNC	0.930*	−0.857*	−0.928**	−0.967**	−0.921**		0.909**	0.788	0.877**
TPC	0.968**	−0.846**	−0.812*	−0.859**	−0.958**	0.909**		0.958**	0.955**
TFC	0.880**	−0.723*	−0.628	−0.708*	−0.887**	0.788*	0.958**		0.863**
AA	0.950**	−0.860**	−0.770*	−0.850**	−0.962**	0.877**	0.955**	0.863**	

**Correlation is significant at 1%.
*Correlation is significant at 5%.

endogenous microorganisms with LABs dominating. The presence of nutrients, organic acids and the acidic environment of the *ting* microbiota could have also supported the growth of other microorganisms. R^2 values (close to 100%) as observed on Table 1 indicate that the proposed mathematical models of the microbial colony count (Equations (7)–(9)) can explain more than 90% experimental observations as a function of the fermentation time and temperature. Using p values to establish the significance of each coefficient and interaction strength of each parameter, the linear factors of fermentation temperature (X_2) had a significant ($p \leq .05$) effect on TBC, TLABC, and TFYC of the *ting* samples (Table 1), while X_1 had a significant effect ($p \leq .05$) on only TLABC. The quadratic effect of both variables (X_1^2 and X_2^2) were significant ($p \leq .05$) on the TLABC of *ting* samples, whereas only X_2^2 had a significant effect ($p \leq .05$) on TBC. It can be observed from Figure 1c,d that the microbial counts increased with increasing fermentation temperature, but do not strongly depend on fermentation time (X_1). Nevertheless, the linear, quadratic, and interactive effect of fermentation temperature on microbial count was positive.

3.4 | TNC, TPC, TFC, and AA

Sorghum grains and subsequent products from them are known to be rich in tannins, flavonoids, phenolic compounds, and antioxidants and thus considered health promoting foods (Awika & Rooney, 2004; Taylor & Duodu, 2015). Experimental and predicted values of TNC, TPC, TFC and AA of *ting* samples are presented in Table 2 and their respective mathematical models presented in Equation (10)–(13). Figure 1f–i depicts the effect of fermentation time and temperature on these parameters. As observed, the effect of fermentation time (X_1) was significantly ($p \leq .05$) negative on all health promoting properties analyzed with the exception of TNC (Table 1). Similarly, the linear effect of fermentation temperature (X_2) had a significant ($p \leq .05$) effect on all the health beneficial properties. This thus, indicates that at increased temperature and sufficiently longer time, the concentrations and amounts of these parameters will decrease. Since the negative linear effect of X_1 and X_2 were significant ($p \leq .05$) on the health promoting parameters, while their corresponding quadratic factors were not, it can be suggested that both variables had a cumulative negative effect on the TNC, TPC, TFC and AA of *ting*. A general decrease of the investigated properties with increase in fermentation time and temperature could be attributed to reduced extractability of the phenolic compounds due to self-polymerization and/or interaction of these compounds with other macromolecules (Beta, Rooney, Marovatsanga, & Taylor, 2000; Taylor & Duodu, 2015). Such reduction and degradation of phenolic compounds in *ting* have also been reported by Svensson, Sekwati-Monang, Lutz, Schieber, and Gänzle (2010) and attributed to the actions decarboxylases, reductases, esterases, and the ability of LABs in fermented sorghum to metabolize phenolic compounds. A strong positive correlation between the AA and TPC (Table 3) strongly suggests that the phenolic contents of the *ting* samples, largely contributed to the antioxidant activities.

3.5 | Multiresponse numerical optimization

The surface plots (Figure 1a–i) shows the effect of different process variables (fermentation time and temperature) on the investigated parameters. A numerical optimization approach was adopted to determine the best experimental conditions for maximum release of phytochemicals accompanied by a good microbial growth, reduced pH, and high organic acid production. The numerical optimization of the process variables was done on Minitab 16 (Minitab Lt. Coventry, UK) and all parameters were investigated. The optimum derived conditions were fermentation time and temperature of 24 hr and 34 °C, respectively. The corresponding predicted parameters at this condition were pH (6.09), TTA (1.31 g/kg), TBC, (6.71 × 10^6 cfu/g), TLABC (2.35 × 10^6 cfu/g), TFYC (1.02 × 10^6 cfu/g), TNC (5.41 mg CE/g), TPC (15.66 mg GAE/g), TFC (9.64 mg CE/g), and AA (1.13 mg TE/g). To confirm the predicted values, the theoretical value was tested in triplicate using the optimal fermentation conditions obtained. Subsequent analysis gave the following results; pH (6.00), TTA (1.34), TBC (6.19 ×

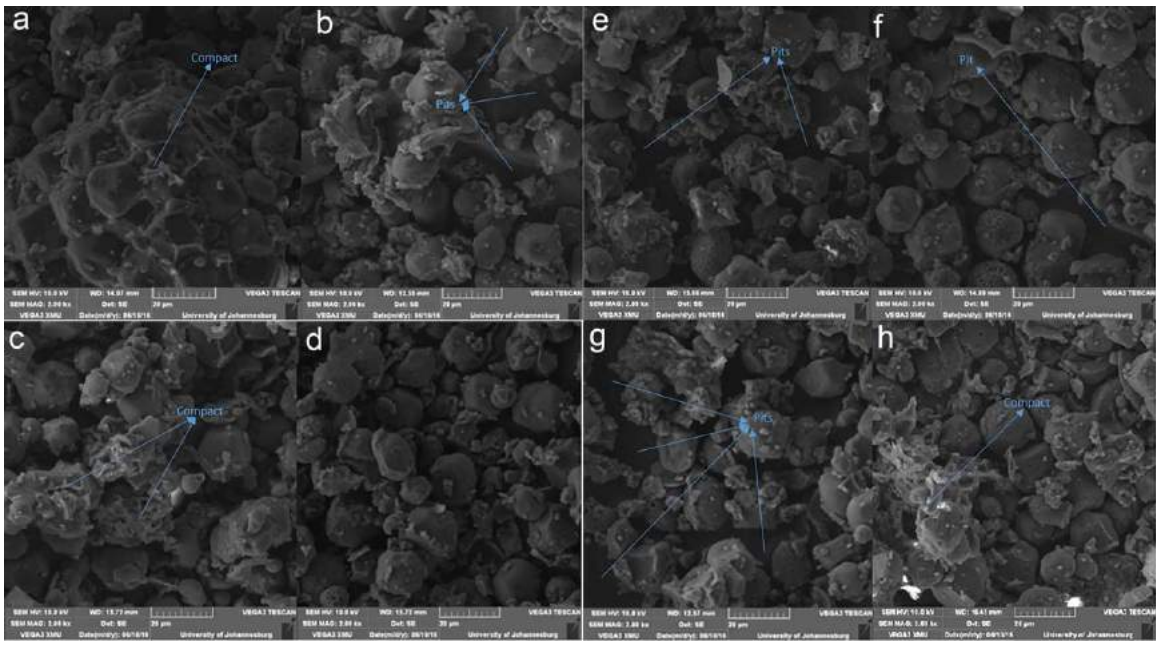


FIGURE 2 Scanning electron images of ting samples: (a) 20 °C 36 hr, (b) 20 °C 60 hr, (c) 27 °C 24 hr, (d) 27 °C 48 hr, (e) 27 °C 72 hr, (f) 34 °C 36 hr, (g) 34 °C 60 hr, (h) 34 °C 24 hr

10^6 cfu/g), TLABC (2.01 × 10^6 cfu/g), TFYC (9.91 × 10^5 cfu/g), TNC (5.36 mg CE/g), TPC (15.48 mg GAE/g), TFC (9.67 mg CE/g), and AA (1.18 mg TE/g). These obtained results are closely related to the numerical optimized data obtained, thus showing that the regression models obtained could adequately predict the parameters.

3.6 | SEM and XRD of the *ting* samples

The SEM images of samples of *ting* were compared with investigate possible morphological changes after fermentation. It can be observed from the micrographs (Figure 2), that the granules were predominantly spherical, with fermentation causing a degradation in the granular structure. There was a gradual change from a more compact, fused and consistent structure to a more loosened, disoriented one, forming pits (Figure 2). This was more pronounced in *ting* samples fermented for longer time and higher temperatures, suggesting increased degradation and hydrolysis of components such as starch and amino acids.

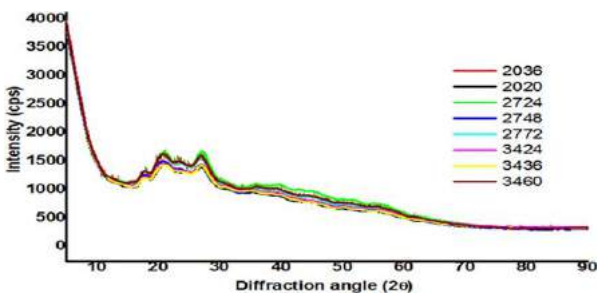


FIGURE 3 XRD patterns of the ting samples: 2036 (20 °C 36 hr), 2060 (20 °C 60 hr), 2724 (27 °C 24 hr), 2748 (27 °C 48 hr), 2772 (27 °C 72 hr), 3424 (34 °C 24 hr) 3436 (34 °C 36 hr), 3460 (34 °C 60 hr)

Differences in the diffraction pattern of *ting* samples as affected by the fermentation variables is presented in Figure 3. The diffractogram of all *ting* samples showed similarities and exhibited the same "A" pattern of diffraction, with significant peaks at angles of 2θ around 17.78, 21, and 27.07°. Differences in relative intensities could be attributed to the difference in the cellular and granular size (as observed with SEM) and the proportion and arrangements of the amylose and amylopectin components, which are known to have an impact on retrogradation and gelatinization.

3.7 | FTIR of the *ting* samples

FTIR spectroscopy was used to evaluate the composition of the obtained *ting* samples in terms of their functional groups, while band intensities could suggest their relative abundance. A comparative evaluation of the average spectra (Supporting Information Figure 1) revealed that the *ting* samples all had strong absorption peaks around 3,300, 2,900, 2,850, 1,740, 1,640, 1,520, and 1,007 cm^{-1}. Broad spectral peaks around 3,300 cm^{-1} is associated with O—H and polyhydroxyl bearing phenolic compounds suggesting the presence of quercetin, alcohols, and phenolic compounds present in fermented foods (Adebiyi et al., 2016; Taylor & Duodu, 2015). Bands occurring at 2,900 or and diffuse ones at 2,850 cm^{-1} could be attributed to alkanes (C—H stretching), aldehydes (H—C═O) and bound water in form of moisture, while peaks at 1,640 cm^{-1} represent conjugated carbonyl bonds which could be from flavonoids and esterified phytosterols (Adiana & Mazura, 2011). Peaks around 1,520 cm^{-1} represents the C═C—C signals of

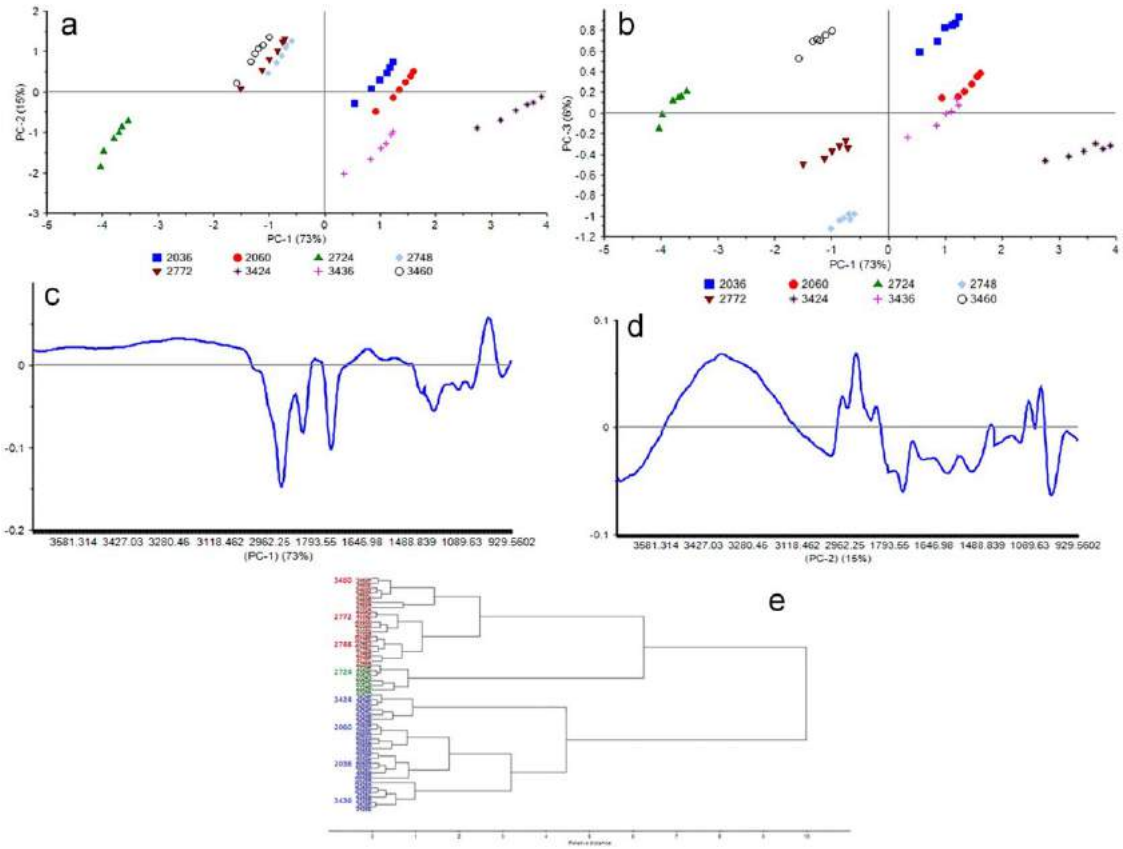


FIGURE 4 Plots of multivariate data analysis of the ting samples: (a) PCA scores plot (PC-1 and PC-2); (b) PCA scores plot (PC-1 and PC-3); (c) PC-1 loadings plot; (d) PC-2 loadings plot; (e) CA dendrogram

condensed tannins, sharp peaks at 1,143 cm^{-1} can be assigned to the —OH aromatic bond present in catechins, while the intense peaks at 1,007 and 930 cm^{-1} suggest the presence of phenolic compounds (flavonoids, tannins, glucosyl moieties), carbohydrates and amines containing the stretching vibrations of =C—O—C, C—C, or vibrational C—O—H bonds (Duodu, Tang, Grant, Wellner, & Belton, 2001; Sinelli, Spinardi, Di Egidio, Mignani, & Casiraghi, 2008). The high intensity bands in this region can be explained by the high amounts of flavonol glycosides and a possible accumulation of proteins (in form of amino acids) in the *ting* samples.

Regions associated with these described bands were selected, pretreated and subjected to PCA using different transformation techniques (Supporting Information Figure 2). The best pretreatment technique in terms of sample grouping coupled with relatively high variation of principal components (PCs) was the SNV pretreated data set (Figure 4a). As observed from Figure 4a, the first two principal components (PCs) accounted for 88% of the total variation. While PC-1 with 73% of the total variation differentiated *ting* samples fermented at 20 °C (for 36, 60 hr) and 34 °C (for 24, 36 hr) on the right, PC-2 with 15% separated the samples fermented at 27 °C (for 48, 72 hr), 34 °C for 60 hr, and majority of samples at 20 °C (for 36, 60 hr) above, from other *ting* samples below. This is also reflected on the discrete grouping formed along the PCs. The clustering as depicted in Figure 4a further confirm the observations on other parameters investigated in this study. Samples fermented for shorter fermentation times generally clustered together and the same was observed for those fermented for relative longer times, with temperature also playing a significant role. An additional PC-3 contributed 6% to the variation, bringing the total variation of the PCs to 94% and effectively differentiated samples fermented at 27 °C (for 48, 72 hr) from *ting* obtained at 34 °C for 60 hr (Figure 4b).

The loadings plot (Figure 4b) revealed that peaks at 2,900, 2,850, and 1,740 cm^{-1} largely contributed to the grouping of *ting* fermented at 27 °C (for 48, 72 hr) and 34 °C for 60 hr (Figure 4c). As observed from Figure 4d, the peak around 3,300 cm^{-1} was the major contributor to the discrimination of samples fermented at 20 °C, while peaks at 1,007 and 930 cm^{-1} influenced samples fermented at 34 °C for 36 hr. The cluster analysis (CA) presented as a dendrogram in Figure 4e, shows three-defined clusters, grouped in terms of sample similarity, and followed patterns of the PCA.

4 | CONCLUSIONS

Using a Doehlert RSM approach, this study investigated the effects of fermentation variables on some selected parameters, that is, pH, titratable acidity, microbial count, tannin content, total phenolic content,

total flavonoid content, and antioxidant activity. Numerical optimization of factors for the fermentation process established that optimal processing temperature and time condition for *ting* production was 34 °C for 24 hr. At these conditions, maximal phenolic, tannin, flavonoid contents, and antioxidant activity were derived, complemented with good microbial growth, reduced pH, and high production of organic acids. The reduced pH and high TTA levels at this optimal condition, would extend shelf life and preserve the *ting* better. Physicochemical characterization of *ting* first reported in this study, showed slight changes in the microstructure and similarity in the diffraction pattern of the differently obtained *ting* samples. FTIR analysis further confirmed the presence of different functional groups, while chemometric analysis effectively showed differentiation and variations in *ting* samples analyzed. Results from this study will be beneficial for the production of high quality *ting* for subsequent consumption.

ACKNOWLEDGMENTS

This work was financially supported via the Global Excellence and Stature (GES) Fellowship of the University of Johannesburg (UJ) granted to the main author (Adebo, O.A). This work was also partly supported by the National Research Foundation (NRF) Center of Excellence (CoE) in Food Security co-hosted by the University of Pretoria (UP) and the University of the Western Cape (UWC), South Africa. Special thanks to Mrs. Nomsa Baloyi, Miss Patience and Mr. Edward Malenga of the Mineral Processing and Technology Research Centre, University of Johannesburg for assistance with FTIR, SEM and XRD analysis.

ORCID

Oluwafemi Ayodeji Adebo http://orcid.org/0000-0002-3757-5137

REFERENCES

Adebiyi, J. A., Obadina, A. O., Adebo, O. A., & Kayitesi, E. (in press). Fermented and malted millet products in Africa: Expedition from traditional/ethnic foods to industrial value added products. *Critical Reviews in Food Science & Nutrition*. Retrieved from https://doi.org/10.1080/10408398.2016.1188056

Adebiyi, J. A., Obadina, A. O., Mulaba-Bafubiandi, A. F., Adebo, O. A., & Kayitesi, E. (2016). Effect of fermentation and malting on the microstructure and selected physicochemical properties of pearl millet (*Pennisetum glaucum*) flour and biscuit. *Journal of Cereal Science*, *70*, 132–139.

Ainsworth, E. A., & Gillespie, K. M. (2007). Estimation of total phenolic content and other oxidation substrates in plant tissues using Folin-Ciocalteu reagent. *Nature Protocols*, *2*, 875–877.

Adiana, M. A., & Mazura, M. P. (2011). Study on *Senna alata* and its different extracts by Fourier transform infrared spectroscopy and two-dimensional correlation infrared spectroscopy. *Journal of Molecular Structures*, *991*, 84–91.

Amadou, I., Gounga, M. E., Shi, Y. H., & Le, G. W. (2014). Fermentation and heat moisture treatment induced changes on the physicochemical properties of foxtail millet (*Setaria italica*) flour. *Food and Bioproducts Processing*, *92*, 38–45.

Ar-Farsi, M. A., & Lee, C. Y. (2008). Optimization of phenolics and dietary fibre extracts from date seeds. *Food Chemistry*, *108*, 977–985.

Awika, J. M., & Rooney, L. W. (2004). Sorghum phytochemicals and their potential impact on human health. *Phytochemistry*, *65*, 1199–1221.

Awika, J. M., Rooney, L. W., Wu, X., Prior, R. L., & Zevallos, L. C. (2003). Screening methods to measure antioxidant activity of sorghum (*Sorghum bicolor*) and sorghum products. *Journal of Agricultural and Food Chemistry*, *51*, 6657–6662.

Beta, T., Rooney, L. W., Marovatsanga, L. T., & Taylor, J. R. N. (2000). Effect of chemical treatments on polyphenols and malt quality in sorghum. *Journal of Cereal Science*, *31*, 295–302.

Desobgo, Z. S. C., Stafford, R. A., & Metcalfe, D. J. A. (2015). Dimethyl sulfide stripping behavior during wort boiling using response surface methodology. *Journal of the American Society of Brewing Chemists*, *73*, 84–89.

Duodu, K. G., Tang, H., Grant, A., Wellner, N., & Belton, P. S. (2001). FTIR and solid state ^{13}C NMR spectroscopy of proteins of wet cooked and popped sorghum and maize. *Journal of Cereal Science*, *33*, 261–269.

Ferreira, S. L. C., dos Santos, W. N. L., Quintella, C. M., Neto, B. B., & Bosque-Sendra, J. M. (2004). Doehlert matrix: A chemometric tool for analytic chemistry–review. *Talanta*, *63*, 1061–1067.

Filli, K. B., Nkama, I., Jideani, V. A., & Abubakar, U. M. (2011). Application of response surface methodology for the study of composition of extruded millet-cowpea mixtures for the manufacture of fura: A Nigerian food. *African Journal of Food Science*, *5*, 884–896.

Kayitesi, E., de Kock, H. L., Minnaar, A., & Duodu, K. G. (2012). Nutritional quality and antioxidant activity of marama–sorghum composite flours and porridges. *Food Chemistry*, *131*, 837–842.

Madoroba, E., Steenkamp, E. T., Theron, J., Huys, G., Scheirlinck, I., & Cloete, T. E. (2009). Polyphasic taxonomic characterization of lactic acid bacteria isolated from spontaneous sorghum fermentations used to produce *ting*, a traditional South African food. *African Journal of Biotechnology*, *8*, 458–463.

Madoroba, E., Steenkamp, E. T., Theron, J., Scheirlinck, I., Cloete, T. E., & Huys, G. (2011). Diversity and dynamics of bacterial populations during spontaneous sorghum fermentations used to produce *ting*, a South African food. *Systematic and Applied Microbiology*, *34*, 227–234.

Meroth, C. B., Hammes, W. P., & Hertel, C. (2003). Identification and population dynamics of yeasts in sourdough fermentation processes by PCR-denaturing gradient gel electrophoresis. *Applied Environmental Microbiology*, *69*, 7453–7461.

Njobeh, P. B., Dutton, M. F., Kock, S. H., Chuturgoon, A., Stoev, S., & Seifert, K. (2009). Contamination with storage fungi of human food from Cameroon. *International Journal of Food Microbiology*, *135*, 193–198.

Nyambane, B., Thari, W. M., Wangoh, J., & Njage, P. M. K. (2014). Lactic acid bacteria and yeasts involved in the fermentation of *amabere amaruranu*, a Kenyan fermented milk. *Food Science & Nutrition*, *2*, 692–699.

Price, M. L., Van Scoyoc, S., & Butler, L. G. (1978). A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. *Journal of Agricultural and Food Chemistry*, *26*, 1214–1218.

Sekwati-Monang, B., & Gänzle, M. G. (2011). Microbiological and chemical characterization of *ting*, a sorghum-based sourdough product from Botswana. *International Journal of Food Microbiology*, *150*, 115–121.

Sinelli, N., Spinardi, A., Di Egidio, V., Mignani, I., & Casiraghi, E. (2008). Evaluation of quality and nutraceutical content of blueberries (*Vaccinium corymbosum* L.) by near and mid-infrared spectroscopy. *Postharvest Biology and Technology*, *50*, 31–36.

Sobowale, S. S., Adebiyi, J. A., & Adebo, O. A. (in press). Optimization of blanching and frying conditions of deep-fat fried bonga fish (*Ethmalosa fimbriata*). *Journal of Food Process Engineering*. Retrieved from https://doi.org/10.1111/jfpe.12551

Svensson, L., Sekwati-Monang, B., Lutz D. L., Schieber, A., & Gänzle, M. G. (2010). Phenolic acids and flavonoids in nonfermented and fermented red sorghum (*Sorghum bicolor* (L.) Moench). *Journal of Agricultural and Food Chemistry*, *58*, 9214–9220.

Taylor, J. R. N., & Duodu, K. G. (2015). Effects of processing sorghum and millets on their phenolic phytochemicals and the implications of this to the health-enhancing properties of sorghum and millet food and beverage products. *Journal of the Science of Food and Agriculture*, *95*, 225–237.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Adebo OA, Njobeh PB, Mulaba-Bafubiandi AF, Adebiyi JA, Desobgo ZSC, Kayitesi E. Optimization of fermentation conditions for *ting* production using response surface methodology. *J Food Process Preserv.* 2018;42:e13381. https://doi.org/10.1111/jfpp.13381

Résumé de l’article

Optimization of fermentation conditions for ting production using response surface methodology

Oluwafemi Ayodeji Adebo, Patrick Berka Njobeh, Antoine Floribert Mulaba-Bafubiandi, Janet Adeyinka Adebiyi, **Zangué Steve Carly Desobgo,** Eugenie Kayitesi

Abstract

This study investigated the effect of fermentation conditions (time and temperature) of sorghum on the composition of ting, using the Doehlert design of response surface methodology (RSM). Fermentation temperature and time were optimized and pH, titratable acidity (TTA), total viable bacteria count (TBC), total lactic acid bacteria count (TLABC), total fungal and yeast count (TFYC), tannin content (TNC), total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activities (AA) were determined. Experimental and predicted values obtained were similar, with statistical indices indicating the validity of the models generated (R^2 between 93.45 and 99.71%, AAD values close to 0, B_f and A_f values close to 1). Numerical multi-response optimization of parameters suggested optimal fermentation conditions to be 34 °C for 24 hr. Physicochemical characterization of ting samples using scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier Transform Infrared Spectroscopy (FTIR) showed slight changes in morphology, similarity in diffraction patterns and presence of different functional groups, respectively. Results of this study could provide information for the commercialization of quality ting.

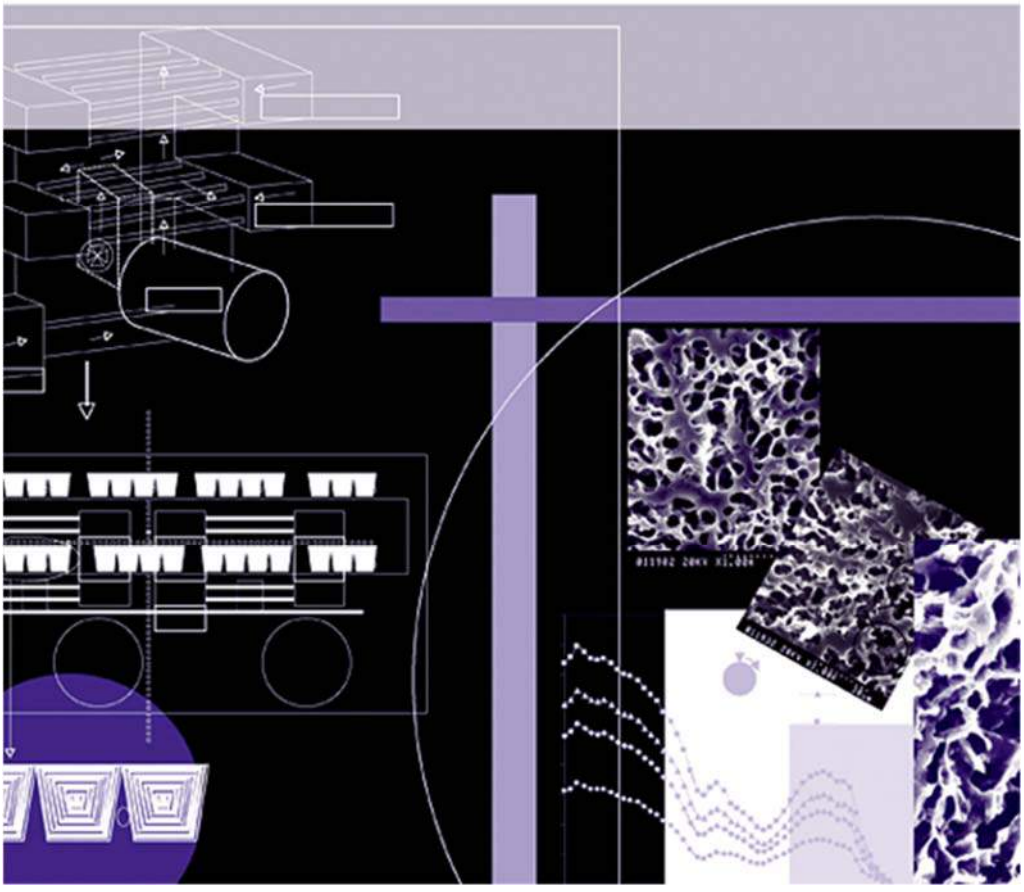
IV.4.12) Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice

Titre de la revue

ISSN 0260-8774

ELSEVIER

journal of food engineering



Comité de lecture

JOURNAL OF FOOD ENGINEERING

The journal publishes original research and review papers on any subject at the interface between food and engineering, particularly those of relevance to industry, including:
– engineering properties of foods, food physics and physical chemistry;
– processing, measurement, control, packaging, storage and distribution;
– engineering aspects of the design and production of novel foods and of food service and catering;
– design and operation of food processes, plant and equipment;
– economics of food engineering, including the economics of alternative processes.
Accounts of food engineering achievements are of particular value.

Editor-in-Chief

PROFESSOR R. PAUL SINGH
Professor of Food Engineering, Department of Biological and Agricultural Engineering,
2042 Bainer Hall, University of California, One Shields Ave, Davis
CA 95616, USA

Editors

PROFESSOR BHESH BHANDARI
School of Land and Food Sciences,
The University of Queensland, Brisbane
QLD 4072, Australia

DR MUKUND V. KARWE
Department of Food Science School of
Environmental and Biological Sciences
Rutgers, The State University of New Jersey
65 Dudley Road, New Brunswick
NJ 08901-8520, USA

DR JUDITH EVANS
Food Refrigeration & Process
Engineering Research Centre
University of Bristol,
Churchill Building, Langford,
Bristol BS40 5DU, UK

PROFESSOR KESHAVAN NIRANJAN
Department of Food Biosciences,
University of Reading, Whiteknights,
Reading RG6 6AP, UK

DR MILAN HOUSKA
Department of Food Engineering
Food Research Institute Prague, Radiova 7,
102 31 Prague 10, Czech Republic

PROFESSOR HOSAHALLI S. RAMASWAMY
Department of Food Science and
Agricultural Chemistry
Macdonald Campus, McGill University
21, 111 Lakeshore, Ste. Anne de Bellevue,
Quebec, Canada, H9X 3V9

Editorial Board

J.D. Aguilera
Universidad Catolica de Chile, Santiago, Chile

H. Chen
USDA/CSREES, Washington, DC, USA

M. Cheryan
University of Illinois, Urbana, USA

V. Davidson
University of Guelph School of Engineering, Guelph, Canada

F. Erdogdu
Mersin University, Mersin, Turkey

M. Farid
University of Auckland, New Zealand

K. Fikiin
Technical University of Sofia, Bulgaria

P. Fito
Polytechnic University of Valencia, Valencia, Spain

P.J. Fryer
School of Chemical Engineering, University of Birmingham, UK

R. Hartel
University of Wisconsin, Madison, USA

L. Levine
Levine & Associates Inc, Plymouth, USA

P. Lewicki
Laboratory of Food Engineering and Machinery, Warsaw, Poland

R. Mascheroni
Universidad Nacional de la Plata, Argentina

K.L. McCarthy
University of California, Davis, CA, USA

B. McKenna
University College Dublin, Ireland

G.S.V. Raghavan
McGill University, Ste Anne De Bellevue, Canada

S. Saguy
Hebrew University of Jerusalem, Rehovot, Israel

G. Schleining
University of Natural Resources and Life Sciences, Vienna

E.P. Scott
Virginia Polytechnic Institute, Blacksburg, USA

C.L.M. Silva
Catholic University of Portugal, Portugal

W.E.L. Spiess
Federal Institute for Nutrition, Karlsruhe, Germany

P. Taoukis
National Technical University of Athens, Athens, Greece

F. Toldrá
Instituto de Agroquimica y Tecnologia de Alimentos, Valencia, Spain

A. Vicente
University of Minho, Portugal

J. Welti-Chanes
Instituto Tecnológico y de Estudios Superiores de Monterrey, México

Printed in the Netherlands

Table des matières

ScienceDirect

Keywords

Author name

Journal of Food Engineering

Volume

Issue

Pages

Journal of Food Engineering

SUPPORTS OPEN ACCESS

Volume 221

Pages 1-166 (March 2018)

Previous vol/issue Next vol/issue

Expand all article previews Download PDFs Export

Editorial Board
Page IFC
Download PDF

Papers

An evaluation of hyperspectral imaging for characterising milk powders
Original research article
Pages 1-10

M.T. Munir, David I. Wilson, W. Yu, B.R. Young

Purchase PDF Article preview

Wheat germ thermal treatment in fluidised bed. Experimental study and mathematical modelling of the heat and mass transfer

Original research article

Pages 11-19

Renato D. Gili, R. Martín Torrez Irigoyen, M. Cecilia Penci, Sergio A. Giner, Pablo D. Ribotta

Purchase PDF Article preview

Drying characteristics and properties of microwave – assisted spouted bed dried semi–refined carrageenan

Original research article

Pages 20-28

M. Serowik, A. Figiel, M. Nejman, A. Pudlo, ... J. Rychlicka–Rybska

Purchase PDF Article preview

Electrical impedance estimation for apple fruit tissues during storage using Cole–Cole plots

Original research article

Pages 29-34

Takashi Watanabe, Yasumasa Ando, Takahiro Orikasa, Satoshi Kasai, Takeo Shiina

Purchase PDF Article preview

Stabilization of oil-in-water-in-oil ($O_1/W/O_2$) Pickering double emulsions by soluble and insoluble whey protein concentrate-gum Arabic complexes used as inner and outer interfaces

Original research article

Pages 35-44

A.G. Estrada-Fernández, A. Román-Guerrero, R. Jiménez-Alvarado, C. Lobato-Calleros, ... E.J. Vernon-Carter

Purchase PDF Article preview

Modeling flow and heat transfer in a scraped surface heat exchanger during the production of sorbet

Original research article

Pages 54-69

Oscar Darío Hernández-Parra, Artemio Plana-Fattori, Graciela Alvarez, Fatou-Toutie Ndoye, ... Denis Flick

Purchase PDF Article preview

Study on high pressure homogenization and high power ultrasound effectiveness in inhibiting polyphenoloxidase activity in apple juice
Original research article
Pages 70-76
Francesca Bot, Sonia Calligaris, Giovanni Cortella, Stella Plazzotta, ... Monica Anese

Purchase PDF Article preview

Infrared (IR) thermography applied in the freeze-drying of gelatin model solutions added with ethanol and carrier agents
Original research article
Pages 77-87
Bárbara Jordana Gonçalves, Amanda Maria Teixeira Lago, Amanda Alvarenga Machado, Tales Márcio de Oliveira Giarola, ... Jaime Vilela de Resende

Purchase PDF Article preview

Effect of ultrasound on the preparation of resveratrol-loaded zein particles
Original research article
Pages 88-94
Qiufang Liang, Xiaofeng Ren, Xi Zhang, Ting Hou, ... Bin Xu

Purchase PDF Article preview

CFD modelling of axial mixing in the intermediate and final rinses of cleaning-in-place procedures of straight pipes
Original research article
Pages 95-105
Jifeng Yang, Bo Boye Busk Jensen, Mikkel Nordkvist, Peter Rasmussen, ... Ulrich Krühne

Purchase PDF Article preview

Improvement of rheological and functional properties of milk protein concentrate by hydrodynamic cavitation
Original research article
Pages 106-113
Krystel Li, Meng Wai Woo, Hasmukh Patel, Lloyd Metzger, Cordelia Selomulya

Purchase PDF Article preview

Stochastic modeling of the transient regime of an electronic nose for waste cooking oil classification
Original research article

Pages 114-123
A.F. Siqueira, M.P. Melo, D.S. Giordani, D.R.V. Galhardi, ... A.L.G. Ferreira

Purchase PDF Article preview

140-GHz subwavelength transmission imaging for foreign body inspection in food products
Original research article
Pages 124-131
Gyeongsik Ok, Kisang Park, Min-Cheol Lim, Hyun-Joo Jang, Sung-Wook Choi

Purchase PDF Article preview

Modelling of water transport with convection effects on amylose transfer in a swelling, eroding and gelatinizing starchy matrix
Original research article
Pages 132-140
A. Briffaz, P. Bohuon, J.M. Méot, B. Matignon-Pons, C. Mestres

Purchase PDF Article preview

Evaluation of HPCD batch treatments on enzyme inactivation kinetics and selected quality characteristics of cloudy juice from *Golden delicious* apples
Original research article
Pages 141-150
A.E. Illera, M.T. Sanz, S. Beltrán, R. Melgosa, ... M.O. Ruiz

Purchase PDF Article preview

Determination of thermal diffusivity of persimmon flesh tissue using three-dimensional structure model based on X-ray computed tomography
Original research article
Pages 151-157
Fumihiko Tanaka, Keitaro Imamura, Fumina Tanaka, Toshitaka Uchino

Purchase PDF Article preview

Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice
Original research article
Pages 158-166
Kombele Aimé Ninga, Sourav Sengupta, Amit Jain, Zangué Steve Carly Desobgo, ... Sirshendu De

Purchase PDF Article preview

Short Communication

511

Microwave popping characteristics of paddy as affected by sample placement and geometry and process optimization

Pages 45-53

Moirangthem Kalpana Devi, Susanta Kumar Das

Purchase PDF Article preview

ISSN: 0260-8774

Copyright © 2018 Elsevier Ltd. All rights reserved

ELSEVIER About ScienceDirect Remote access Shopping cart Contact and support Terms and conditions Privacy policy

Cookies are used by this site. For more information, visit the cookies page.

Copyright © 2018 Elsevier B.V. or its licensors or contributors. ScienceDirect ® is a registered trademark of Elsevier B.V.

RELX Group™

Pages de l’article

Journal of Food Engineering 221 (2018) 158–166

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice

Kombele Aimé Ninga [a], Sourav Sengupta [b], Amit Jain [b], Zangué Steve Carly Desobgo [a], Emmanuel Jong Nso [a], Sirshendu De [b, *]

[a] Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455, Adamaoua, Cameroon
[b] Department of Chemical Engineering, Indian Institute of Technology, Kharagpur 721 302, India

ARTICLE INFO

Article history:
Received 9 April 2017
Received in revised form
4 August 2017
Accepted 26 October 2017
Available online 30 October 2017

Keywords:
Guava juice
Pectin
Pectinase
Non-Michaelis-Menten
Allosteric effects

ABSTRACT

The objective of the current study is to investigate the hydrolysis of pectinaceous matter in guava juice and to model the depectinization kinetics using commercial pectinase from *Aspergillus niger*. The procedure involves enzymatic treatment of guava juice at 45 °C with enzyme concentration (% w/w) 0.033, 0.055, 0.078 and 0.1. The degree of hydrolysis of pectinaceous matter and the rate of enzymatic reaction are determined. The results show an increase in the degree of hydrolysis with time for each enzyme concentration. Depectinization kinetics reveal allosteric behavior and is modeled using the Hill Equation. The image analysis of the sample using field emission scanning electron microscopy shows a change in the smoothness and homogeneity of the sample, indicating degradation of pectin network.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Guava (*Psidium guajava*), belonging to family *Myrtaceae* and genus *Psidium*, is a tropical plant native to Mexico and available throughout South America, Asia, Europe, and Africa. It is one of the most cultivated fruit crops in many tropical and subtropical countries. The fruits contain large amount of vitamins and minerals, having high levels of polyphenolic antioxidants (referred to as "superfruits" in the popular literature because of their high antioxidant capacity). Guava contains flavonoids, triterpenoids, and other biologically active secondary compounds (Flores et al., 2015). It contains high concentration of vitamin C (100–200 mg/100 g), more than fresh orange juice (60–80 mg/100 g) (Akesowan and Choonhahirun, 2013).

Guava is extremely perishable, having shelf life of only two days at room temperature (Teixeira et al., 2016). Therefore, it is usually consumed as fresh, or processed into various commercial products including pulp, squash, nectar, puree, paste, canned slices in syrup and juice. Out of these, the juice has become economically important because of its high nutritional values, making it an alternative to other beverages such as carbonated and caffeinated drinks (tea and coffee) (Akesowan and Choonhahirun, 2013; Lee et al., 2006). In addition, guava juice is also used for the production of fruit wine by fermentation (Sevda and Rodrigues, 2011).

Guava juice contains colloids that are mainly polysaccharides (pectin, cellulose, hemicellulose, and lignin), protein, and tannins. These particles can settle during storage, leading to heterogeneity of the juice. Pectin makes the juice clarification difficult, as it is generally associated with plant polymers and cell debris having fiber-like molecular structure, thereby creating fouling during filtration. Presence of pectin makes the guava juice viscous and turbid (Liew Abdullah et al., 2007; McCook-Russell et al., 2012; Rai et al., 2004). Pectic polysaccharides are polygalacturonate molecules, in which 1–4-*d*-galacturonic acid chains are linked with branches of l-rhamnopyranosyl residues, and neutral side chains of L-arabinose, D-galactose and D-xylose. These are the major components of cell wall and middle lamella of plant tissues. Pectin undergoes structural changes during development and ripening of the fruits, thereby contributing significantly to textural softening of ripening fleshy fruits (Das and Majumdar, 2010). Pectin content of ripened guava ranges from 0.58%–0.66% (Surajbhan et al., 2012).

Viscosity and turbidity of guava juice can be decreased by enzymatic depectinization, degrading pectin and polysaccharides. Pectinase hydrolyzes pectin and causes pectin–protein complexes to flocculate, so that the resultant juice has much lower pectin and viscosity, facilitating the subsequent filtration process. Enzymatic hydrolysis of pectic substances depends on several operating

* Corresponding author.
E-mail address: sde@che.iitkgp.ernet.in (S. De).

https://doi.org/10.1016/j.jfoodeng.2017.10.022
0260-8774/© 2017 Elsevier Ltd. All rights reserved.

factors such as enzyme concentration, incubation time and temperature (Lee et al., 2006). In most cases, pH is not taken as a parameter, as the hydrolysis is done at the natural pH of the fruit juice.

There has been study exploring the kinetics of enzymatic hydrolysis of pure pectin in general (Bélafi-Bakó et al., 2007). In addition, some studies exist on kinetics of depectinization of juice extracted from various fruits, like, apple, red currant, black currant, sugar beet, passion (Kiss et al., 2008; Klinchongkon et al., 2017). But, in all these studies, pectin was isolated from their sources before investigating on kinetics of hydrolysis. Hydrolysis kinetics of these extracted pectins as well as pure pectin showed Michaelis-Menten type behavior. In a practical industrial setting, extraction of pectin from the fruit juice and their hydrolysis become unnecessarily complex and cost intensive. Thus, in a real life scenario, depectinization needs to be undertaken on actual fruit juice. However, in case of depectinization of actual guava juice, pectin hydrolysis becomes complicated in presence of other polysaccharides, like, cellulose, hemicellulose, lignin, etc. These compounds may accelerate or inhibit the hydrolysis reaction. These complex interactions were not accounted in the previous studies (Bélafi-Bakó et al., 2007; Kiss et al., 2008; Klinchongkon et al., 2017). Based on these complex interactions, the hydrolysis of pectin molecules may or may not exhibit hyperbolic behavior, as described by the Michaelis-Menten kinetics. Researchers have studied depectinization in real life fruit juices (Akesowan and Choonhahirun, 2013; Kaur et al., 2009, 2011; Lee et al., 2006; Liew Abdullah et al., 2007; Rai et al., 2004; Surajbhan et al., 2012) as well, but they analyzed the system using response surface methodology to obtain the optimum operating conditions. Response surface methodology is a black box method fitting a polynomial equation to the experimental data, without providing any insight on fundamental understanding of depectinization kinetics. Baş and Boyaci (2007) reported that response surface methodology is not a suitable tool to predict the rate of enzyme reaction kinetics, as the generated model is inadequate and kinetic parameters of the enzyme lack high accuracy.

As mentioned, response surface based analyses did not elicit the underlying reaction mechanism, nor they established reaction kinetics, that is mandatory to design a reactor successfully. This has been attempted in present study and herein lies the novelty of the present work. To the best of knowledge of the authors, reports on the reaction mechanism of depectinization of actual guava juice are rare in literature. Therefore, the objective of the current work is to study the kinetics of the decay of pectinaceous substances during the enzymatic treatment of guava juice along with possible mechanism, and interpret the optimum operating conditions of depectinization.

2. Materials and methods

2.1. Materials

Guava fruits (*Psidium guajava*), used for the experiments, were purchased from local market in Kharagpur, West Bengal, India. They were selected based on their maturity and ripeness.

2.1.1. Enzymes and other chemicals

The list of enzymes and other chemicals used in the present study are:

Pectinase (isolated from *Aspergillus niger,* activity: 8000–12000 U/g); bovine serum albumin; pectin; sodium potassium tartrate; gallic acid; D-galacturonic acid monohydrate; 2,2-Diphenyl-1-picrylhydrazyl (DPPH); copper sulfate pentahydrate ($CuSO_4.5H_2O$); Folin Ciocalteu's phenol reagent. All chemicals were of analytical grade.

2.2. Methods

2.2.1. Guava juice extraction

The guava fruits of proper maturity and ripeness were washed using tap water, rinsed, trimmed to remove blemishes, cut in small pieces and deseeded manually by using a 16-mesh sieve. Based on preliminary studies, a bulk solution of the guava pulp was prepared by mixing the pure pulp with water at a ratio of 35% w/w. The bulk solution was blended using a food processor, packaged in plastic cans and stored in the freezer for further analysis.

2.2.2. Enzyme treatment of the pulp

The enzyme treatment of the pulp was performed following the protocol described by Akesowan and Choonhahirun (2013), with some modifications. The guava pulp was thawed before use, and 100 g of pulp was weighed in a 250 mL beaker. Literature survey reveals that most of the earlier studies for enzyme hydrolysis were performed for enzyme concentration up to 0.1% (Lee et al., 2006; Liew Abdullah et al., 2007). For enzymatic treatment of banana juice (Lee et al., 2006) and carambola fruit juice (Liew Abdullah et al., 2007), optimum enzyme concentrations were 0.084%, and 0.1% respectively. Hence, in the current study, four enzyme concentrations of 0.033%, 0.055%, 0.078% and 0.1% w/w were considered.

The preliminary study with 0.033%, 0.055%, 0.078% and 0.1% w/w of enzyme dose at 25 ± 2, 45 ± 2 and 55 ± 2 °C revealed 45 ± 2 °C as the temperature of optimal activity. Therefore, further experiments were conducted at 45 ± 2 °C. The beaker was put in a water bath at this temperature for 5 min under continuous stirring. Dried enzyme extract was added in each sample at different ratios (0.033%, 0.055%, 0.078% and 0.1% w/w of initial guava pulp). The mixture was then stirred using a Remi Motor agitator, type RQ 122 (supplied by Elektrotechnik Ltd, Kolkata, India) at 1500 rpm. For each enzyme concentration, different incubation times were applied (3, 5, 8, 12, 15, 18, 20, 40, 60, 80 and 90 min). After completion of respective incubation times, the mixture was transferred into a glass sampling bottle. The bottle was put in a boiling water bath (95 °C) and allowed to stand for 5 min to inactivate the enzymes. The mixture was cooled and filtered by a cheese cloth. The filtrate was collected and kept in polyethylene terephthalate (PET) bottles, and stored in the freezer for further analysis. The experiments were performed in triplicate. For each sample, the following parameters were analyzed: viscosity, pH, total soluble sugar (TSS), color, antioxidant activity and concentration of pectin, total polyphenol, protein and reducing sugar.

2.3. Analysis

2.3.1. Viscosity

The viscosity of guava juice was determined at room temperature (30 ± 1 °C), as described by Jain and De (2016), using an Oswald capillary viscometer (Pisco, Kolkata, India).

2.3.2. pH and total soluble sugar (TSS)

pH was determined using a multimeter pocket tester (EUTECH Instruments Ltd, Singapore). TSS was estimated using an ABBE type refractometer (Excel International, Kolkata, India).

2.3.3. Color

The color of guava juice was determined by measuring the absorbance at 420 nm, using a UV-VIS spectrophotometer (M/s Perkin Elmer, Connecticut, USA).

2.3.4. Pectin concentration

Pectin was extracted from guava juice following the protocol

described by Masmoudi et al. (2008) with some modifications. Pectin was precipitated by adding 15 mL of 96% w/w ethanol to 10 mL of guava juice under agitation. The obtained mixture was kept in the refrigerator overnight at 10 °C, and the pectin gels were centrifuged at 10,000 rpm for 15 min. The supernatant was collected in PET sampling bottles and stored in the freezer for further analysis. To remove the mono and disaccharides, the pectin precipitate was washed thrice with 50%, 75% and 96% v/v ethanol, and centrifuged at 10,000 rpm for 10 min at room temperature. Pectin concentration of guava juice samples was determined using carbazole method developed by McComb and McCready (1952) with some modifications. Firstly, the pectinaceous matters remaining in the centrifuge tubes were collected and dissolved in 0.05 N NaOH solution, and then the volume was made up to 100 mL. The samples were then allowed to stand for 30 min to de-esterify the pectin. 6 mL of H_2SO_4 was introduced in test tubes and the test tubes were cooled to 3 °C in an ice bath. Thereafter, 1 mL of the sample was added and the mouth of the test tube was covered. The tubes were heated for 10 min in a boiling-water bath, and then allowed to cool at room temperature. After that, 0.5 mL of 0.15% w/v carbazole reagent was added. The mixture was allowed to stand for 25 ± 5 min, and the transmittance was measured at 520 nm using a spectrophotometer (M/s Perkin Elmer, Connecticut, USA). Pectin concentration was calculated according to the calibration curve obtained using galacturonic acid monohydrate standard. The degree of hydrolysis of pectinaceous matters was determined using the following equation:

$$\textit{Degree of hydrolysis}\ (\%) = \frac{[S]_{t=0} - [S]_t}{[S]_{t=0}} \times 100 \quad (1)$$

where, $[S]$ is the pectin concentration and t is the time. The rate of reaction was also determined using the following equation:

$$\textit{Rate of reaction}\ (\text{mg/L.min}),\ v = \frac{[S]_i - [S]_{i-1}}{t_i - t_{i-1}} \quad (2)$$

The rate of reaction (v) was plotted against pectin concentration, and it was modeled using Hill Equation (Marangoni, 2003). The use of Hill equation can be explained by the fact that the plot of reaction rate with pectin concentration describes a sigmoidal pattern, instead of the hyperbolic one typically exhibited by Michaelis-Menten behavior. It was observed that fitting the data with Michaelis-Menten equation gave a poor match, with R^2 values much less than 1. Thus, an attempt was made to have a detailed understanding of the mechanism that makes the current system deviate from usual Michaelis-Menten kinetics.

The Hill equation is given as

$$v = \frac{V_{\max}[S]^n}{K + [S]^n} \quad (3)$$

where $V_{\max}$ and n refer to the maximum reaction rate and Hill coefficient, respectively. K is expressed as $K = [S_{50}]^n$, where $[S_{50}]$ is the substrate concentration at which the reaction rate is half of its maximum value, i.e., $v = V_{\max}/2$. For each enzyme concentration, the values of the $V_{\max}$ and n were obtained by minimizing the sum of squares at each experimental data, using MATLAB 2014b. The sum of squares is presented as,

$$s = \sum_{i=1}^{N} \left(\frac{v_{\exp,i} - v_{sim,i}}{v_{\exp,i}} \right)^2 \quad (4)$$

where, $v_{\exp,i}$ and $v_{sim,i}$ are the experimental and simulated values of the rate of reaction at i-th time point.

2.3.5. Total polyphenol

Total polyphenol was measured using modified Folin and Ciocalteu method (Sagu et al., 2014). The results were expressed as mg of gallic acid equivalents per 100 mL.

2.3.6. Protein concentration

The protein concentration of the guava juice was determined according to the method developed by Lowry et al. (1951) using bovine serum albumin as standard.

2.3.7. Reducing sugar

The reducing sugar concentration of guava juice was estimated using cyanoacetamide method as described in the International Oenological Codex (2012), with some modifications. 2 mL of the supernatant (section 2.3.4) was introduced in a 100 mL volumetric flask and distilled water was added up to 100 mL. 2 mL of this diluted sample was mixed with 4 mL of cold borate buffer (100 mM, pH 9.0) and 2 mL of cyanoacetamide solution (1% w/v). Then, the test tube was put in boiling water bath for 10 min and cooled. After cooling, the absorbance was measured at 273 nm. The calibration curve was plotted using D-galacturonic acid (concentration ranging from 0 to 250 μg/mL) as standard.

2.3.8. Antioxidant activity

The antioxidant activity was measured using the DPPH method. The percentage of antioxidant activity ($AA\%$) of each substance was assessed by DPPH free radical assay. The measurement of the DPPH radical scavenging activity was performed according to the methodology described by Mensor et al. (2001). The scavenging activity percentage ($AA\%$) was determined as:

$$AA\ (\%) = 100 - \left[\frac{A_{sample} - A_{blank}}{A_{control}} \times 100 \right] \quad (5)$$

where, A_{sample}, A_{blank} and $A_{control}$ are the values of absorbance of the sample, blank and control, respectively.

2.4. Morphology of the samples

The samples of guava juice were spread on a microscopic glass cover (18 mm) and vacuum dried in desiccator for 10 days. The image analysis was done using Field Emission Scanning Electron Microscopy (FESEM) (JSM-7610F, JEOL, Japan). FESEM analysis was performed to assess the morphology of the structures in guava juice samples.

3. Results and discussion

3.1. Effect of process parameters on the degree of hydrolysis

For each set of process parameters (enzyme concentration and time), the degree of hydrolysis was determined to quantify the extent of degradation of the pectinaceous matters in the guava juice, and the results are presented in Fig. 1a. From the figure, it appears that for each enzyme concentration, degree of hydrolysis increases with time. For enzyme concentration 0.033% w/w, there is a continuous increase in the degree of hydrolysis with decreasing slopes. This could be explained by the fact that the pectinaceous substances were still in juice and the extent of hydrolysis is incomplete. For 0.055% w/w and 0.078% w/w enzyme concentrations, there was a sharp increase in the degree of hydrolysis up to 20 min of reaction, followed by a sluggish change. Higher rate of hydrolysis within first 20 min indicates a significant decrease in pectin concentration, with progressive accumulation of reaction products. The slight increase in the degree of hydrolysis beyond

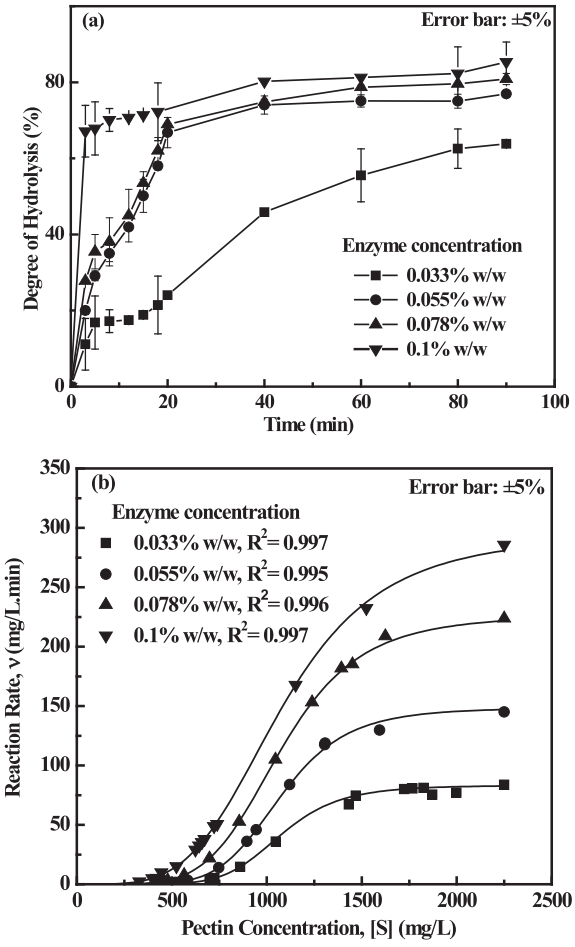


Fig. 1. (a) Degree of hydrolysis versus time for different enzyme concentrations; (b) reaction kinetics exhibited by pectinase with guava juice as the substrate for different enzyme concentrations (solid lines represent the model curves obtained from Hill equation).

20 min is due to decrease in the amount of substrates and the saturation of the reaction medium by the products formed. The same trend was observed for 0.1% w/w enzyme concentration, but the slope of the hydrolysis curve is higher in the initial stages of reaction. It is observed that the degree of hydrolysis after 5 min at 0.1% enzyme concentration is almost two folds, compared to 0.078% w/w, owing to the high enzyme concentration. Combo et al. (2012) reported an accumulation of mono, di and trimers of galacturonic acid after 5 min of hydrolysis of polygalacturonic acid using commercial pectinase from *A. niger*, thereby initiating inhibition of hydrolysis. As depicted in the figure, for 0.078% and 0.1% w/w enzyme concentration, variation of degree of hydrolysis is marginal beyond 40 min. The average difference in degree of hydrolysis between 0.078% and 0.1% enzyme concentration is 4.6%, i.e. well within the errors involved in the measurements (±5%). Hence, 0.078% w/w has been chosen as the optimal enzyme concentration. The optimal concentration of 0.078% w/w for guava juice is comparable with that of banana juice (0.084%) (Lee et al., 2006) and carambola juice (0.1%) (Liew Abdullah et al., 2007). Thus, 0.078% w/w of enzyme concentration and 40 min of treatment time can be considered as optimum one for guava juice depectinization.

3.2. Depectinization kinetics of guava pulp

Variation of the rate of reaction with pectin (i.e. the substrate) concentration for different enzyme concentrations is presented in Fig. 1b, exhibiting a sigmoidal type trend. This behavior deviates from the ideal Michaelis-Menten kinetics that was observed with pure pectin (Bélafi-Bakó et al., 2007). The deviation can be explained by the presence of some naturally occurring compounds which can act either as activators or inhibitors. The guava juice contains some sugar molecules (monomers, dimers, oligomers) originating from the maturation and ripening of guava. During maturation, insoluble protopectin molecules are degraded into monomers and oligosaccharides (Prasanna et al., 2007). These oligosaccharides have affinity with pectinase, as described below, thereby promoting an allosteric effect on the enzymes. The Hill Equation is adequate to model this phenomenon (Marangoni, 2003). Solid lines in Fig. 1b represent the model curves obtained by fitting the experimental data to Hill equation for different enzyme concentrations. The coefficient of determination (R^2) has been evaluated corresponding to each curve, in order to assess the goodness of fit, and provided in the same figure. Details regarding the values of n and V_{max} obtained from the model have been discussed later in sections 3.2.1 and 3.2.2.

The mechanism behind Hill kinetics has been illustrated in Fig. 2. The enzyme is assumed to have multiple substrates or ligand binding sites. The binding of one substrate molecule induces structural and/or electronic changes, resulting in altered substrate binding affinities in the remaining vacant sites (cooperativity) (Fig. 2a). The enzyme-substrate affinity can either increase in case of positive cooperativity, or decrease for negative cooperativity. On the other hand, binding of the substrate or non-substrate (activator or inhibitor) can affect the activity of the enzyme (allosterism) (Fig. 2b). The allosteric response can be homotropic in case of modulation of enzyme activity strictly by substrate molecules, or heterotropic for modulation of enzyme activity by non-substrate molecules or combinations of substrate and non-substrate molecules (Marangoni, 2003).

In case of polygalacturonases from *A. niger*, different possible reactions occurring on the substrate binding sites are represented in Fig. 3. Fig. 3a describes various possibilities of cleavage of a substrate molecule and the progress of depectinization. A substrate with a reduced end can be hydrolyzed at various locations of the glycosidic bond, thereby forming different products. Fig. 3b describes the case of a substrate bound to the enzyme at a precise binding site, where the catalysis occurs. One product (monomer) is released and the other one (oligomer) remains on the substrate, but the new complex formed is non-productive and exhibits an inhibition for the other substrates in the bulk. Fig. 3c describes the affinity of the substrate with a given binding site. On one hand, when the substrate is bound to the enzyme at a given binding site, the complex is non-productive and substrate inhibition takes place. On the other hand, the same substrate bound to another subsite may lead to a productive complex. Therefore, the mechanism of cleavage can be a single-attack with release of oligomers after the reaction, or multiple-attack (also known as processivity). It implies that the enzymatic hydrolysis of substrate may release one product, and the other product remains bound to the substrate, and the complex is also productive leading to release of other products (Benen et al., 1999, 2003; Pařenicová et al., 1998, 2000).

3.2.1. Effect of enzyme concentration on Hill coefficient (n)

Fig. 4a presents the effect of enzyme concentration on the Hill coefficient. The figure exhibits a decrease in the value of n from 7 to 4, as enzyme concentration is increased from 0.033% w/w to 0.1% w/w. This can explain the decrease in the extent of the sigmoidicity of the curve with enzyme concentration (Fig. 1b).

Decrease in the value of the Hill coefficient implies the reduction of cooperativity in the substrate binding process, thereby lowering

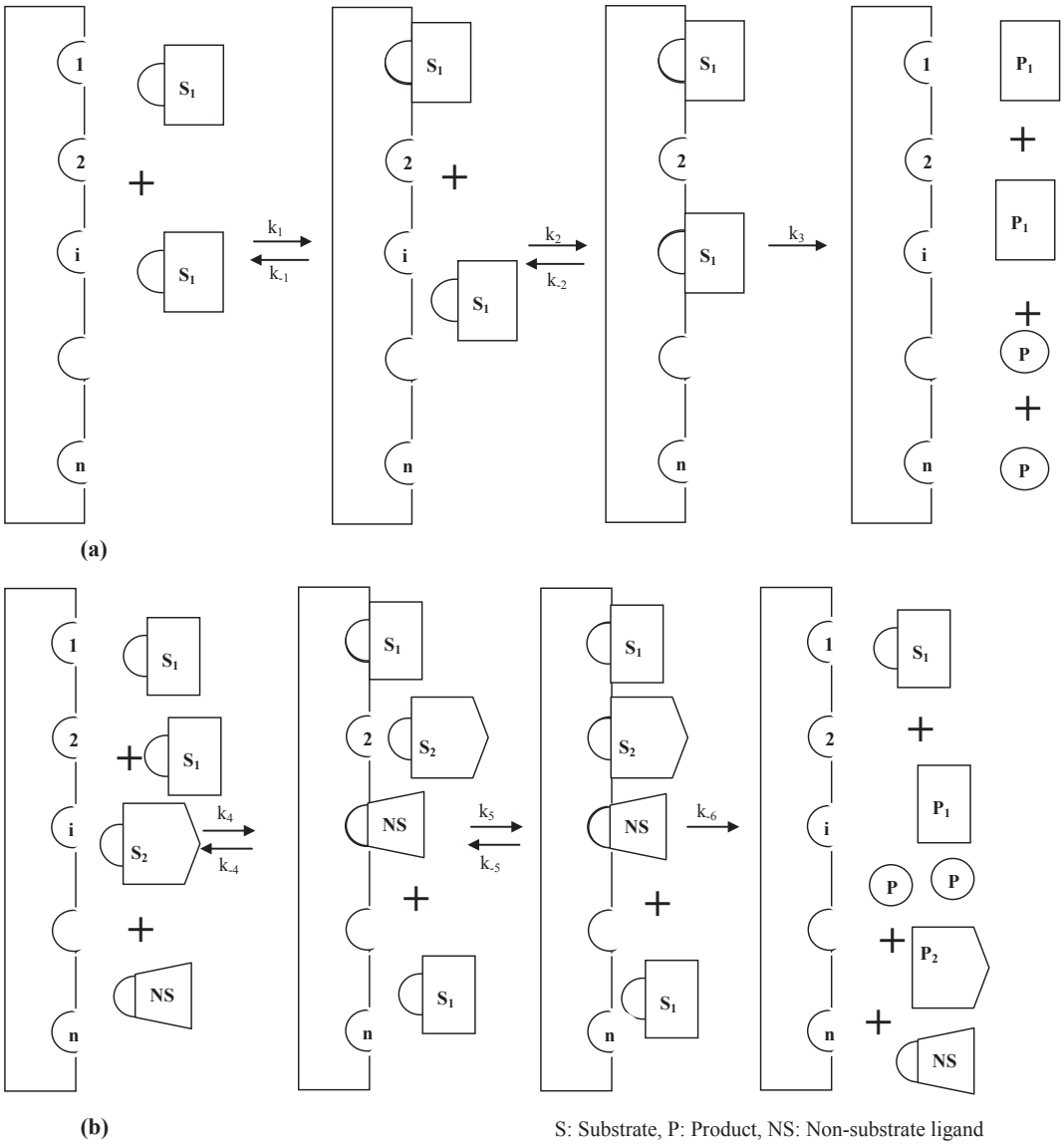


Fig. 2. Schematic for mechanism of Hill kinetics: (a) cooperativity mechanism; (b) allosteric mechanism.

the number of active substrate-binding sites with enzyme concentration (Marangoni, 2003). Decrease in the number of substrate-binding sites could be explained by the affinity between the substrate-binding sites and some oligomers as described below.

A. niger is a saprophytic filamentous fungus, having a broad arsenal of pectinolytic enzymes to break down the complex structure of pectins. The polygalacturonases from *A. niger* are known to be of endo type. The mode of action of the endopolygalacturonases consists of a random cleavage of the glycosidic bonds along the pectin chains, thereby releasing a broad range of products of different degrees of polymerization (Prasanna et al., 2007). *A. niger* possesses at least seven isoforms of polygalacturonases (PG) namely: PGI, PGII, PGA, PGB, PGC, PGD and PGE. Apart from the PGD isoform which possesses 4 binding sites (−3 to +1), the other isoforms possess at least 7 subsites suitable for the binding of the substrates. Therefore, multiple subsites are involved in the binding of the substrate due to length of the cleft found in the structure of polygalacturonases (Benen et al., 2003).

Release of large products due to random split of the pectin molecules by the isoforms of PG occurs in early stages of the reaction. These large products are degraded in course of reaction into low degree of polymerization (DP) oligoGalA (monomers, dimers, trimers etc.), until the smallest substrate is hydrolyzed. Extent of the reaction increases with enzyme concentration, increasing the rate of hydrolysis. The mechanism involved is mostly the processivity, in which a compound (usually the smallest) is released while the other one remains at the active site of the enzymes (Benen et al., 2003). Each isoform of PG has an affinity with a precise oligoGalA. PGI as well as PGA, PGC and PGD are processive enzymes with PGA and PGC being processive from DP 7 onward and PGD (the only isoform to hydrolyze dimer) from DP 4 onward. The oligoGalA can also have some preference with some binding sites. The hexamers will preferably bind to the subsites −5 to +1 with the release of pentamers that will remain bound to the subsites −5 to −1 because of their affinity to those subsites. That affinity can lead the pentamers to exhibit a competitive inhibition to the PGI when they are used as substrates (Fig. 3b). However, when they are bound to the subsites −4 to +1 or −3 to +2, the complex formed

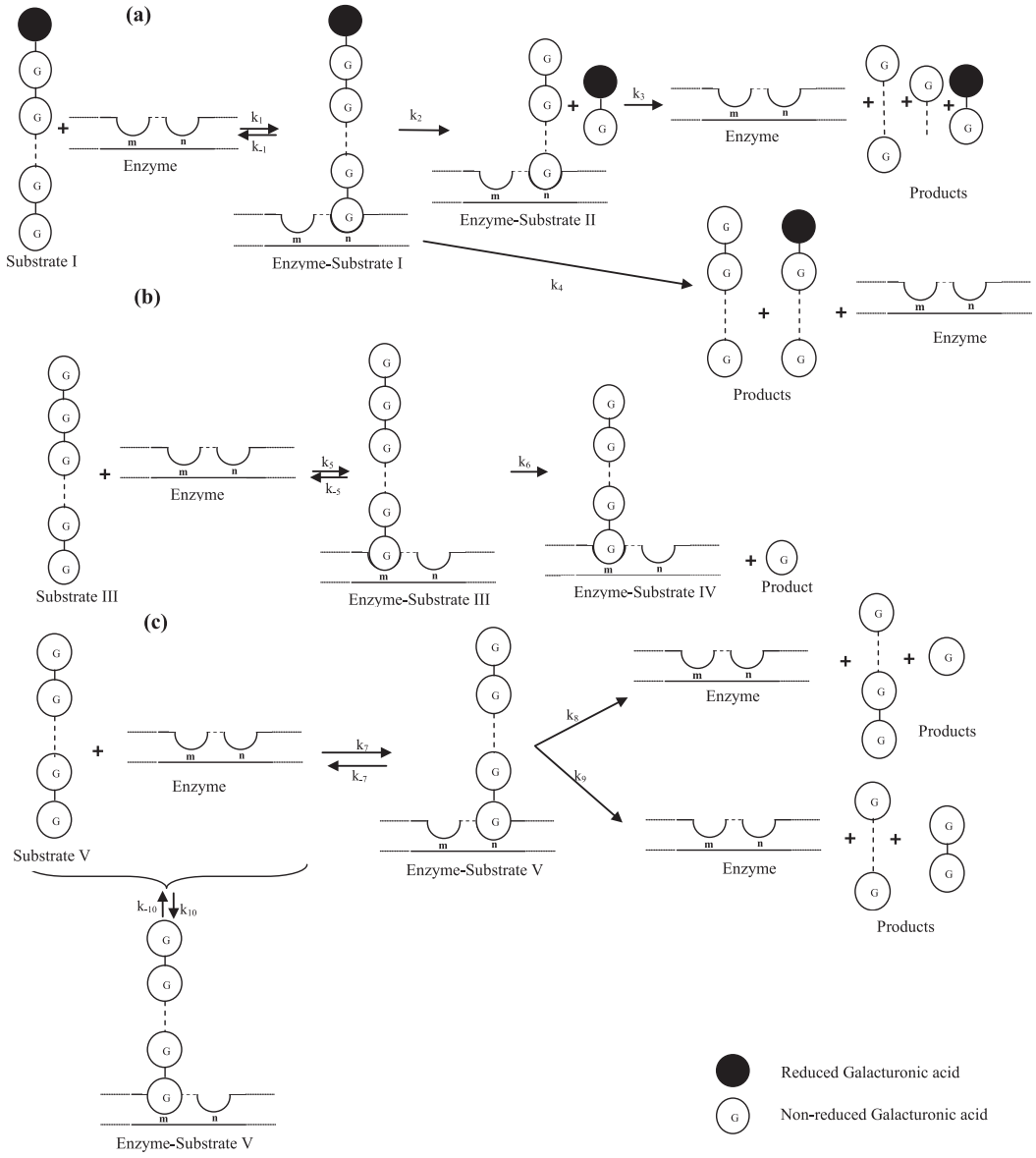


Fig. 3. Schematic for mechanism of the possible reactions taking place in the subsites of the pectinases for *A. niger* exhibiting an allosteric effect leading to the Hill Kinetics; (a) Processivity (b) Substrate Inhibition (c) Enzyme-substrate affinity with given binding sites; m and n = Substrate binding sites; k: reaction constants.

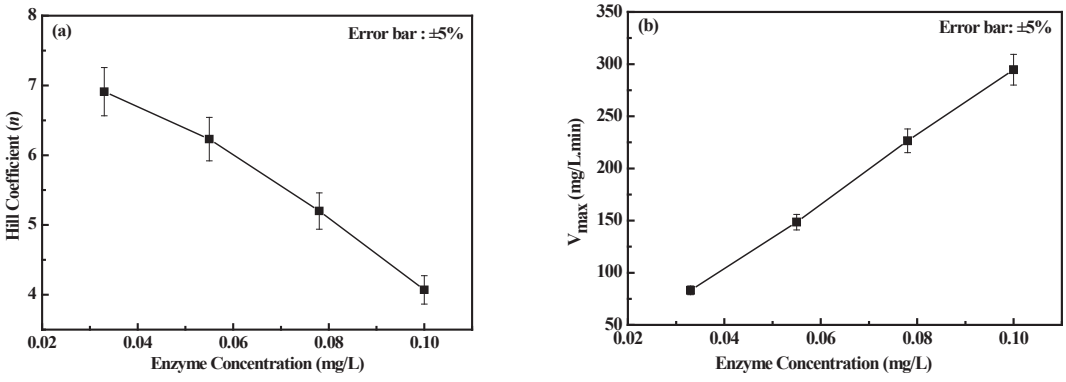


Fig. 4. Effect of enzyme concentration on (a) Hill coefficient (n); (b) maximum reaction rate (V_{max}).

will be productive with formation of products (Van Pouderoyen et al., 2003).

The trimer, which is usually the smallest substrate, will be degraded mostly at prolonged incubation time, making the hydrolysis slow (Benen et al., 2003). This could explain the decrease in the slope of degree of hydrolysis profile, at later time (40 min onwards) for each enzyme concentration (Fig. 1a).

In Hill equation, n is either equal to or less than the number of active binding sites (Marangoni, 2003). Prinz (2010) reported high values of Hill coefficient (4 and above) in the analysis of dose response curves. The current study involves the use of pectinase and it is a mixture of seven polygalacturonase isoforms, each having several binding sites known as subsites. Apart from the isoform PGD which has four subsites, the other six isoforms has at least seven subsites each (Benen et al., 1996, 2003). It is already stated that n is either equal to or less than the number of active binding sites. Thus, the value of n obtained (4–7), although seemingly high, corroborates literature data.

3.2.2. Effect of enzyme concentration on maximum rate of reaction (V_{max})

Fig. 4b presents the effect of the enzyme concentration on the value of V_{max}. There is a monotonic increase in the value of V_{max} from 83.2 mg/L.min to 294.7 mg/L.min with an increase in enzyme concentration from 0.033% w/w to 0.1% w/w. With increase in enzyme concentration, the rate of reaction increases leading to the formation of more products. Therefore, an increase in the enzyme concentration led to the increase of the maximum rate of reaction.

3.3. Effect of process conditions on other parameters of the juice

For each processing conditions (enzyme concentration, time), the following parameters were determined: viscosity, pH, TSS, color, total polyphenol, protein concentration, reducing sugar, and antioxidant activity. Table 1 shows the chemical, nutritional composition as well as the rheological parameters of raw guava juice and the sample treated after 90 min, at each enzyme concentration. It is observed that the samples undergoing enzymatic treatment exhibit higher values of reducing sugar and TSS, as compared to those of the raw sample. This is due to the fact that pectin molecules release reducing sugar during enzymatic hydrolysis. An increase in the enzyme concentration accelerates this process due to intensified degradation. Breakdown of pectin molecules causes a substantial decrease in viscosity (10% of the viscosity of raw sample). The enzymatic treatment did not show a significant effect on the antioxidant activity of the guava juice. The treated samples also underwent a decrease in protein and polyphenol concentration and pH values, similar to the findings of Sagu et al. (2014).

3.4. FESEM analysis of the samples

FESEM analysis of the samples was performed to assess the shape and structure of the particles in fruit juice as well as homogeneity of the samples on microscopic glass cover. For each enzyme concentration, the samples treated after 90 min were analyzed, and a comparison was made with the sample without enzymatic treatment. The results are shown in Fig. 5. It reveals that the guava juice without enzymatic treatment contained round-shaped particles of different sizes. Increase in enzyme concentration led to an increase in the smoothness of the surface. The image corresponding to 0.033% w/w enzyme concentration exhibits particles of different shapes at the surface. For higher enzyme concentration, homogeneity of the sample as well as smoothness of the surface was improved. This could be explained by the hydrolysis of pectin molecules resulting in disintegration of the pectin network with the release of low molecular weight products. As a result, more liquid phase was formed, spreading at the surface of the glass cover.

4. Conclusions

Kinetics of depectinization of guava juice was investigated in the present study. The optimum enzyme concentration and treatment time were 0.078% w/w and 40 min at 45 °C. The hydrolysis of pectinaceous matters was modeled using Hill equation, and the effect of enzyme concentration on Hill coefficient (n) and V_{max} was assessed. The value of n decreased with increase in enzyme concentration from 7 to 4, due to a decrease in binding sites of the enzyme. Reduction in the number of binding sites was due to allosteric effects, owing to naturally occurring compounds in the juice and the products of hydrolysis. The enzymatic treatment of the guava pulp led to an increase in the reducing sugar content of more than two folds for 0.078% and 0.1% w/w. For each enzyme concentration, viscosity decreased by 90% with enzymatic treatment. The values of pH, protein and polyphenol concentration also decreased with enzymatic treatment. FESEM images of the samples showed a change in surface morphology, indicating promotion of hydrolysis of pectin network.

Earlier studies on depectinization of pectin involved pectin isolated from fruit juice and not on the actual juice. The novelty of the present work lies in the fact that kinetic modeling of hydrolysis of the pectinaceous matters in actual guava juice was investigated in detail, providing an insight to inherent molecular mechanism. The results reveal that presence of polysaccharides in actual guava juice led to departure from the traditional Michaelis-Menten kinetics, and exhibited sigmoidal variation. On an industrial scale, depectinization needs to be undertaken on actual fruit juice itself and not the pectin extracted from it. Thus, the developed depectinization kinetic expression would help in identifying the optimum operating conditions and designing the scaled up

Table 1
Physicochemical, nutritional and rheological parameters of the raw guava juice as well as the samples treated at different enzyme concentrations at the end of 90 min.

Sample Identity	pH	TSS (Bx)	Color (A)	Protein (mg/L)	Polyphenol (mg GAE/ 100 mL)	Antioxidant activity (%)	Viscosity (mPa.s)	Reducing sugars (mg/L)
Sample-1(Enzyme conc.-0.033% w/w)	3.51 ± 0.01	2.27 ± 0.15	15.01 ± 1.09	554.3 ± 67.1	47.2 ± 4.9	94.3 ± 0.8	1.273 ± 0.04	5251 ± 91
Sample-2(Enzyme conc.-0.055% w/w)	3.34 ± 0.01	2.23 ± 0.06	13.06 ± 0.83	511.9 ± 6.7	45.9 ± 3.2	94.5 ± 1.4	1.074 ± 0.08	9534 ± 244
Sample-3(Enzyme conc.-0.078% w/w)	3.39 ± 0.01	2.07 ± 0.12	13.40 ± 0.51	514.9 ± 20.3	44.9 ± 1.6	93.8 ± 0.2	1.223 ± 0.07	12304 ± 1066
Sample-4(Enzyme conc.-0.10% w/w)	3.43 ± 0.02	2.20 ± 0.00	12.29 ± 0.34	502.4 ± 66.4	47.0 ± 4.7	95.0 ± 0.9	0.969 ± 0.01	13393 ± 5290
Raw sample	3.70 ± 0.02	1.7 ± 0.10	9.83 ± 0.32	615.7 ± 28.6	60.4 ± 0.4	94.7 ± 0.3	17.72 ± 3.18	5162 ± 216

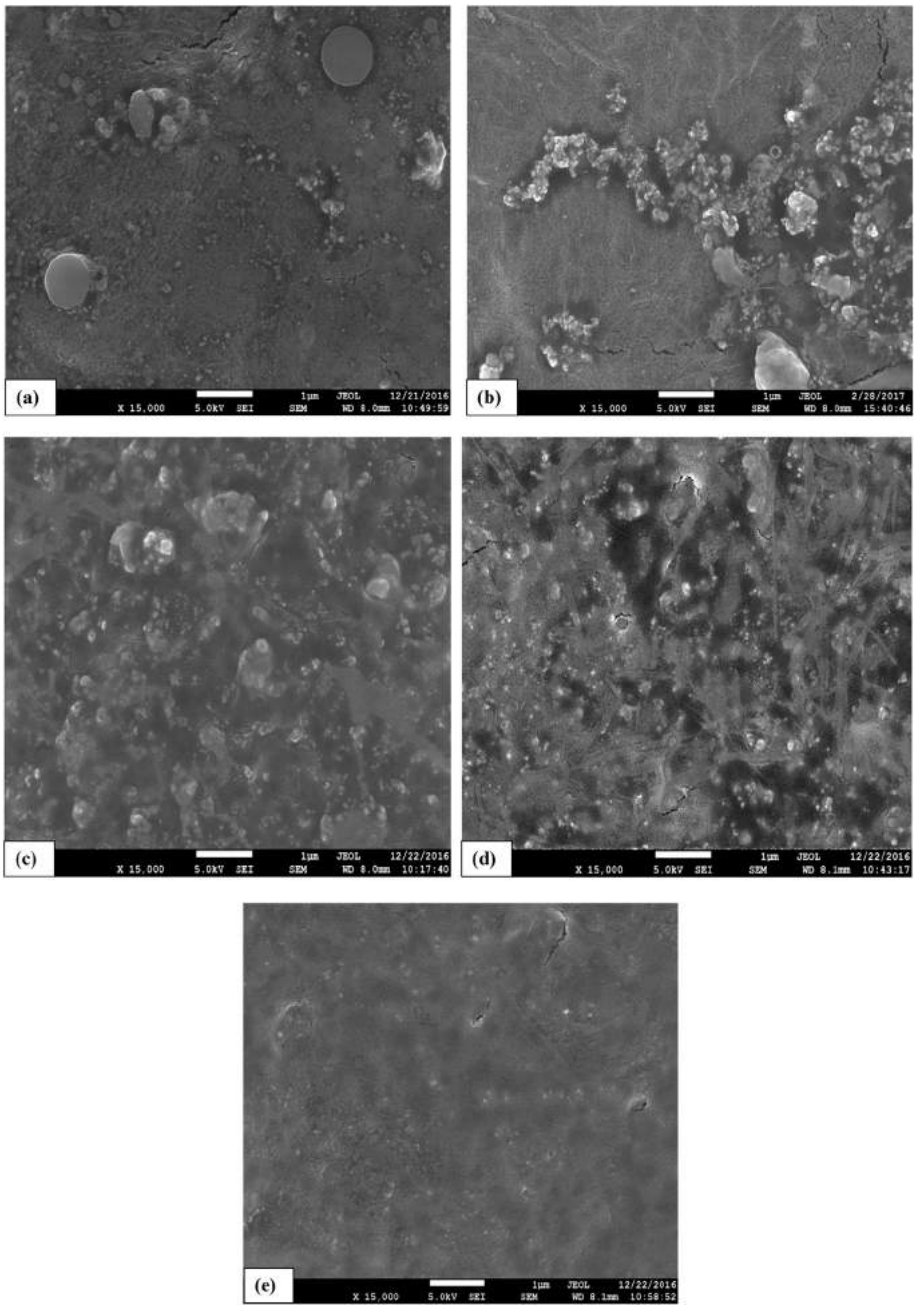


Fig. 5. FESEM images of the guava samples: (a) sample without enzymatic treatment; (b) sample treated with enzyme concentration of 0.033% w/w for 90 min; (c) sample treated with enzyme concentration of 0.055% w/w for 90 min; (d) sample treated with enzyme concentration of 0.078% w/w for 90 min; (e) sample treated with enzyme concentration of 0.1% w/w for 90 min.

reactor with fundamental understanding. Consequently, a precise knowledge of depectinization kinetics would aid in the designing and scaling up of subsequent juice clarification process equipments.

Acknowledgement

The authors acknowledge and thank The World Academy of Sciences for the advancement of science in developing countries (TWAS) and the Department of Biotechnology (DBT, India), Grant No. DBT-TWAS/CICS/332/2016 dt. 24.11.2016 for awarding the author Kombele Aimé Ninga, the DBT-TWAS Sandwich Post-graduate Fellowship Award to work at the Department of Chemical Engineering, IIT Kharagpur, West Bengal, India. Any opinions, findings and conclusions expressed in this paper are those of the authors and do not necessarily reflect the views of TWAS and/or DBT.

References

Liew Abdullah, A.G., Sulaiman, N.M., Aroua, M.K., Megat Mohd Noor, M.J., 2007. Response surface optimization of conditions for clarification of carambola fruit juice using a commercial enzyme. J. Food Eng. 81 (1), 65–71.

Akesowan, A., Choonhahirun, A., 2013. Effect of enzyme treatment on guava juice production using response surface methodology. J. Animal Plant Sci. 23 (1), 114–120.

Baş, D., Boyaci, İ.H., 2007. Modeling and optimization I: usability of response surface methodology. J. Food Eng. 78 (3), 836–845.

Bélafi-Bakó, K., Eszterle, M., Kiss, K., Nemestóthy, N., Gubicza, L., 2007. Hydrolysis of pectin by *Aspergillus niger* polygalacturonase in a membrane bioreactor. J. Food Eng. 78 (2), 438–442.

Benen, J., Parenicova, L., Kusters-van Someren, M., Kester, H., Visser, J., 1996. Molecular genetic and biochemical aspects of pectin degradation in *Aspergillus*. In: Visser, J., Voragen, A.G.J. (Eds.), Pectins and Pectinases. Elsevier, Amsterdam, The Netherlands, pp. 331–346.

Benen, J.A.E., Kester, H.C.M., Visser, J., 1999. Kinetic characterization of *Aspergillus niger* N400 endopolygalacturonases I, II and C. Eur. J. Biochem. 259 (3), 577–585.

Benen, J.A.E., van Alebeek, G.J.W.M., Voragen, A.G.J., Visser, J., 2003. Mode of action analysis and structure-function relationships of *Aspergillus niger* pectinolytic enzymes. In: Voragen, F., Schols, H., Visser, R. (Eds.), Advances in Pectin and Pectinase Research. Springer-Science+Business Media, B.V., The Netherlands, pp. 235–256.

Combo, A.M.M., Aguedo, M., Goffin, D., Wathelet, B., Paquot, M., 2012. Enzymatic production of pectic oligosaccharides from polygalacturonic acid with commercial pectinase preparations. Food Bioprod. Process. 90 (3), 588–596.

Das, A., Majumdar, K., 2010. Fractional changes of pectic polysaccharides in different tissue zones of developing guava (Psidium guajava L.) fruits. Sci. Hortic. 125 (3), 406–410.

Flores, G., Wu, S.B., Negrin, A., Kennelly, E.J., 2015. Chemical composition and antioxidant activity of seven cultivars of guava (Psidium guajava) fruits. Food Chem. 170 (1), 327–335.

International Oenological Codex, 2012. Determination of Polygalacturonase Activity in Enzymatic Preparations. http://www.oiv.int/public/medias/4352/e-coei-1-actpga-en.pdf. Accessed 03 August 16.

Jain, A., De, S., 2016. Aqueous extraction of bitter gourd (*Momordica charantia* L.) juice and optimization of operating conditions. Fruits 71 (6), 379–387.

Kaur, S., Sarkar, B.C., Sharma, H.K., Singh, C., 2009. Optimization of enzymatic hydrolysis pretreatment conditions for enhanced juice recovery from guava fruit using response surface methodology. Food Bioprocess Technol. 2 (1), 96–100.

Kaur, S., Sarkar, B.C., Sharma, H.K., Singh, C., 2011. Response surface optimization of conditions for the clarification of guava fruit juice using commercial enzyme. J. Food Process Eng. 34 (4), 1298–1318.

Kiss, K., Cserjesi, P., Nemestothy, N., Gubicza, L., Belafi-Bako, K., 2008. Kinetic study on hydrolysis of various pectins by *Aspergillus niger* polygalacturonase. Hung. J. Ind. Chem. 36 (1–2), 55–58.

Klinchongkon, K., Khuwijitjaru, P., Adachi, S., 2017. Degradation kinetics of passion fruit pectin in subcritical water. Biosci. Biotechnol. Biochem. 81 (4), 712–717.

Lee, W.C., Yusof, S., Hamid, N.S.A., Baharin, B.S., 2006. Optimizing conditions for enzymatic clarification of banana juice using response surface methodology (RSM). J. Food Eng. 73 (1), 55–63.

Lowry, O.H., Rosebrough, N.J., Farr, A.L., Randall, R.J., 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem. 193, 265–275.

Marangoni, A.G., 2003. Enzyme Kinetics: a Modern Approach. John Wiley & Sons, Inc., New Jersey (Chapter 8).

Masmoudi, M., Besbes, S., Chaabouni, M., Robert, C., Paquot, M., Blecker, C., Attia, H., 2008. Optimization of pectin extraction from lemon by-product with acidified date juice using response surface methodology. Carbohydr. Polym. 74 (2), 185–192.

McComb, E.A., McCready, R.M., 1952. Colorimetric determination of pectic substances. Anal. Chem. 24 (10), 1630–1632.

McCook-Russell, K.P., Nair, M.G., Facey, P.C., Bowen-Forbes, C.S., 2012. Nutritional and nutraceutical comparison of Jamaican *Psidium cattleianum* (strawberry guava) and *Psidium guajava* (common guava) fruits. Food Chem. 134 (2), 1069–1073.

Mensor, L.L., Menezes, F.S., Leitão, G.G., Reis, A.S., Dos Santos, T.C., Coube, C.S., Leitão, S.G., 2001. Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. Phytotherapy Res. 15 (2), 127–130.

Pařenicová, L., Benen, J.A.E., Kester, H.C.M., Visser, J., 1998. pgaE encodes a fourth member of the endopolygalacturonase gene family from *Aspergillus niger*. Eur. J. Biochem. 251 (1–2), 72–80.

Pařenicová, L., Kester, H.C.M., Benen, J.A.E., Visser, J., 2000. Characterization of a novel endopolygalacturonase from *Aspergillus niger* with unique kinetic properties. FEBS Lett. 467 (2–3), 333–336.

Prasanna, V., Prabha, T.N., Tharanathan, R.N., 2007. Fruit ripening phenomena- an overview. Crit. Rev. Food Sci. Nutr. 47 (1), 1–19.

Prinz, H., 2010. Hill coefficients, dose–response curves and allosteric mechanisms. J. Chem. Biol. 3, 37–44.

Rai, P., Majumdar, G.C., DasGupta, S., De, S., 2004. Optimizing pectinase usage in pretreatment of mosambi juice for clarification by response surface methodology. J. Food Eng. 64 (3), 397–403.

Sagu, S.T., Nso, E.J., Karmakar, S., De, S., 2014. Optimisation of low temperature extraction of banana juice using commercial pectinase. Food Chem. 151, 182–190.

Sevda, S.B., Rodrigues, L., 2011. Fermentative behavior of Saccharomyces strains during guava (Psidium guajava L) must fermentation and optimization of guava wine production. J. Food Process. Technol. 2 (4), 1000118.

Surajbhan, S., Singh, A., Joshi, C., Rodrigues, L., 2012. Extraction and optimization of guava juice by using response surface methodology. Am. J. Food Technol. 7 (6), 326–339.

Teixeira, G.H.A., Júnior, L.C.C., Ferraudo, A.S., Durigan, J.F., 2016. Quality of guava (Psidium guajava L. cv. Pedro Sato) fruit stored in low-O2 controlled atmospheres is negatively affected by increasing levels of CO_2. Postharvest Biol. Technol. 111, 62–68.

Van Pouderoyen, G., Snijder, H.J., Benen, J.A.E., Dijkstra, B.W., 2003. Structural insights into the processivity of endopolygalacturonase I from *Aspergillus niger*. FEBS Lett. 554 (3), 462–466.

Résumé de l’article

Kinetics of enzymatic hydrolysis of pectinaceous matter in guava juice

Kombele Aimé Ninga, Sourav Sengupta, Amit Jain, **Zangué Steve Carly Desobgo**,

Emmanuel Jong Nso, Sirshendu De

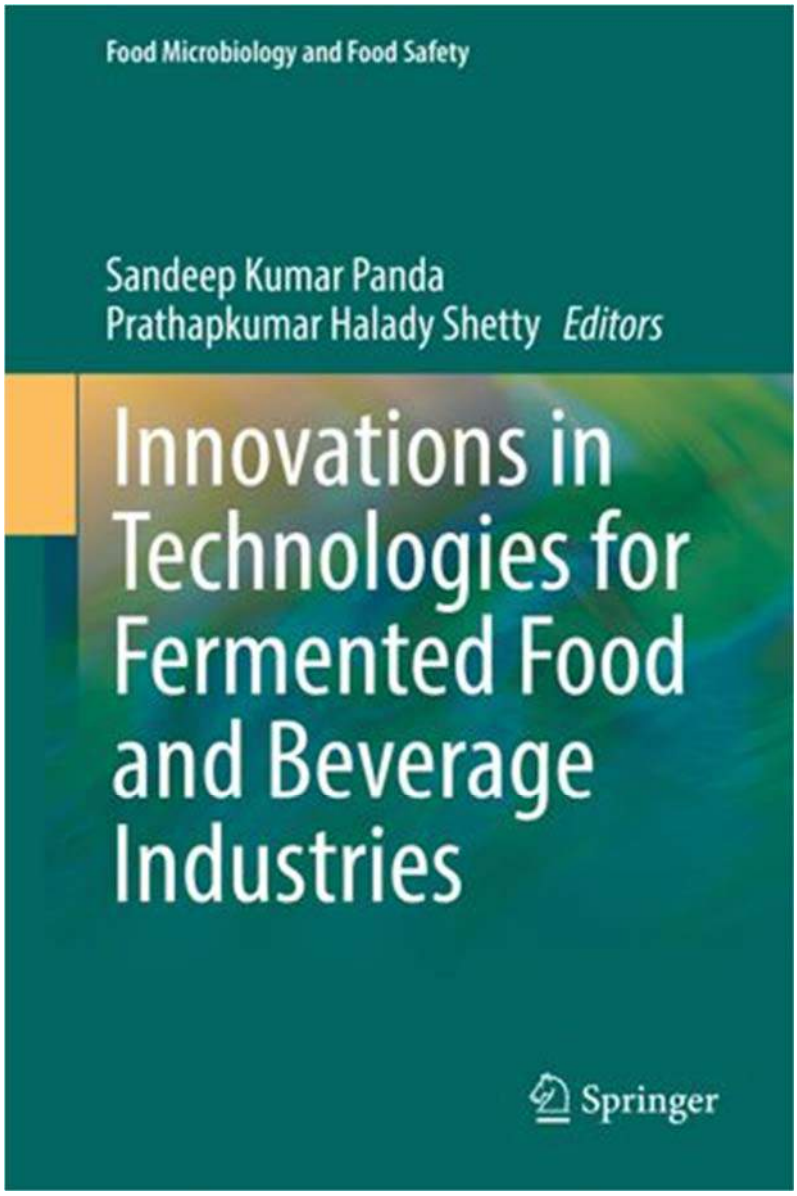
Abstract

The objective of the current study is to investigate the hydrolysis of pectinaceous matter in guava juice and to model the depectinization kinetics using commercial pectinase from Aspergillus niger. The procedure involves enzymatic treatment of guava juice at 45 °C with enzyme concentration (% w/w) 0.033, 0.055, 0.078 and 0.1. The degree of hydrolysis of pectinaceous matter and the rate of enzymatic reaction are determined. The results show an increase in the degree of hydrolysis with time for each enzyme concentration. Depectinization kinetics reveal allosteric behavior and is modeled using the Hill Equation. The image analysis of the sample using field emission scanning electron microscopy shows a change in the smoothness and homogeneity of the sample, indicating degradation of pectin network.

Keywords: Guava juice, Pectin, Pectinase, Non-Michaelis-Menten, Allosteric effects

IV.4.13) Chapter 11: Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry

Titre du livre


Food Microbiology and Food Safety
Sandeep Kumar Panda
Prathapkumar Halady Shetty Editors
Innovations in Technologies for Fermented Food and Beverage Industries
Springer

Comité de lecture

Food Microbiology and Food Safety Series

The Food Microbiology and Food Safety series is published in conjunction with the International Association for Food Protection, a non-profit association for food safety professionals. Dedicated to the life-long educational needs of its Members, IAFP provides an information network through its two scientific journals (Food Protection Trends and Journal of Food Protection), its educational Annual Meeting, international meetings and symposia, and interaction between food safety professionals.

Series Editor

Michael P. Doyle, *Regents Professor of Food Microbiology (Retired), Center for Food Safety, University of Georgia, Griffith, GA, USA*

Editorial Board

Francis F. Busta, *Director, National Center for Food Protection and Defense, University of Minnesota, Minneapolis, MN, USA*
Patricia Desmarchelier, *Food Safety Consultant, Brisbane, Australia*
Jeffrey Farber, *Food Science, University of Guelph, ON, Canada*
Vijay Juneja, *Supervisory Lead Scientist, USDA-ARS, Philadelphia, PA, USA*
Manpreet Singh, *Department of Food Sciences, Purdue University, West Lafayette, IN, USA*
Ruth Petran, *Vice President of Food Safety and Pubic Health, Ecolab, Eagan, MN, USA*
Elliot Ryser, *Department of Food Science and Human Nutrition, Michigan State University, East Lansing, MI, USA*

Editors
Sandeep Kumar Panda
School of Basic Sciences
Indian Institute of Technology
Bhubaneswar, India

Prathapkumar Halady Shetty
Department of Food Science
and Technology
Pondicherry University
Kalapet, Pondicherry, India

Food Microbiology and Food Safety
ISBN 978-3-319-74819-1 ISBN 978-3-319-74820-7 (eBook)
https://doi.org/10.1007/978-3-319-74820-7

Library of Congress Control Number: 2018937645

© Springer International Publishing AG, part of Springer Nature 2018
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Table des matières

Contents

1 **Innovative Technologies and Implications in Fermented Food and Beverage Industries: An Overview** 1
Lopamudra Sahu and Sandeep Kumar Panda

2 **Lactic Acid Bacteria and Yeasts as Starter Cultures for Fermented Foods and Their Role in Commercialization of Fermented Foods** 25
Sujatha Kandasamy, Digambar Kavitake, and Prathapkumar Halady Shetty

3 **Advances in Microbial Fermentation and Fermented Food for Health** 53
Sudhanshu S. Behera, Pankajini Bal, Sushrirekha Das, Smita H. Panda, and Nakulananda Mohanty

4 **Advances in Fermentation Technology for Novel Food Products** 71
Oluwafemi A. Adebo, Patrick B. Njobeh, Adedola S. Adeboye, Janet A. Adebiyi, Sunday S. Sobowale, Opeolu M. Ogundele, and Eugenie Kayitesi

5 **Advances in Technology and New Product Development in the Beer, Wine, and Spirit Industry** 89
Inge Russell and Julie Kellershohn

6 **Alcoholic Beverages: Technology and Next-Generation Marketing** 105
Julie Kellershohn

7 **Advances in Probiotics, Prebiotics and Nutraceuticals** 121
Swati S. Mishra, Prafulla K. Behera, Biswabandita Kar, and Ramesh C. Ray

8 Probiotic Dairy Products: Inventions Toward Ultramodern Production 143
Spiros Paramithiotis and Eleftherios H. Drosinos

9 Non-dairy Probiotic Foods: Innovations and Market Trends 159
Gargi Dey

10 Technological Interventions in Fermented Meat Production: The Commercial Perspective 175
Nevijo Zdolec

11 Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry 189
Steve Carly Zangué Desobgo

12 Advances in Genetic Engineering for Higher Production and Quality Improvement of Food and Beverages 221
Aly Farag El Sheikha

13 Innovative and Safe Packaging Technologies for Food and Beverages: Updated Review 257
Ishrat Majid, Mamta Thakur, and Vikas Nanda

14 Role of Consumers in Innovation of Novel Food and Beverages 289
Shalini Sehgal

15 IPRs in Respect to Food and Beverages 297
Sripathi Rao Kulkarni

16 Application of Computational Intelligence Techniques for Forecasting Problematic Wine Fermentations Using Data from Classical Chemical Measurements 317
Gonzalo Hernández, Roberto León, and Alejandra Urtubia

Index 331

Pages du chapitre

Chapter 11
Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry

Steve Carly Zangué Desobgo

Abstract Fermentation is an inexpensive and low-energy method of conserving decomposable unprocessed materials. Many foods have microbial sources or include components generated by fermentation using microorganisms. This procedure is helpful for extending the usability of food and drinks, as well as improving the health benefits of products. This chapter examines the modern aspects of food and beverage fermentation in large-scale fermenters. Descriptions of fermenters and their underlying technology are provided for each case to demonstrate the link between the equipment and the process. Engineering characteristics are reported for bioreactor scale-up, including important problems in the scaling and exploitation of bioreactors. Agitation in bioreactors is also discussed. Some aspects associated with bioreactor/fermenter design when computer simulation is used are reported. Finally, the technology of modern bioreactor types is presented.

Keywords Fermentation · Microorganism · Scaling up · Bioreactor · Food · Beverage · Technology

Introduction

Fermenting is a biotechnological unit operation involving microbes. Through fermenting, raw sustainable substrates are changed to added-value products, such as fermented beverages and food, enzymes, alcohols, acids, and others. The production of commercial fermented products has improved from focused genetic

S. C. Z. Desobgo (✉)
Department of Food Process and Quality Control, University Institute of Technology of the University of Ngaoundere, Ngaoundere, Cameroon

Department of Biotechnology and Food Technology, Faculty of Science, University of Johannesburg, Johannesburg, South Africa
e-mail: desobgo.zangue@gmail.com

© Springer International Publishing AG, part of Springer Nature 2018

S. K. Panda, P. H. Shetty (eds.), *Innovations in Technologies for Fermented Food and Beverage Industries*, Food Microbiology and Food Safety,
https://doi.org/10.1007/978-3-319-74820-7_11

engineering methods that created modern microbial strains (Campbell-Platt 1994). The development of end or subsidiary products is reliant on the selected microbial variety and ecological conditions, such as bioreactor type. For an ideal fermenting procedure, the microbe variety should be chosen and created in light of the desired end product. Information on the biochemical modifications of matured foods can help producers to control their results by modifying varieties and conditions. In addition to development conditions, media, strains, and fermenting methods influence outcomes and hence profitability. Fed-batch, continuous, and batch fermentation systems can be selected for high efficiency. Continuous and fed-batch systems can handle substrate restriction amid fermentation procedures. Higher efficiency also can be achieved by the immobilization of cells, which can be derived incrementally from the biomass collection in the bioreactor, leading to an expanded assembly of biocatalysts in the bioreactor.

Modern large-scale fermentation procedures can vary throughout the beverage and food industry. The focal point of these procedures are generally bioreactors, which can be categorized by the bioreactor feeding operation (continuous, fed-batch, or batch), fixation of the biocatalyst, stirring system of the bioreactor (hydraulic, pneumatic, or mechanical agitation), and the accessibility of oxygen (anaerobic, microaerobic, or aerobic), among others. The choice of bioreactor or fermentation technique for a specific application should consider the advantages and inconveniences of every setup. This decision should include the properties and accessibility of essential crude materials, any important venture and working costs, manageability, accessibility of a skilled workforce, and the desired efficiency and quantifiable profit (Inui et al. 2010). In large-scale applications, every fermentation technique needs to run effectively and dependably; thus, a significant aspect in the choice of a fermentation/bioreactor procedure is the capital expenses per unit of item recuperated. However, even with a plan and effective operation, issues with the subsidiary product and wastewater administration are unavoidable in large-scale operations.

This chapter is focuses on the aspects of fermenters in food manufacturing, biotechnological approaches, and the modernization and design of bioreactors in the industry.

Modern Fermenters for Food and Beverages

Beer Fermenter Technology

Fermenter for Lager Beers

Worldwide, most beer is manufactured using a variety of lager *Saccharomyces carlsbergensis* yeast, which has a tendency drift away from the base of the fermentation vessel. Thus, the tanks used for the fermentation of lager beer—which are the most well-known and critical in brewing—should take into consideration this yeast property.

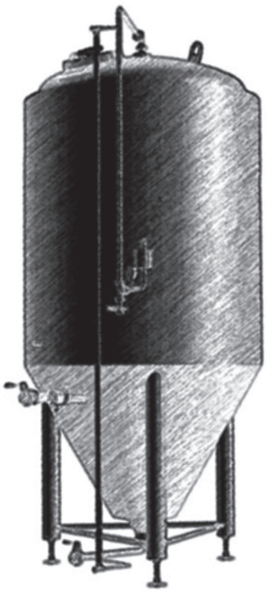


Fig. 11.1 Fermentation and lagering tank

A noteworthy achievement in fermenter configuration was the implementation of closed fermenters. Leopold Nathan patented his plans for cylindrical tanks, which were vertical with funnel-shaped bases, in 1908 and 1927. Modern versions of the Nathan tank are now the most used fermenters. The size of these tanks range from 100 to 6000 hL. An important attribute of these tanks is their well-defined cone at the bottom. An inclination of 70° is necessary for the yeast to subside into the bottom of the tank toward the end of fermentation (Fig. 11.1). This design allows most of the yeast to be isolated, resulting in a relatively yeast-free lager. In a few designs, improvements and storage can occur in one tank from fermentation, without centrifugation of the brew during transfer to another tank for development. A number of advantages have been noted for cylindroconical tanks compared with round or open square fermenters (Briggs et al. 2004), including a reduction in capital expenses of 25–35%, a reduction in operating expenses of 50–65%, reduction of product losses, expanded vessel usage, less introduction of bitter compounds, reduced space requirements, and potential for the collection of CO_2.

Lager fermenters are generally three to four times shorter in their diameter than the height and use an operation pressure of 1–1.5 bar. European fermentation tanks for lager beer commonly use shorter tanks with a diameter-to-height ratio of <2:1, which causes fermentation to equalize more completely than in horizontal vessels. In taller tanks with a proportion of >3:1, there is an tendency for increased generation of more alcohol to the detriment of esters. Expanding the dimensions of the tank can decrease the expenses per unit volume; doubling the dimensions of the tank results in a cost increment of approximately 35% (Briggs et al. 2004).

Fig. 11.2 Stainless steel fermenter tank

Cylindroconical tanks cannot be completely filled for fermentation. A substantial volume of froth is created by the advancement of CO_2, which can cause the pressure discharge valves to clog. Initially, fermentation tanks for lager beer were steel with a glass or epoxy tar lining. However, this coating must be regularly inspected to ensure its integrity. Furthermore, mellow steel is inclined to rust; thus, present-day wtanks are typically made of stainless steel using chrome-nickel (Fig. 11.2). Usually, 304 stainless is used; however, V2A steel is not completely impervious to chloride particles or to pH <4.5. This is not typically an issue for fermenters when solutions with an elevated chloride substance 316 can be determined; however, it is significantly costlier than 304 steels.

The fermenter should be outfitted with a cooling attribute to release the heat created during fermentation and to enable required temperature control. The tanks are filled and exhausted from the bottom, which decreases oxygen entrance. Pipes are fitted to the tanks for the addition of wort, evacuation of yeast, and expulsion of lager. There are also pressure and vacuum alleviation systems. In most of today's tank, the vessels used a pipe-work system. The valves are therefore either associated with each tank or gathered into a "valve routing block" to which each tank is associated; the valves are either manually or remotely controlled. Fermenters also need protection. Outside tanks should be protected against the elements, which may differ significantly depending on geographical location. Indoor vessels also need some protection to minimize the need for system temperature control.

Ale Beer Fermenters

Because lager brews are the most common type of beer worldwide, most technological advancements in fermentation have been associated with cylindroconical tanks. However, in the United Kingdom and Ireland, stouts and ales are

Fig. 11.3 Square tank for wheat beer fermentation

the customary beers. These brews are regularly created with top fermenting yeast varieties, similar to some German and Belgian ales. Conventional ale fermentation uses an open solitary tank to ease yeast expulsion, such as Yorkshire vessels (Anon 2008).

Square tanks (Fig. 11.3) from Yorkshire were initially manufactured with stone and slate, with a size up to 50 hL. However, today's Yorkshire squares are almost always manufactured with stainless steel (304) and have capacities up to 850 hL to accommodate the production needs of a modern brewhouse. Yorkshire squares have a lower section that is isolated from the exposed upper part by a slightly slanting deck. Underneath is a progression of channels known as organ funnels, and perhaps a few sewer vents with spines around the edge. On the highest point of the deck, there is an outlet with an embedded attachment to help remove the yeast.

Vinegar Fermentation Tanks

The word *vinegar* comes from the French *vin aigre* ("harsh wine"). The total ethanol concentration (%v/v) and acetic acid concentration (%w/v)—termed the global concentration (GK)—needs to be consistent throughout acetification. The GK yield is the remaining vinegar, indicated as a level of the GK toward the beginning of acetification. There are various factors affecting acetification, including the oxygen, alcohol, and microbes (Hutkins 2006; Adams 1985; Hills 2014). Wine is normally fermented in tanks, although barrels may be used in some cases, especially for white wine. Generally, wine was historically manufactured in simple, solid, nonmetallic, mineral-matter containers called *lagars*, in which the grapes would be crushed. Lagars are still used occasionally in Portugal by a few winemakers.

Fig. 11.4 Frings acetator technology

In the culture strategies for vinegar, microorganisms form a film at the surface between the air and acidifying environment; this appears to be a straightforward process, yet it may experience varying levels of complexity. The fast process of obtaining vinegar is due to the speed of acetification, which can be increased by expanding the area of dynamic microbial film and enhancing oxygen exchange to the acidifying stock. The acidic microorganisms develop as a film on an inactive material pressed into a false-bottomed tank. The acidifying stock is splashed onto the inert material surface and streams down in opposition to the counter-current flow of air. The inert material in which the microbes are packed is typically composed of a lignocellulosic substance, such as sugarcane bagasse, wood fleece, or vine twigs; however, different substances, such as coke, have also been used. The acetic acid stock begins in a marsh at the tank base and reflows up to the point where the desired level of acidity is attained. A quicker reaction rate indicates that the wash was heated during entry via the bed; thus, on the span of the fermenter, some chilling might be required. The procedure is completed in a semi-continuous system to maintain a high acidity level throughout the process, with a large portion of the biomass held inside the bed.

A commonly used fast vinegar procedure, with a controlled temperature and constrained air circulation, will typically acidify a vinegar stock with a GK value of 10 and an underlying ethanol percentage of 3% in 4–5 days. The quickest acetification rates are accomplished by submerged acidification, in which acetification microbes are suspended in a environment that is oxygenated by air sparging. The most powerful commercial system is the Frings Acetator (Fig. 11.4), which uses a self-preparing aerator to achieve extremely efficient oxygen exchange.

To quickly and efficiently submerge a culture, a semi-continuous operation regularly takes 24–48 h. However, this operation requires much more oversight than

what is required for simpler methods. The acetification organisms are very vulnerable to air supply interruptions. To survive suspended in a pH environment of 2.5 and an acidity of 10–14%, the microbes require a consistent provision of energy from air. An air supply interruption of just 1 min in a stock with a GK value of 11.35 can completely and permanently halt acetification; that is, the acetification will not continue when air circulation resumes.

Fermenters in Winemaking

Inox tanks started to gain widespread acceptance in the late 1970s. The advantages of this material include ease of cleaning and the capacity to operate in cooling techniques. Two levels of inox have been used in the manufacturing of fermenters. Grade 304 is most suitable for the fermentation of red wine. The superior grade 316, which contains molybdenum, is stronger and more resistant to erosion; this grade is suitable for both white and red wines. The top of inox tanks may be either open or shut, with a fermentation lock. Variable limit tanks are likewise possible and are helpful, even when the tanks are only halfway filled. These tanks have a drifting metal top, held up by an inflatable plastic tire at the edge. Fiberglass tanks are also occasionally used as a less expensive option to inox. In the early twentieth century, many produced replaced their wooden tanks with inox; however, wood is again gaining interest as a material for tank development at some small- and medium-sized wineries. The most common vessels of winemakers are stainless steel and cylindrical (Fig. 11.5) with an inner cover. The cover is held in situ by an expansive

Fig. 11.5 Wine fermenter tank

vinyl cap, allow the top to be safe at any height in the vessel. Most vats have a level base with a low port on one depleting side. These vats should be put on a stand or depleted using gravity. A few models have three legs welded in situ; these vats also usually have a cone-molded base with an additional deplete port in the middle. Some larger tanks have a built-in stainless-steel coat or belt connected over the center for cooling. A glycol cooling unit may be linked to ports on the coat when chilling is desired. Normally, these vessels are costlier than vessels without a chilling coat. The stainless-steel material is exceptionally chemically inactive and completely safe for beverages. Cleaning is simple with the top evacuated. The cover of a variable limit tank has a port that is suitable for a maturation bolt; thus, these vessels can be used as open or shut fermenters.

The fermentation of red wine uses the whole grape. When manufacturing red wine, two facts should be considered. First, during fermentation, yeast generate CO_2 gas and alcohol. As the CO_2 rises into and out of the wine, a portion gets caught in the peels and causes them to float on the wine surface in a mass named "the cap." The cap rises over the surface of the liquid, which causes the must volume to extend in the vessel. Thus, when charging red wine fermentation tanks, one should select a fermenter that it is somewhat larger than the desired final volume of wine. The skins in the "top" should be washed with the fluid wine a few times each day during fermentation. For large volumes, this can be achieved using a procedure called a "pump-over."

White wines are manufactured using only the grape juice. The maceration and detachment of the juice from the solids occurs before the start of fermentation. Because there are no solids, there is no compelling reason to punch the top. However, white wines are exceptionally touchy to oxygen introduction, so a mechanism to restrict oxygen intake is desirable. Consequently, open-top fermenters are not used. Sealed fermenters are the best choice for making white wines.

Bread Proofers

To guarantee reliable outcomes and maintain production schedules, specific equipment may be used to control the speed and characteristics of fermentation in breadmaking. A proofer of dough (also referred to as a proofing oven or box) is a heating chamber used as a part of baking to promote the yeast fermentation of dough through moderate temperatures and managed humidity. Warmer temperatures increase yeast activity, resulting in increased CO_2 creation and a higher, quicker rise of the dough. Dough is usually allowed to rise in the proofer prior to baking, but it can also be used for the principal rise or mass fermentation. Proofer temperatures can range from 70 °F (21 °C) up to 115 °F (46 °C). Bakers often use large temperature- and humidity-managed proofers.

A dough retarder (Fig. 11.6) is a chiller used to self-manage the yeast fermentation while proofing a mixture. Decreasing the dough temperature creates a steady, slow rise with other maturation characteristics, resulting in more elaborate flavors.

Fig. 11.6 Stainless steel automatic dough retarder proofer

In sourdough bread production, chilling declines the wild yeast activity of the Lactobacilli (Gänzle et al. 1998), which creates flavoring from acetic and lactic acid, for example. Sourdough that is chilled prior to baking may have greater sourness. To prevent the batter from drying, a wind stream is maintained in the mixture retarder. Industrial bakers frequently chill the dough at approximately 50 °F (10 °C).

A banneton is a kind of wicker bin used to give structure to molded chunks of bread during sealing. A banneton wicker bin is also called a brotform or proofing bushel. It is regularly used for dough that is too delicate or soft to keep up its shape while rising. The bread is ordinarily removed from these crates prior to baking. Traditionally, these bushels are made from wicker; however, some new proofing crates have been manufactured using rattan, cane, spruce pulp, terracotta, and polypropylene. A banneton sometimes has a material liner (usually cloth) to keep the mixture from adhering to the sides of the container. However, with use, bannetons usually become non-stick because a small amount of flour collects in them. These wicker containers are used both to give shape to the dough and to draw off humidity from the outside layer. Bannetons are available in elliptical or round shapes.

Dairy Product Fermentation

Lactic acid bacteria play an important role in the creation of fermented milk products. They can ferment lactose and produce lactic acid, which decreases the milk pH (Tamime 2008; Park 2009). As a consequence, the pH attains the isoelectric point of the protein (casein), which is the main protein in milk. At that point, the positive and negative charges are in equilibrium. The casein then coagulates and coagulum

appears (Tamime 2008; Park 2009; Clark et al. 2009). This causes both biochemical and physical transmutations in the item. When integrated with lactic acid, starter yeasts may produce organic molecules, such as acetaldehyde, ethanol, acetic acid, diacetyl, and exopolysaccharides, which affect the consistency and flavor profiles of the product (Clark et al. 2009; Hutkins 2006). Thus, variants of cultures and production conditions can cause different characteristics for these products.

Cheesemaking Mechanization

Mechanization and automation have been implemented for the large-scale manufacture of cheese. Huge industrial units stocking a few million kilograms of milk each day. The fat-to-casein ratio for cheese can be achieved via mechanized methods. Cheese can be manufactured in mechanized tanks in which the filling process is controlled using a computer. Culture expansion, cutting, cooking, stirring, renneting, and discharging operations also can be automated (Fig. 11.7). Encased double-jacketed tanks are available with mechanical stirring and cutting instruments. The mixing and cutting tools turn on a pole horizontally or vertically with adjustable speed. Computerized cheesemaking processes and the ability to control pH inline also help to reduce labor costs. Numerous tanks are available with a mechanized gel-quality analyzer to systematize the cutting stage. Whey and curd division can be executed on a depleting conveyer. In a cheddaring tower, air pressure and vacuum

Fig. 11.7 Coagulation vat

pressure can be used for the curd pressing, which is salted and processed in a mellowing/salting transporter. This salted curd can be squeezed and shaped into 18-kg pieces in a piece former, followed by automated packing and transportation to the aging room (Chandan 2014).

Yogurt Fermenters

Large amounts of yogurt can be delivered in a series of individual cupboards. This procedure can be mechanized for continuous production through a tunnel organization. However, the idea of continuous yogurt manufacturing is novel. Pallets with pots of yogurt can be set on a conveyor or smooth rollers and pass through a tunnel composed of two areas. Hot air is circled in the tunnel hatching portion. The pallet rate is determined by the rate of the transport line, which in turn is managed by the speed of lactic acid generation in the drain. Toward the completion of the fermentation time, which is proportionate to pH 4.5, the pallets pass through the cooling segment so that the warm air is supplanted by the introduction of cool air. The yogurt is halfway cooled in this area; the final cooling happens in the chill store. Because the yogurt is moving during the hatching/cooling stages, great care should be taken to prevent harm to the coagulum.

An update to the tunnel organization has been described in the literature (Bylund 1995). The loaded containers of the inoculated milk are put in open-plan cartons and separated from each other. The goal is that the coursing warm/chill air in the brooding and chilling stages can reach each individual container and provide precise temperature control (Fig. 11.8). At the point when the predetermined ideal pH (normally 4.5) is achieved, the time has come to begin cooling. The crates (pallets) are motionless during brooding. They are put in the hatching part of the tunnel to discourage handling.

Through differentiation, the coagulum of mixed yogurt is created in mass. The structure of the gel is destroyed earlier or during the chilling and bundling stages. Nevertheless, preparing the drain base for the production of blended yogurt is as depicted previously. The types of fermentation vats used in factories for the creation of blended yogurt include the following:

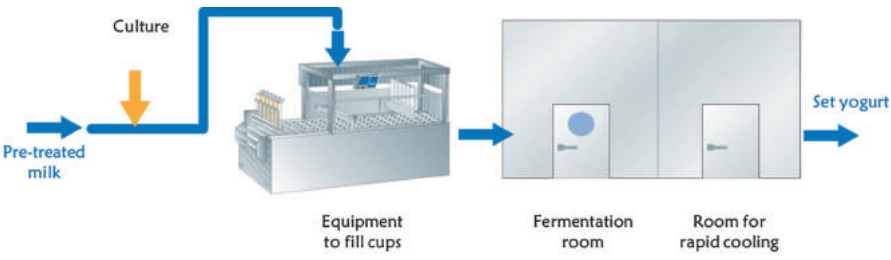


Fig. 11.8 Production of set yogurt

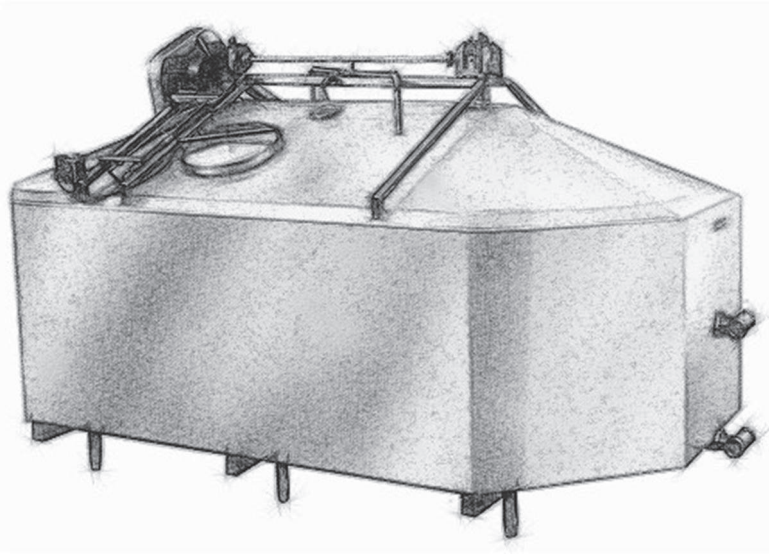


Fig. 11.9 Yogurt coagulation vats

- *Flexible tanks:* A flexible tank is assigned as a number duty vat, with one dedicated to milk fermentation. It is a water-jacketed tank in which vapor can be used during the warming stage; circulating chilled water is used to cool the drain to 40–45 °C. The temperature is kept at 42 °C during the fermentation stage. Finally, chilled water is used to cool the yogurt.
- *Fermentation tanks:* Fermentation tanks are protected, as the end goal is to maintain an even temperature during the hatching stage. The stirring technique in such vats is unforced (Fig. 11.9) because the cone-shaped base encourages simple expulsion of the coagulum (see Fig. 11.9).
- *Chilling/fermentation tanks:* Chilling/fermentation tanks are water jacketed. Hot water (40–45 °C) is circulated during the brooding stage, followed by cold water for incomplete cooling of the coagulum.
- *Sterile fermentation tanks:* Sterile fermentation tanks are modified versions of ordinary fermentation vessels. These vats are utilized for the manufacture of yogurt under germ-free conditions. The vat is protected and suitable for use with a pH electrode and thermometer. The air penetrating and leaving the tank is separated. The essential goal of an aseptic aging tank is to limit contamination of the yogurt with molds and yeast. A sterile tank is always pressurized with germ-free air; a similar approach is used for the generation of mass starters with an aseptic tank.

For protection, each tank is furnished with an additional pipe for air, as well as a security system to keep the vat from exploding from the vacuum created by the drop-in temperature in the wake of cleaning. All of the above vats have a froth-diminishing inlet fitting that mitigates the issue of foam generation in the vat.

Furthermore, most of today's yogurt fermentation vats are fitted with a pH meter to monitor lactic acid generation by the starter (Watanabe et al. 2008; Corrieu et al. 2005; Mulchandani et al. 1995).

Meat Fermenters and Fermentation Technology

The filling of frankfurters takes place in computer-regulated cooling chambers, where they are left to mature for development and improvement of microbes. A typical chamber is shown in Fig. 11.10. Humidity, temperature, and air velocity should be carefully managed to control microbial development and catalyst activity.

Meat maturation technology differs between the United States and Europe. High maturation temperatures (35–40 °C) are common for U.S. frankfurters, followed by a gentle warming procedure as a sort of pasteurization, rather than drying. Hence, cultures such as *Pediococcusacidilactici* or Lactobacillus plantarum, which develop well, are commonly used. In Europe, different technologies might be used, depending on the area and atmosphere. There is a trend to produce short-handled, smoked wieners in chilly and muggy countries (e.g., northern Europe), whereas a prolonged process for dried hotdogs is common in drier and hotter nations (e.g., Mediterranean region).

In northern European countries, frankfurters are aged for around 3 days at transitional temperatures (25–30 °C), followed by a short maturation duration (about

Fig. 11.10 Maturation chamber

3 weeks). These frankfurters are put through a fast drop of pH and are generally smoked for a particular taste (Eva et al. 1997; Demeyer and Stahnke 2002). Mediterranean wieners require a longer duration of preparation. Maturation occurs at moderate temperatures (18–24 °C) for around 4 days, followedd by mellow drying for a more extended time, generally months. *L. curvatus* or *L. sakei* are most frequently used as starters (Toldrá et al. 2001, 2014; Toldrá 2008, 2010). The duration needed for the aging step depends on the temperature and type of microorganisms used.

The process is very different in China and other Asian nations, where frankfurters are first dried at 48 °C for 36 h and afterward at 20 °C for 3 days. Aging is moderately poor; the harsh taste, which is viewed as undesirable, is thus lessened. Chinese crude sausage is eaten in the wake of warming (Leistner 1992).

Vegetable Fermentation Containers

Not all receptacle materials are suitable for maturation. Aging happens in acidic, salty conditions. Metal, aside from high-grade commercial stainless steel, can pit and debase; thus, it is generally not used. Ceramic vessels and plastic receptacles are more stable. Regardless of material, the selected food receptacle should be simple to wash and without profound abrasions, pits, or fragments that can provide a refuge for unsafe microorganisms or influence the aging. Wooden vessels are used to age vegetables; however, they can be challenging to keep intact and sterile. Vessels and other gear should be cleansed in hot, foamy water before use. Chlorine should not be used to clean the equipment because the remaining chloramine and chlorine deposits on the container could affect the development of maturing microbes. If chlorine is used, the equipment should be washed again to eliminate any lingering chemicals.

Ceramic vessels are available in different shapes and sizes. When selecting a container, both the shape and size should be considered. For food safety and adequate maturation, it is vital to have the saline solution/juices at a level of 1–2 in. over the aged vegetables. Such a vegetable plunge allows the items to remain without oxygen, which supports the development of lactic acid microorganisms and other maturing life forms. Keeping the vegetables immersed accounts for the salt to plaster the item, which additionally promotes the development of lactic organisms. Thus, it is critical to select a maturing crock that allows the vegetables to be totally immersed under the saltwater liquid. The style of vessel does not influence the vegetables' security but could influence quality. It is vital to cover the items for both quality and safety.

Plastic vessels also can be used effectively to ferment vegetables, particularly polyethylene vessels with high density (HDPE-2 plastic) that are free of bisphenol and phthalate. These chemicals have been introduced to a few plastics to increase their adaptability; however, they can affect human health, especially for children.

Fig. 11.11 Glass container for anaerobic fermentation of vegetables

Glass vessels (Fig. 11.11) may be used. However, care must be taken to ensure they are not chipped, broken, or split. Quart canning jugs may be used. However, spoilage could be an issue because it can be harder to keep vegetables immersed.

Engineering Aspects for Bioreactor Scale-up

Fundamental Problems in the Design and Operation of Bioreactors

An efficient bioreactor regulates, encloses, and controls a biological reaction. To achieve this, a chemical technician should take account of two items. The first is the appropriate reactor factors for the specified physical, biological, and chemical system. A macro-kinetic (chemical) system embraces microorganism excrescence and matter manufacture. Microorganisms will embrace bacterium, fungi, yeast, and fish, plant, animal, and bug cells, as well as other biological matter. The opposite space of dominant significance in a bioreactor design affects the bioreaction factors, such as restrained temperature, optimum pH, adequate substratum (conventionally a source of carbon; essentially fats, proteins, and sugars), water accessibility, salts as nutrients, vitamins, gas, evolution of gas, and removal of byproducts.

Ideally, a bioreactor should be planned to promote the best physiology of the microorganism, eliminate or reduce pollution from undesirable microbes, and prevent changes to the microorganism. This section provides an outline and summary of bioreaction techniques, the benefits and downsides of a variety of system types, and their everyday applications. A number of subtopics are beyond the scope of this

chapter, including biology, sterilization, heat transfer, rheology, mixing, fluidization, surface phenomena, mass transfer and transport enhancements, hydrokinetics, instrumentation, and method management.

Agitation in Bioreactors

The stirring mode within a bioreactor produces the fluid movement that allows many alternative tasks to be achieved. A typical agitated bioreactor is shown in Fig. 11.8. Important features to understand include the interactions between the liquid movement, the agitator momentum, and the power input devoted to the bioreactor and these assignments. In addition, it is necessary to understand how a change to the scale affects these relationships. Several of these aspects are often studied before a bioprocess has been selected; these physical features are most pertinent to microorganism fermentations. The characteristics that are specific to the organism are developed and can sometimes diverge for each case. The features that are more relevant for scale-up are discussed later. The physical aspects have been discussed elsewhere for conditions significant to an extensive variety of life forms (Gupta and Ibrahim 2013; Laskin et al. 2011; Nienow et al. 1997, 2010, 2011; Doran 2013).

This section explores the significance of microbial maturations for which the thickness does not substantially exceed that of water, such as microscopic organisms and yeast. Thus, sticky polysaccharide and filamentous frameworks are excluded from this discussion. With such low thickness, the stream in the bioreactor is turbulent from a 5-L bench bioreactor to the largest scale. That is, the Reynolds number can be calculated as $R_e = \left(\rho_L N D^2 / \mu\right) > \sim 10^4$, where R_e is the development medium thickness (kg/m^3), ρ_L is its consistency (Pa s), D is the impeller length (m), and N is its speed (rev/s). For scale-up, because the stream is turbulent, the substantial estimation of the Reynolds number does not make a difference. Turbulent stream speculations can be used to examine the fluid mechanics in the bioreactors over the scales.

The movement of oxygen in a fermentation broth has been investigated since the 1940s when "submerged fermentations" were first used. The subject was revisited recently (Laskin et al. 2011; Al-Rubeai 2015; Pangarkar 2015). The general oxygen request of the cells throughout the batch or fed-batch fermentation should be met by the oxygen exchange rate and the request increments as long as the quantity of cells is expanding. Generally, for each mole of O_2 used, 1 mol of CO_2 is created (Pangarkar 2015). Subsequently, an extremely high oxygen exchange rate must be achievable. This rate relies upon the mass exchange coefficient, $k_L a$(1/s), and the driving force for mass exchange, ΔC, because

$$\text{OUR} = k_L a \times \Delta C \tag{11.1}$$

Estimations of k_La provide essential data about a bioprocess or bioreactor. These calculations indicate that handling conditions provide a sufficient supply of oxygen for the expansion of cells. Likewise, k_La can be utilized to optimize control factors over the lifecycle of a bioprocess. That optimization would be founded on the oxygen request at different points in time and the development period of the organic matters. Barometers for optimization could include item yield, power utilization, or preparation time.

The oxygen exchange rate of a bioreactor is emphatically affected by the hydrodynamic conditions being utilized as part of the bioprocess (Fig. 11.8). These conditions are a component of energy scattering, which relies on the working conditions, physicochemical characteristics of a culture, geometrical variables of the bioreactor, and the attendance of oxygen-devouring cells.

During cell culture, oxygen is exchanged from a gas (commonly an air pocket or headspace) to a fluid, so it can eventually be ingested into a cell and expended. In the most straightforward terms, this procedure can be depicted as the flux over a hindrance layer communicated as a result of the driving force and mass transport coefficient (k_La) in Eq. 11.2:

$$J^0 = k_G \times \left(p_G - p_i\right) = k_L \times \left(C_i - C_L\right) \tag{11.2}$$

In that condition, J^0 is the oxygen molar flux (mol/m^{2}s) by the means of the gas–liquid network, k_G and k_L are the neighborhood mass-exchange coefficients, p_G is the oxygen halfway weight in the gas stage, and C_L is the broken-down oxygen fixation in the fluid. Index i alludes to values in the gas–liquid network.

Because interfacial focuses are not straightforwardly quantifiable, it is normal to consider a unique instance of Eq. 11.1 that portrays flux under or at harmony:

$$J^0 = k_G \times \left(p_G - p^*\right) = k_L \times \left(C^* - C_L\right) \tag{11.3}$$

In Eq. 11.3, p^* is the oxygen weight in balance with the fluid stage, C^* is the oxygen immersion in the mass fluid, and K_G and k_L are the general mass-exchange coefficients. In any case, when the dissolvability of oxygen in water is low and most mass exchange resistance is on the fluid side of the interface, the general mass-exchange coefficient can be thought to be equivalent to the neighborhood coefficient ($K_L = k_L$). Accordingly, the oxygen mass exchange rate per unit of reactor volume (dCO_2/dt) is acquired by duplicating the general flux of the gas–liquid interfacial range per unit fluid volume using Eq. 11.4:

$$\frac{d\mathrm{CO}_2}{dt} = k_L a \times \left(C^* - C_L\right) \tag{11.4}$$

The mass adjustment for the dispersed oxygen in the very blended fluid stage is portrayed in Eq. 11.5:

$$\frac{dC}{dt} = \text{OTR} - \text{OUR} \tag{11.5}$$

Here, *dC/dt* is the amassing oxygen rate in the fluid stage, *OTR* is the oxygen exchange rate from gas to fluid, and *OUR* is the oxygen take-up rate of the microorganisms. The last term can be calculated by multiplying $qO_2 \times CX$, where qO_2 is the specific oxygen take-up rate of the microorganism utilized and *CX* is the biomass fixation.

Without biomass or with non-respiring cells, biochemical responses do not occur and OUR = 0. For this situation, Eq. 11.5 can be disentangled as follows:

$$\frac{dC}{dt} = k_L a \times \left(C^* - C_L\right) \tag{11.6}$$

Because it is difficult to measure k_L and a independently, the item $k_L a$ is treated as a solitary quantifiable variable: the volumetric mass-exchange coefficient. Assurance of $k_L a$ is accomplished by recording the framework reaction following a change of the harmony oxygen fixation.

Integrating the outflow of the past condition yields Eq. 11.5:

$$\ln \frac{\left(C^* - C_2\right)}{\left(C^* - C_1\right)} = k_L a \times \left(t_2 - t_1\right) \tag{11.7}$$

Here, C_1 is the convergence of oxygen at time t_1. For example, in a framework that focuses on dispersed oxygen with an underlying estimation of 0, this equation progresses toward becoming an instance that declines the broken-down oxygen fixation:

$$\ln\left(1 - \frac{C_L}{C^*}\right) = -k_L a \times t \tag{11.8}$$

For the case of an issue that decreases the dispersed oxygen fixation, the equation moves toward becoming

$$\ln\left(\frac{C_{L0}}{C_L}\right) = k_L a \times t \tag{11.9}$$

Here, $k_L a$ is affected by numerous factors. Variables incorporate everything from a bioreactor's size and configuration to the sparging of gas, blending, cell line, media sort, temperature, pH, salt substance, and antifoaming specialists (2). When one of those elements changes, the elements of the bioprocess, including $k_L a$, also change. Given such a broad weakness, it is not surprising that genuine in-preparation $k_L a$ estimation has been constrained. Researchers have depended to a large degree

on the implicit usefulness of the bioprocesser to maintain an appropriate oxygen stream rate.

Because k_La estimations include checking levels of dispersed oxygen following a framework issue, the outcomes can be affected by the reaction time (or speed) of a sensor making those judgments. Sensors with reaction times (τr) on the request of the main demand time steady of the mass-exchange ($1/k_La$) require careful treatment of their information to account for the time delays in readings reported by the oxygen sensor.

For the impact of this effect to be negligible, a general guideline is that the sensor's reaction time must be less than one-tenth of the time required for mass exchange. If a sensor's reaction time does not meet this prerequisite, the information must be treated with Eq. 11.10:

$$C_{\mathrm{me}}\left(t\right) = C^{*} + \frac{C^{*} - C_{0}}{1 - \tau_{r} k_{L} a}\left[\tau_{r} k_{L} a e^{\frac{-t}{\tau_{r}}} - e^{\left(-k_{L} a\right)}\right] \tag{11.10}$$

in which $C_{\mathrm{me}}(t)$ is the deliberate estimation of oxygen at time t. That condition cannot be linearized, so the nonlinear fitting of the observed reaction information is required to estimate k_La.

The estimation of k_La is interesting for both the size and setup of a reactor vessel. Although some observationally inferred articulations have been defined for k_La in non-Newtonian liquids, there is not an endless supply of conditions that can influence the outcomes. Similarly, anticipating k_La is impractical, and k_La estimations should be performed only for bioreactors.

The estimation of k_La rate constants can be calculated for any reactor vessel, from a shaker carafe to the most advanced single-use bioreactor. However, the applicability of k_La to a wide range of elements likewise changes the most ideal approach to quantify it. Correspondingly, distinctions in dispensable bioreactor development and working technique indicate a need to change the general guidelines for k_La estimation. This is not very troublesome, but rather is essentially an impression of contrasts in bioreactors.

The estimation of k_La is similar for both O_2 exchange from the air to the broth and CO_2 from it. For oxygen exchange, the driving force is the distinction between the oxygen focus around the bubbles and that in the broth, which should be held over the basic dO_2 throughout the fermenter for the duration of the procedure. Likewise, the dCO_2 must be stored underneath, which will prompt a decrease in fermentation rate or efficiency.

In low-thickness frameworks, it has been reported (Pangarkar 2015) that k_La is subject to only two parameters: the aggregate mean specific energy dissemination rate forced on the framework, $\left(\overline{\varepsilon_T}\right)_g$ (W/kg) and the shallow air speed *vs* (m/s), which is equal to (vvm/60) (volume of broth) / (X – the sectional area of the bioreactor). $\left(\overline{\varepsilon_T}\right)_g$ and v_S should together be adequate to deliver the vital k_La, where

$$k_L a = A\left(\overline{\varepsilon_T}\right)_g^{\alpha} \left(v_S\right)^{\beta} \tag{11.11}$$

This equation is independent of the impeller type and scale, and α and β are generally approximately 0.5 ± 0.1 regardless of the fluid. However, A is largely dependent on the development medium characteristics (Pangarkar 2015; Kroschwitz 2007). An expansion of antifoam that decreases $k_L a$ or salts that increase $k_L a$ may prompt a 20 overlay distinction in $k_L a$ for similar estimations of $\left(\overline{\varepsilon_T}\right)_g$ and v_s. Regular estimations of $\left(\overline{\varepsilon_T}\right)_g$ are approximately 5 W/kg. For the air flow rate, there is approximately 1 volume of air for each volume of development medium (vvm). Because the estimation of $k_L a$ is comparable for both O_2 and CO_2 exchange, if scale-up is implemented at a steady vvm (or near it), the driving force for the movement of O_2 in and CO_2 out will remain basically consistent over the scales. In this scenario, because vvm scales with the fermenter volume and *vs* scales with its cross-sectional zone, *vs* is incremental. There is some deliberation about whether $\left(\overline{\varepsilon_T}\right)_g$ should incorporate the influence of the sparged air ($\approx vsg$, where g is the acceleration from gravity, 9.81 m^2/s), which becomes significant on scale-up at steady vvm. This approach should also solve issues with high dCO_2 on scale-up (Nienow 2006).

Modernization of Fermenters Using Computer Simulations

The scale-up of bioreactors is necessary to increase the amount and efficiency of manufacturing. However, the design, development, and assessment of bioreactors for large-scale production are expensive and time-consuming. Some basic restricting variables include fluid mechanics, such as incomplete mixing, supplement and oxygen circulation, and mass exchange. The yield of biomolecules in an aerobic bioreactor shifts significantly with general oxygen mass exchange ($K_L a$). To increase the yield of bioreactor operations, it is common to increase oxygen admission. However, this expanding gas stream rate also causes issues. First, it causes extreme shear force on biomolecules and cells, possibly harming them (although evidence for this in the literature is sparse). Second, extreme oxygen promotes frothing, which influences reaction volumes and thus affects efficiency. A bioreactor's operations and its surroundings are frequently determined by exploratory work, which is costly and delays production. (Biomolecular yields also rely upon biology and biochemistry; however, these topics are outside the scope of this chapter.)

Computational liquid dynamics (CLD) can be used to recreate and optimize blending, gas hold-up and mass exchange coefficients, and the dispersion of gasses inside bioreactors. Also, CLD can be used to simulate upstream operation steps, such as cleaning-in-place exercises, sanitization cycles, and the area and rates for including food, buffers, and nutrients. CLD can help to improve a bioreactor procedure by evaluating shear stresses, stream fields, and mass-exchange qualities. Downstream procedures, such as the scale-up of columns for chromatography, can

be determined using CLD. This section concentrates on the hydrodynamic and blending impacts during the scale-up of bioreactors and combined multiphase liquid-gas hydrodynamics, as well as the transfer of oxygen in conveying and mixed tank bioreactors.

Impact of Mixing

Almost all bioreactors used in industry are mixed tank reactors that include liquid blending. Vessel arrangements and impellers can affect item quality, yield, and purity. Often, a blended tank configuration results in incomplete blending. Examinations with CLD and blending speculations can provide insight into bioreactor scale-up. CLD can demonstrate blending impacts, including a forecast of mix times, control numbers, turbulence amounts, and shear amounts. CLD also tells the time-history of turbulence and shear amounts accomplished by cells in a bioreactor. These insights can be a important component for scaling-up bioreactors alongside the customary tip-speed rules or power numbers. For example, during scale-up or downsizing investigations, these forecasts can help to determine impeller rpm speeds, types, and locations. Most organizations lack the adaptability to change impellers or purchase new gear, so they must select the correct reactor vessel from the available reactors inside the facility. CLD expectations can be regularly reviewed with ease through small-scale tests, such as downsize runs. Because the fundamental principles do not vary with scale, these models can apply over different scales (Wittmann et al. 2017; Paul et al. 2004; Baltz et al. 2010).

Mass Transfer Liquid-Gas Impact

In large-scale aerobic bioreactors, oxygen is typically a constraining component because of its low dissolvability into culture media. Dispersed oxygen concentrations are required to meet basic oxygen requests by microorganisms (Flickinger 2013; McDuffie 2013; Nielsen et al. 2012). The rate of air decreases below a dispersed oxygen concentration of 0.005–0.02 mM/L for most life forms. This should be unsurprising over a range of scales that can span four levels of magnitude between laboratory research and production levels. In mammalian cell-culture bioreactors, CO_2 generation and outcome mass exchange are also of importance.

The modelling perspective portrayed here for oxygen exchange is sufficiently general to be applied when investigating CO_2 development. The mixing consistency is basic for oxygen circulation in a bioreactor; however, different variables affecting mass exchange include bubble size dispersion, dispersed oxygen concentration, and liquid pressure. Bubble size determines the accessible interfacial ranges for liquid-gas mass exchange and is influenced by parameters such as turbulence, shear rate, and buoyancy. Bubbles disperse and join together due to their associations with

turbulent swirls, which provides conveyance for a range of bubble sizes. When bioreactors are scaled up from the research laboratory to production size, their design must meet both oxygen conveyance and oxygen mass exchange requirements. Therefore, a precise predication of bubble size conveyance is required to determine the stream attributes and interfacial zones for heat and mass exchange computations (Nielsen et al. 2012; McDuffie 2013).

Planning

A bioreactor outline and scale-up comprehension can be increased through orderly modelling trials that start with blending investigations using CLD and blending speculations. In an organized display approach, blending can be considered and later consolidated with multiphase stream flow using bubble connections and size distribution to foresee gas–liquid mass exchange. A summary of approaches to address foreseeable oxygen exchange for bioreactors is presented here, with testing approval for two contextual analyses. An arrangement of a populace adjustment equation for bubble number thickness is combined with CLD estimations to anticipate bubble measure distribution. For the two cases considered here, the gas hold-up and fluid volumetric mass exchange coefficients were both observed to be in complete concurrence with trial results. The advantages of an appropriate plan include monitoring hazards during scale-up and decreasing downtime.

Configuration of Fermentation Vessels

This section explores the engineering applications and aspects of a range of fermentation technologies, as well as the advantages and drawbacks of the individual technologies. The fermentation techniques discussed here include surface/tray, trickle-bed setups, continuous, air-lift loop, batch, submerged, and semi-continuous. As mentioned previously, almost all of the technologies have broad applicability.

Fermentation in Batch Bioreactors

Many fermentations are batch-wise (Fig. 11.12). A batch fermenter with a stirred system is an upright, closed, tube-shaped vat with baffles connected to the wall, a water coat or heating/cooling convolution, a gadget for persuasive air circulation (called a sparger), a mechanical stirrer that generally has two or more impellers, a way to introduce nutrients and organisms, a way to collect samples, and outlets for releasing gasses. Today's fermenters are often computerized and generally have methods for constantly observing, recording, or controlling pH, oxidation/reduction

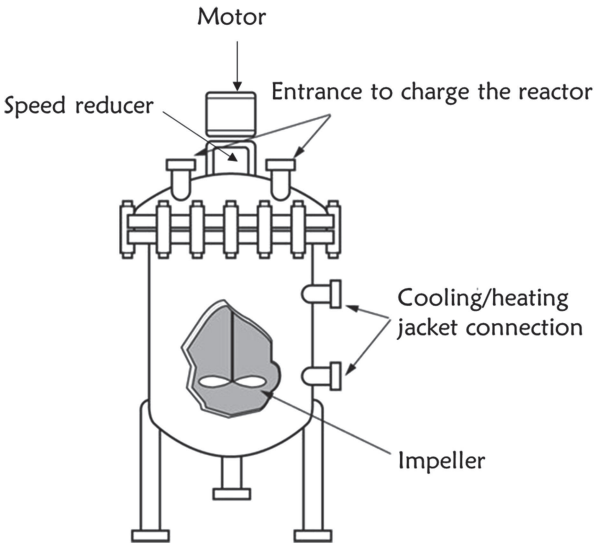


Fig. 11.12 Batch reactor diagram

potential, dissolved oxygen, CO_2 and O_2 effluent, and fermentation compounds. However, a fermenter without all of these gadgets can still be operated manually.

The primary part of batch fermentation is usually sterilization. Then, the disinfected medium is injected with microbes that were selected to attain a particular outcome. Throughout a vigorous reaction, cells, substratum, vitamins, nutrient salts, and aggregations of the item fluctuate with time. The correct admixture maintains the variations in characteristics and temperature at satisfactory levels. To achieve aerobic growth, the environment is aerated to produce a never-ending flow of a chemical element. Frothy byproducts (similar to CO_2) are removed, and gas-shifting and aeration procedures occur virtually ceaselessly. An alkali or acid is intercalary if the pH scale must be governed. To maintain adequate frothing levels, antifoaming agents may also be intercalary if required by a foam-sensing element.

A large chrome-steel batch bioreactor for manufacturing beer is shown in Fig. 11.1. (A batch bioreactor is analogous to the fermenter showed in Fig. 11.3, although without the reprocess loop.) One of the main types of batch systems is the receptacle bioreactor, which is used for economical aerobic bioreactions for items such as acids and antibiotics. In this system, the plates are filled with the medium as well as the microbes; furthermore, the airflow gives rise to the fermentation, during which the exhalation gas is released (Najafpour 2006; Cinar et al. 2003). Once the fermentation is complete, the final result is far from the plates. Thus, this technique is ineffective for manufacturing large commercial quantities. It drops rapidly to the edge and exposes the immersing tank systems, which are planned to hold considerably higher capacities.

Generally, batch fermentation systems have a variety of benefits, including the following: smaller risk of poisoning or cell change, because of a comparatively transient extension amount; less capital risk than continual procedures for a similar

fermenter volume; additional adaptability for a variety of objects and biotic systems; and greater product transformation levels because of confidence in the development quantity (Cinar et al. 2003). The drawbacks include the following: lower efficiency levels because of the time required for cooling, sterilizing, heating, filling, evacuating, and cleaning the fermenter; multiple target instrumentations because of the recurring need for sterilization; greater cost associated with the need for many subcultures for immunization; higher prices for task and/or method management because the method is not continuous; and the risks associated with large-scale industrial sanitation, such as possible contact with unhealthy microbes or toxins. Typical implementation problems for batch fermenters include the following: a need to create the item with a reduced risk of pollution or microbe mutation; operations in which only very small quantities of items are created; a method that utilizes one reactor to create a variety of products; and techniques during in semi-continuous or batch item break-up is suitable.

Tubular Fermenters

The tube-shaped fermenter received its name because it looks like a tube. Tubular fermenters are usually continuous unperturbed fermenters in which the reactants progress in a predictable route. Reactants enter from one side and evacuate from the other side, with no stirring. Because of the lack of stirring, there is a progressive reduction in the concentration of substrate between the inlet point and the outlet; at the same time, the product expands similarly.

Fermentation in Continuous Bioreactors

A continuous mixed fermenter is basically like a batch fermenter, with a difference in the inlet and outlet media. An explanation of the attributes of continuous fermentation is very involved. A culture environment, which is either aseptic or contains microbes, is constantly added into the fermenter to maintain a consistent state (Chen 2013; El-Mansi et al. 2011). The product is also removed constantly from the fermenter. Reaction factors and constraint factors are stable, allowing for a consistent state inside the fermenter (El-Mansi et al. 2011). The outcome is continuous profitability and yield.

This setup has a number of potential advantages, including the following: expanded possibility for procedure automatization; lower task cost because of robotization; reduced unprofitable time associate with purging, filling, and sanitizing the reactor; reliable item quality because of consistent operating conditions; reduced danger to staff because of mechanization; and decreased stress on equipment from sanitizing. The disadvantages of continuous fermenters include the following: limited adaptability, even when only slight varieties in the procedure are

needed (e.g., throughput, environment, oxygen temperature, fixation); obligatory consistency of crude materials to guarantee that the procedure remains continuous; larger capital investment in the charge and mechanization of the vessel; greater costs for the continuous sanitation of the environment; higher operating costs with the nonstop recharging of insoluble, strong substratum, such as straw; and greater danger of tainting and cell transformation because of the moderately short development timeframe. A continuous bioreaction is sometimes used for procedures with high-volume generation; techniques using gas, fluid, or dissolvable substrates; and methods including microbes with high change dependability. Typical finished products include vinegar, processed wastewater, and baker's yeast.

Fermentation Using Semi-continuous Bioreactors

Semi-continuous bioreactors use a hybrid method of continuous and batch functioning in a variety of procedures. Most commonly, the fermentation begins in a batch system, until the development-restricting substrate has taken over (Lim and Shin 2013; El-Mansi et al. 2011). At that point, the substratum is bolstered to the fermenter as indicated (batch) or is maintained by an increased culture time (continuous). For auxiliary metabolite generation, in which cell development and item creation regularly happen in distinct stages, the substrate is usually included at a predefined rate. Like batch fermenters, semi-continuous fermenters do not stop operating.

This setup has a number of advantages, including the following: increase yield, resulting from a very defined development period during which no cells are added or removed; more opportunities to optimize the environmental conditions of the microbes concerning the period of development or generation and maturation of the culture; and almost stationary functioning, which is vital for transforming organisms and those at risk for tainting (El-Mansi et al. 2011). The disadvantages include the following: lower efficiency levels because of the time-consuming need for filling, warming, sanitizing, cooling, discharging, and cleaning the fermenter; greater labor costs; and potentially powerful process control requirements for the procedure. Semi-continuous fermenters are typically used when continuous techniques are not feasible, such as when slight transformation or pollution of the organism occurs. These fermenters are also used when batch techniques do not provide the desired efficiency levels.

Mixed Tank: Submerged Bioreactors

The most well-known oxygen-consuming bioreactor being used today is the mixed tank reactor (El-Mansi et al. 2011; Saxena 2015; Inamdar 2012). Ideal for large-scale implementations, this bioreactor requires low capital and has low task expenses. For research center investigations with small volumes, the stirring vessel

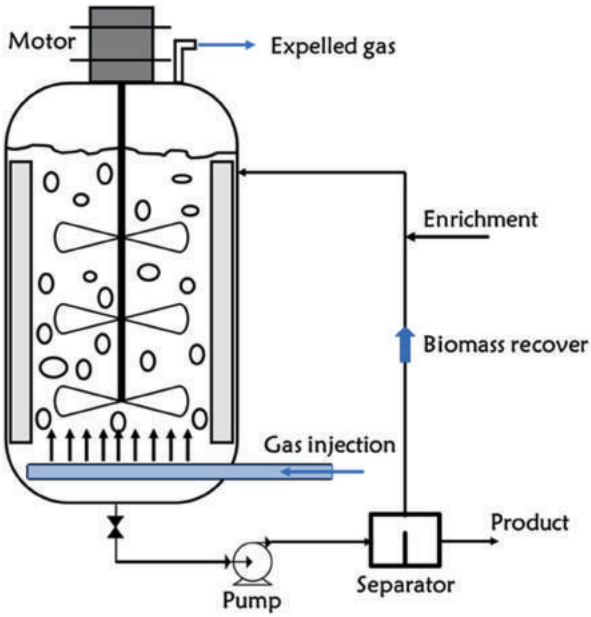


Fig. 11.13 Stirred tank – submerged bioreactors

is normally contained in glass. A stainless-steel vessel is used for large-scale (industrial) implementations. The height-to-diameter ratio of the vessel can vary based on the evacuation requirements.

The operating standards of a mixed tank bioreactor are generally basic. As shown in Fig. 11.13, the inoculum and clean medium is brought into a disinfected tank, and the air injection regularly infiltrates at the base. For ideal stirring, the tank highlights an instigator system as well as confounds, which have a whirlpool effect that could obstruct legitimate stirring. In the beginning of the procedure, warm water may be passed through the baffles to warm up the equipment; afterward, cold water could be circled within them to protect against overheating. The number of baffles commonly ranges from 4 to 8. As the fermentation advances, the bubbles delivered by the air injection are isolated by the fermenter as they progress upward.

A variety of fermenters are currently in use. The most widely recognized is the four-bladed circle turbine. More modern designs have 12 or 18 sharp edges, or sunken ones, which seem to enhance the hydrodynamics. At the highest point of the tank, gas fumes are released and the item streams down, where it is removed from the tank. In a constant-stream mixed tank reactor, the substrate is continuously sustained in the framework and the item is consistently removed and isolated, with the substrate returned once again into the tank for reuse. Likewise, with uniform chemical reactors, bioreactors can be used in parallel or series with controlled reuse streams.

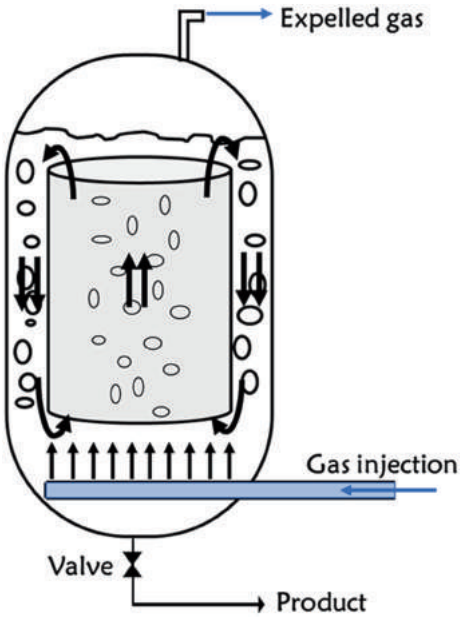


Fig. 11.14 Airlift bioreactor

Airlift Reactor Equipment

In an airlift reactor (also called a tower reactor), the bubble column includes an assembly conduit (Saxena 2015). Various airlift reactors are being used today. Air is commonly sent via an irrigator into the base of a median draft tube, which guides the flow of air and the milieu (Fig. 11.14). Gas goes up the tube, shaping bubbles, and gas fumes separates at the highest point of the section. Degassed fluid then descends, and the item is depleted from the tank. The tube is intended to act as an interior heat exchanger; otherwise, a heat exchanger could be attached to an inward flow loop (Saxena 2015).

The airlift approach has a few benefits over other customary bioreactors, such as the classical fermenter. For example, it has a straightforward design with no moving parts or fermenter shaft seals, which requires less maintenance, has less danger of deformities, and needs less demanding sanitation. Furthermore, it has a smaller shear rate for more prominent adaptability, the ability to be used to develop both animal and plant cells; effective gas-stage withdrawal; a substantial and defined interfacial contact zone with less energy input; a highly controlled stream and productive stirring; well-characterized residence time for all stages; expanded mass-exchange because of the improved oxygen solvency accomplished in extensive tanks with more noteworthy pressures; the possibility for large-volume tanks and thus expanded yield; and greater heat release compared with customary mixed tanks.

The fundamental weaknesses of this approach include the following: higher start-up capital investments because of the large-scale procedures; more prominent air throughput and high pressures required, especially for large-scale operation; limited abrasion with an ideal pressure driven diameter for the ascender and downcomer; limited productivity of gas pressure; great difficulty in maintaining steady levels of substratum, supplements, and oxygen with the microbes circling through the bioreactor and states transforming; and wasteful gas/fluid detachment while frothing occurs. However, these disadvantages can and should be controlled for when planning airlift frameworks. For example, if just a single area serves as the sustain source, the microbe would encounter endless cycles of high development followed by starvation; this would cause undesirable results, low yields, and high death rates. A design with numerous sustain points would eliminate this hazard, particularly for large-scale operations. Similar dangers are found with a solitary passage point for oxygen; oxygen should be transmitted at different places inside the vessel, with most of the air entering at the base to circle the liquid through the reactor.

External-Loop Airlift Reactors

Another kind of airlift technology is the airlift external-loop reactor system (AELR), which is generally used for a batch system. The AELR illustrates a different perspective, where the downcomer and vessel are actually higher than they

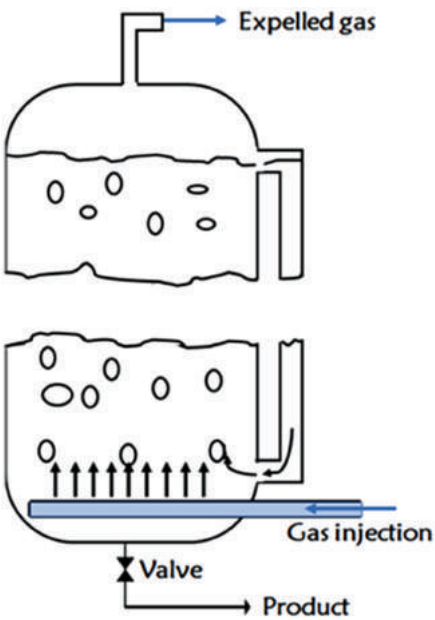


Fig. 11.15 External-loop airlift bioreactor

appear for the specific extended diameter (Fig. 11.15). As a variation of the airlift technique, the AELR uses a prompted course to coordinate air and fluid throughout the vessel. This approach comprises a riser and an outer downcomer, which are associated with the base and the top, respectively (Saxena 2015). As infused air at the base of the riser makes gas bubbles that start to ascend through the principal tank, gas fumes separate at the top; the subsequent dense solution drops through the downcomer.

The AELR has a few advantages over the classic airlift technique, including the following: effectual heat exchange and productive temperature control; a small abrasion with an ideal pressure-driven width for both the downcomer and riser; a highly defined time for the individual segments of the AELR; an expanded open door for estimation and control in the riser and the downcomer; and free control of the gas input-rate and fluid speed by a throttling gadget in the riser and downcomer.

Fluidized Bed Fermenters

Fluidized bed fermenters are similar to tube-shaped fermenters. In both continuous mixed fermenters and tube-shaped fermenters, there is a genuine threat of the microorganisms being drained. The fluidized bed reactor addresses this issue as a hybrid of the mixed tank and tubular tank setups. The organisms in a fluidized bed fermenter are maintained in suspension by a circulating rate whose power adjusts to gravity. If the movement was smaller, the bed would stay settled. If the circulating rate was at a higher speed than the mass of the organisms, elutriation would occur, with the organisms being drained from the fermenter.

Anaerobic Bioreactions

Anaerobic bioreactions occur within a number of setups, such as ethanol creation, winemaking, lager blending, and wastewater treatment. Advances have been reported for wine, ethanol, and lager creation due to product changes and decreased assembly costs. Consistent bioreactors have been marketed for brewing, but group fermenters continue to receive capital investments. Waste treatment is a field that has developed because of very useful innovations in setup; however, not as much consideration has been given to creating more modern wastewater treatment systems.

Conclusion

Today, fermentation operations are under pressure from demands for changes to product ranges and the scale of manufacturing. This can be ascribed to a variety of factors, including large-scale bioprocesses and improved fermentation techniques, which have prompted the advancement of new fermented foods. To drive these procedures—both new and old—a comprehensive understanding of food fermentation is required. Policymaking has also played a part in hastening improvements within this industry. For example, modern policies have expanded research and development investments for new equipment designs, and in addition to guiding the directions, standards, and licensed innovations that address the issues resulting from increased production. Thus, this chapter presented an outline of various aspects of modern bioreactors and innovations in the industry. The nutritional status of fermented foods can likewise be enhanced by the informed selection of maturing organisms with respect to the human diet and gastrointestinal microbiota. In this regard, fermented food could be viewed as an augmentation of food absorption and aging procedures; thus, it could be designed to provide valuable benefits to human health and well-being. Another planned technique to increase the metabolic efficiency of bioprocesses is the use of appropriately controlled ultrasonication, which can be used at the biocatalyst level (cells and catalysts) to improve their capacity and sonobioreactor execution.

References

Adams RD (1985) Vinegar. In: Wood B (ed) Microbiology of fermented foods. Elsevier, Philadelphia, pp 1–49

Al-Rubeai M (2015) Animal Cell Culture. Cell Engineering, vol 9. Springer International Publishing. https://doi.org/10.1007/978-3-319-10320-4

Anon (2008) Whitbread's Brewery - Incorporating The Brewer's Art (Paperback). Read Books, United Kingdom

Baltz RH, Demain AL, Davies JE (2010) Manual of industrial microbiology and biotechnology. ASM Press, Washington, DC

Briggs DE, Boulton CA, Brookes PA, Stevens R (2004) Brewing science and practice. Woodhead Publishing Limited and CRC Press LLC, Cambridge

Bylund G (1995) Cultured milk products. In: Dairy processing handbook. Tetra Pak Processing Systems AB, Lund, pp 241–262

Campbell-Platt G (1994) Fermented foods – a world perspective. Food Res Int 27:253–257

Chandan RC (2014) Dairy – fermented products. In: Clark S, Jung S, Lamsal B (eds) Food processing: principles and applications, 2nd edn. Wiley, Chichester, pp 405–436

Chen H (2013) Modern solid state fermentation: theory and practice. Springer Netherlands, Dordrecht

Cinar A, Parulekar SJ, Undey C, Birol G (2003) Batch fermentation: modeling: monitoring, and control. CRC Press, New York

Clark S, Costello M, Drake MA, Bodyfelt F (2009) The sensory evaluation of dairy products. Springer, New York

Corrieu G, Monnet C, Sepulchre AM (2005) Use of strains of Streptococcus thermophilus which are incapable of hydrolyzing urea in dairy products. USA Patent
Demeyer D, Stahnke L (2002) Quality control of fermented meat products. In: John K, David L (eds) Meat processing: improving quality. Woodhead, Cambridge, UK, pp 359–393
Doran PM (2013) Bioprocess Engineering Principles. Engineering professional collection. Waltham, M. A. & Academic Press, 225 Wyman Street, Waltham, MA 02451, USA
El-Mansi EMT, Bryce CFA, Demain AL, Allman AR (2011) Fermentation Microbiology and Biotechnology, Third Edition. CRC Press, Taylor & Francis group, Boca Raton
Eva H, de la Hoz L, Juan AO (1997) Contribution of microbial and meat endogenous enzymes to the lipolysis of dry fermented sausages. J Agric Food Chem 45(8):2989–2995
Flickinger MC (2013) Upstream industrial biotechnology, 2 volume set. Wiley, New York
Gänzle MG, Ehmann M, Hammes WP (1998) Modeling of growth of Lactobacillus sanfranciscensis and Candida milleri in response to process parameters of sourdough fermentation. Appl Environ Microbiol 64(7):2616–2623
Gupta BS, Ibrahim S (2013) Mixing and crystallization: selected papers from the international conference on mixing and crystallization held at Tioman Island, Malaysia in April 1998. Springer Netherlands, Dordrecht
Hills M (2014) Cider Vinegar. 2nd edn. Sheldon Press, Great Britain
Hutkins RW (2006) Microbiology and technology of fermented foods. Blackwell Publishing, Ames
Inamdar STA (2012) Biochemical engineering: principles and concepts. PHI Learning, New Delhi
Inui M, Vertes AA, Yukawa H (2010) Advanced fermentation technologies. In: Vertes AA, Qureshi N, Blashek HP, Yukawa H (eds) Biomass to biofuels. Blackwell Publishing, Ltd, Oxford, pp 311–330
Kroschwitz JI (2007) Kirk-Othmer encyclopedia of chemical technology, vol 25, 5th edn. Wiley, Hoboken
Laskin AI, Sariaslani S, Gadd GM (2011) Advances in Applied Microbiology, vol 77. First edn. Academic Press, San Diego, USA
Leistner F (1992) The essentials of producing stable and safe raw fermented sausages. In: Smulders FJM, Toldrá F, Flores J, Prieto M (eds) News technologies for meat and meat products. ECCEAMST, Audet Tud – schreen, B.V., Utrecht, pp 1–19
Lim HC, Shin HS (2013) Fed-batch cultures: principles and applications of semi-batch bioreactors. Cambridge University Press, Cambridge
McDuffie NG (2013) Bioreactor design fundamentals. Elsevier Science
Mulchandani A, Bassi AS, Nguyen A (1995) Tetrathiafulvalene-mediated biosensor for L-lactate in dairy products. J Food Sci 60:74–78
Najafpour G (2006) Biochemical Engineering and Biotechnology. First edn. Elsevier Science, New York
Nielsen J, Villadsen J, Lidén G (2012) Bioreaction Engineering Principles. Second edn. Springer USA
Nienow AW (2006) Reactor engineering in large-scale animal cell culture. Cytotechnology 50:9–33
Nienow AW, Edwards MF, Harnby N (1997) Mixing in the Process Industries. Second edn. Butterworth-Heinemann, Johannesburg
Nienow AW, McLeod G, Hewitt CJ (2010) Studies supporting the use of mechanical mixing in large scale beer fermentations. Biotechnol Lett 32(5):623–633. https://doi.org/10.1007/s10529-010-0213-0
Nienow AW, Nordkvist M, Boulton CA (2011) Scale-down/scale-up studies leading to improved commercial beer fermentation. Biotechnol J 6(8):911–925. https://doi.org/10.1002/biot.201000414
Pangarkar VG (2015) Design of multiphase reactors. Wiley, Hoboken
Park YW (2009) Bioactive components in milk and dairy products. Wiley, Ames

Paul EL, Atiemo-Obeng VA, Kresta SM (2004) Handbook of industrial mixing: science and practice. Wiley, Hoboken
Saxena S (2015) Applied microbiology. Springer India, New Delhi
Tamime AY (2008) Structure of dairy products. Wiley, New York
Toldrá F (2008) Meat biotechnology. Springer, New York
Toldrá F (2010) Handbook of meat processing. Wiley, Oxford
Toldrá F, Sanz Y, Flores M (2001) Meat fermentation technology. In: Hui YH, Nip WK, Rogers RW, Young O (eds) Meat science and applications. Marcel Dekker, New York, pp 537–563
Toldrá F, Hui YH, Astiasaran I, Sebranek J, Talon R (2014) Handbook of Fermented Meat and Poultry. Second edn. Wiley, Oxford, UK
Watanabe K, Fujimoto J, Sasamoto M, Dugersuren J, Tumursuh T, Demberel S (2008) Diversity of lactic acid bacteria and yeasts in Airag and Tarag, traditional fermented milk products of Mongolia. World J Microbiol Biotechnol 24:1313–1325
Wittmann C, Liao JC, Lee SY, Nielsen J, Stephanopoulos G (2017) Industrial Biotechnology: Products and Processes, vol 4. Advanced Biotechnology, First edn. Wiley-VCH, Germany

Résumé du livre

Modernization of Fermenters for Large-Scale Production in the Food and Beverage Industry

Steve Carly Zangué Desobgo*

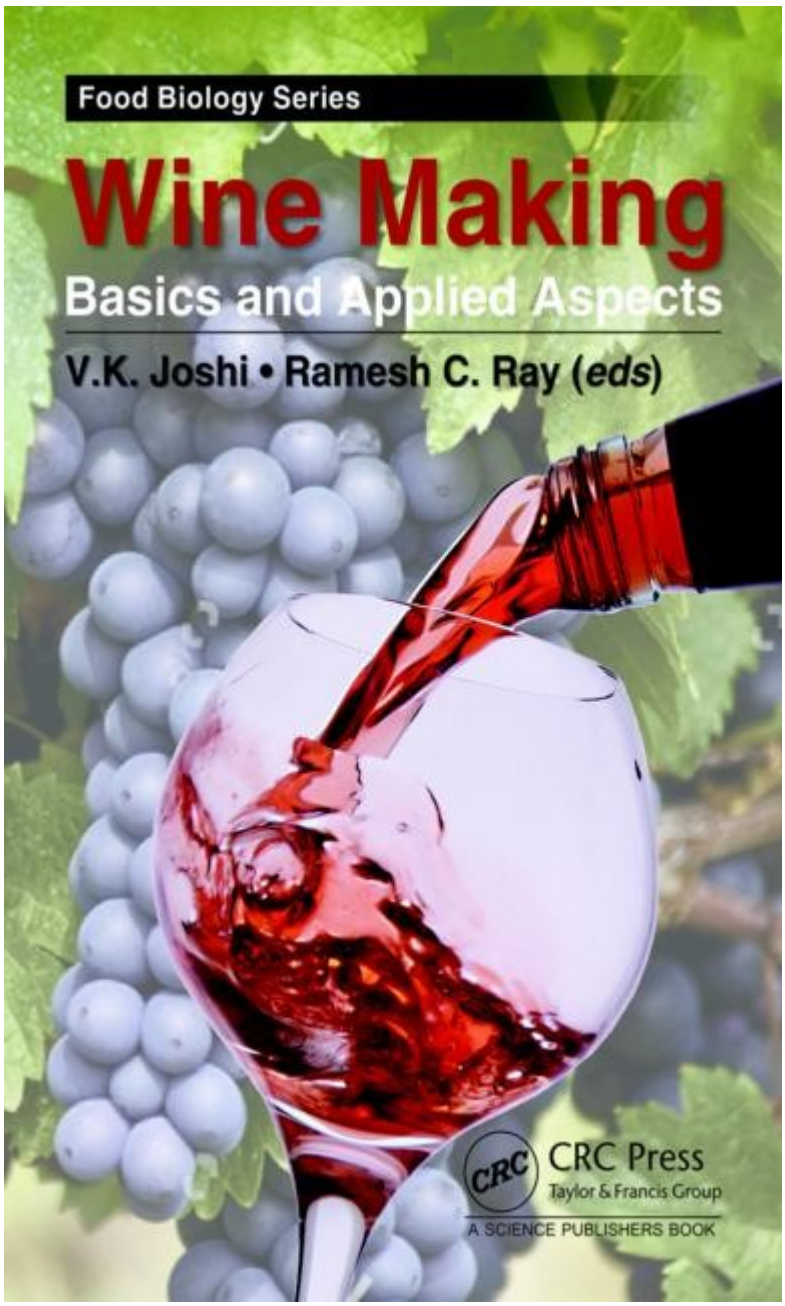
Abstract

Fermentation is an inexpensive and low-energy method of conserving decomposable unprocessed materials. Many foods have microbial sources or include components generated by fermentation using microorganisms. This procedure is helpful for extending the usability of food and drinks, as well as improving the health benefits of products. This chapter examines the modern aspects of food and beverage fermentation in large-scale fermenters. Descriptions of fermenters and their underlying technology are provided for each case to demonstrate the link between the equipment and the process. Engineering characteristics are reported for bioreactor scale-up, including important problems in the scaling and exploitation of bioreactors. Agitation in bioreactors is also discussed. Some aspects associated with bioreactor/fermenter design when computer simulation is used are reported. Finally, the technology of modern bioreactor types is presented.

Keywords: Fermentation, Microorganism, Scaling up, Bioreactor, Food, Beverage, Technology

IV.4.14) Chapter 19: Winemaking: Control, Bioreactor and Modelling of Process

Titre du livre



Wine Making: Basics and Applied Aspects

1st Edition

V. K. Joshi, Ramesh C. Ray

CRC Press

February 15, 2020 **Forthcoming**

Reference - 700 Pages - 4 Color & 160 B/W Illustrations

ISBN 9781138490918 - CAT# K349988

Series: Food Biology Series

Comité de lecture

CRC Press
Taylor & Francis Group

Contact Us Menu

Editorial Contacts

Our editorial staff is fully equipped to handle a wide variety of inquiries.

Please contact an editor if you are interested in publishing a book with CRC Press, copublishing, sponsoring or contributing to a series or book, or have ideas for one. (links are to direct e-mail address).

Business & Management

Kristine Mednansky

Disciplines: Healthcare Administration, including Lean & Quality Management; Patient Safety; Financial Management; Strategy & Leadership; and Information Management

Tel: (630) 482-9886

Michael Sinocchi

Disciplines: Lean Manufacturing & Lean Service; Quality & Six Sigma; Product Development; and Supply Chain Management; Green Manufacturing & Sustainability; Lean & Quality Improvement

Tel: (212) 216-7867

Biological Science

Randy Brehm

Disciplines: Agriculture, Crop Science, Forestry, Horticulture, Plant Sciences, Soil Sciences, Wildlife Science

Tel: (561) 361-6088

Chuck Crumly

Disciplines: Cell, Developmental, and Molecular Biology; Microbiology; Virology; Systematics; and Evolution

Tel: 510-710-2712

Alice Oven - Senior Editor

Disciplines: Disciplines: Botany; Ecology; Zoology; Evolutionary Biology; Animal Science;

Veterinary Science; Laboratory Animal Science; and Marine Science
Tel: +44 (20) 755 19992

Renu Upadhyay

Disciplines: All Areas
Tel: +91 11 4315 5159

Chemistry

Fiona Macdonald/Publisher - Senior Publisher

Disciplines: Chemical Information; Handbook of Chemistry & Physics
Tel: (561) 998-2564

Barbara (Glunn) Knott

Disciplines: Analytical Chemistry; Industrial and Applied Chemistry; Materials Chemistry and Physical Chemistry
Tel: (207) 672-3857

Hilary LaFoe

Disciplines: Organic and Inorganic Chemistry, Environmental Chemistry, Green Chemistry, Pharmaceutical Science, Sustainable Science & Drug Discovery
Tel: +44 (0)7717 800251

Renu Upadhyay
Disciplines: All Areas
Tel: +91 11 4315 5159

Computer Science

Rick Adams

Disciplines: Computer Science, Gaming, and Graphics
Tel: (614) 446-2151

Randi Cohen

Disciplines: Computer Science
Tel: (757) 240-7501

Sean Connelly

Disciplines: Game Development, Animation, Web Design/Development
Tel: (781) 313-8822

Engineering

Cindy Carelli

Disciplines: Manufacturing Engineering & Quality; Reliability Engineering; Industrial Engineering; Ergonomics & Human Factors; Operations Research; Industrial Hygiene; and Occupational Health & Safety
Tel: (352) 536-9510

Marc Gutierrez

Discipline: Biomedical Engineering and Biotechnology, Electrical Engineering and Optical Sciences
Tel: (561) 998-2528

Nora Konopka - Editorial Director

Disciplines: Electrical Engineering; Computer Engineering; and Nanotechnology
Tel: (561) 998-2531

Kyra Lindholm

Disciplines: Mechanical, Aerospace/Aviation, and Nuclear Engineering
Tel: (561) 430-4848

Ed Needle

Disciplines: Construction and Real Estate
Tel: +44 (20) 701 76142

Jonathan Plant

Disciplines: Mechanical, Aerospace, and Nuclear Engineering
Tel: (781) 635-5004

Allison Shatkin

Disciplines: Chemical Engineering; Materials Science and Engineering; Plastics & Polymer Engineering; Petroleum Engineering
Tel: (561) 843-8407

Gagandeep Singh

Disciplines: Engineering
Tel: +91 11 431 555 180

Environmental Science

Nora Konopka/Publisher

Tel: (561) 998-2531

Léon Bijnsdorp

Disciplines: Conference Proceedings in Engineering, Earth Sciences, & Water Sciences
Tel: +31-71-524-3089

Janjaap Blom/Publisher

Disciplines: Geotechnical Engineering; Earth Sciences; Water Sciences; & Energy
Tel: +31-71-524-3080

Alistair Bright

Disciplines: Geotechnical Engineering; (Renewable) Energy
Tel: +31 71 524 3088

Joe Clements

Disciplines: Civil Engineering; Environmental Engineering; Water Engineering & Science; Clean Tech & Renewable Energy
Tel: (561) 361-6016

Tony Moore

Disciplines: Civil Engineering; Environmental Engineering; Water Engineering & Science
Tel: +44 (20) 701 76672

Irma Shagla Britton

Disciplines: Earth Sciences and Environmental Sciences, GIS, and Remote Sensing

& Cartography
Tel: (561) 361-6067

Forensics and Homeland Security

Mark Listewnik

Disciplines: Forensics Science
Tel: (508) 614-1467

NOTE: In 2016, the CRC Press Criminal Justice books were unified with the Routledge imprint. You can find Editorial Contacts for criminal justice and criminology at: https://www.routledge.com/contacts/editorial

Food Science

Steve Zollo

Disciplines: Food Science & Culinary Arts
Tel: (561) 998-2547

Information Technology (IT)

Rich O'Hanley - Senior Publisher

Disciplines: Communications Engineering & Networking; Information Security; Physical Security; and Applied Manufacturing
Tel: (917) 351-7146

He Ruijun

Disciplines: Communications & Networking; Information Security; Physical Security; Applied Manufacturing Software Engineering; Systems Development; Database; and IT
Tel: +86 10 5845 2830

John Wyzalek

Disciplines: Project Management; Information Technology; Software Engineering; Data Analytics and Big Data
Tel: (917) 351-7149

Mathematics
Sunil Nair - Editorial Director

Disciplines: Mathematics, Financial Mathematics, Computational Biology, Imaging Sciences, and Visualization
Tel: +44-20-7017-6346

Bob Ross

Discipline: Mathematics
Tel: (781) 535-9277

Callum Fraser

Discipline: Mathematics: includes Financial Mathematics, Recreational Mathematics, Discrete Mathematics, Applied Mathematics, Pure Mathematics, and more
Tel: +44 20 701 74000

Aastha Sharma
Discipline: Mathematics, Statistics, Physics and Computer Science (South Asia)
Tel: (91) 11 43155175

Medicine

Joanna Koster
Senior Publisher Disciplines: Undergraduate Textbooks and Revision Guides; Non-Clinical Medicine including skills and training, medical education, healthcare systems and services; Anatomy & Physiology; Emergency Medicine; General Practice; General/Internal Medicine; Medical Genetics; Medical Imaging; Occupational & Environmental Medicine;
Tel: +44 (20) 337 73780

Miranda Bromage

Disciplines: Surgery and Surgical Specialties, ENT, Orthopedics & Trauma, Urology, Forensic Medicine, Neurology, Pathology
Tel: +44 (20) 755 19463

Robert Peden

Disciplines: Dermatology & Cosmetic Science, Cosmetic Dentistry, Gynecology & Obstetrics, Reproductive Medicine, Women's Health, Fetal Medicine, Pediatrics & Neonatology, Oncology & Palliative Medicine
Tel: +44 (20) 701 76674

Shivangi Pramanik

Disciplines: Cardiology, Endocrinology & Diabetes, Microbiology & Infectious Disease, Pulmonary Medicine, Public Health & Preventative Medicine, publishing for the Indian subcontinent
Tel: +91 11 4315 5210

Nutrition

Randy Brehm

Disciplines: Clinical Nutrition; Nutrition Science; and Sports Nutrition
Tel: (561) 361-6088

Physics

Francesca McGowan (covered by Rebecca Davies)

Discipline: Physics, including Astronomy, Condensed Matter, Geophysics, High Energy, Medical Physics, Biophysics, Nuclear, Particle, Plasma and Sensors

Rebecca Davies

Discipline: Physics, including Astronomy and Astrophysics, Popular Science, Condensed Matter, Geophysics, High Energy, Medical Physics and Biomedical Engineering, Biophysics, Nuclear, Particle, Plasma and Sensors

Statistics

Rob Calver

Discipline: Statistics
Tel: +44-20-7017-6334

David Grubbs

Discipline: Statistics
Tel: (561) 998-2524

John Kimmel

Discipline: Statistics
Tel: (949) 391-8329

CRC Press Editorial Staff

Table des matières

For Instructors Request Inspection Copy

Select Format:

Hardback

Quantity:

1

GBP £190.00

Availabe for Pre-Order. This item will ship after February 15, 2020

Pre-Order

Add to Wish List

FREE Standard Shipping!

Additional Book Information

Table of Contents

Introduction: Wine and Wine Making. Compositional, Nutritional, Therapeutic Value of Wine and Toxicology. Wine as A Complete Functional Beverage: A Perspective. Grape Varieties for Wine Making. Advances in Fruit Ripening, Maturation and Harvest of Fruits. Advances in Fruit Ripening, Maturation and Harvest of Fruits. Varietal Impact on Wine Quality and Aroma. Positive and Negative Aspects of Botrytis in Wine Production. Genetic Engineering in Fruit Crops. Wine Making: Microbiology. Wine Fermentation Microbiome: An Overview of The Yeasts Ecology. Wine Yeast: Physiology and Growth Factors. Malolactic Bacteria in Wine making. Biochemistry if Wines. Genetic Engineering of Microorganisms in Wine Making. Oenological Enzymes. Additives, Adjuvants, Packages, Closures and Labels in Enology. Biogenic Amines in Wine. Immobilized Yeast in Wine making. Wine making: Control, Bioreactor and Modeling of Process. Wine Maturation and Aging. Wine Making: Basic and Recent Developments. Cider. Bandy Production: Fundamentals and Recent Developments. Bioaugmentation and Bio valorization of Winery Wastes and Waste Water. Advances in Analytical Techniques in Enology. Advances in Analytical Techniques for The Determination of Toxic Components, Microelements, Aroma Compounds and Therapeutic Significance. Astringency and Color of Wine: Role, Significance, Mechanism and Methods of Evaluation

Instructors

We provide complimentary e-inspection copies of primary textbooks to instructors considering our books for course adoption.

Pages du chapitre

19 Winemaking: Control, Bioreactor and Modelling of Process

Steve C.Z. Desobgo[1*] and Emmanuel J. Nso[2]

[1] Department of Food Process and Quality Control, University Institute of Technology of the University of Ngaoundere, P.O. Box 455, Ngaoundere, Cameroon

[2] Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI), University of Ngaoundere, P.O. Box 455 ENSAI, Ngaoundere, Cameroon

1. Introduction

Agribusiness is embedded in production systems; hence the many current procedures subject to in-depth studies on methods to develop better systems for safety and quality. It is the way to ensure the quality and respect for the requirements of security, the system costs and natural effect. Among the classification (specifically structuring, preservation, separation and bioconversion) of nourishment forms, bioconversion incorporates most likely the biggest class of procedures. It is focal in the generation of maturing foods with some outstanding cases from the winemaking factory. Winemaking is customarily considered to be beginning with the blending of the berries and the introduction of yeast to realise fermentation. Innovation, smashing and regular squeezing could be viewed as the final stages of the vineyard operation. The control of quality of wine is basically essential. Institution study has accentuated the necessity to examine vulnerability to oxygen, extraction management of the substances from the skin, temperature monitoring amid fermentation, observing of sugar depletion and monitoring of microbes and malo-lactic fermentation. At present, the search is on for better quality items, keeping in mind that the general utilisation of wine is reducing, interest in astounding wines is expanding. Buyers are drinking less though 'better'. Wine producers throughout the world are consolidating winemaking techniques of centuries with new methodologies and thoughts, to satisfy purchaser's interest for better item quality and a maintainable and healthy lifestyle.

This chapter presents an overview of winemaking, monitoring, safety and quality control, which display the activities concerning each unit operation, the bioreactor characteristics and uses and finall , innovative approaches aimed at optimising the process efficienc .

2. Overview of Winemaking

2.1 Juice Extraction

As soon as grapes are received in the winery, they ought to be destemmed as well as squeezed with the particular ultimate objective to extract the juice (Soufleros, 1997a; 1997b). Likewise, care should be taken to keep the seeds in place. At the point when the outer securing seed shell is cracked, the huge measures of phenolic substances that the seeds hold, will concede to the wine and impart it an astringent taste (Ough, 1992). In the wake of stemming and pulverising, the juice moves into either a device used for draining, or a significant holding vessel or the concerned red grapes inside a fermenter. Within white cultivars, the prompt expulsion of juice in the peels and seeds is basic, as there are important measures of tannin-like substances in the peels. The touch between peel and juice (in the wake of pulverising) outperforms at 12 hours as the usual basement temperature might be destructive to the consequent wine and the degree of sensory characteristics that are involved (Ough, 1992). The must, to be transformed for white wine, is expelled from the skins, as they remain an important wellspring of regular microbial action and the level of phenol removal from the skins is restricted (Boulton *et al*., 1996). Mash should be right away removed

*Corresponding author: desobgo.zangue@gmail.com

from the factory as it rapidly attracts dreadful little animals and diverse aggravations (Vine *et al*., 1997). Of course, the juice from red grapes is less fragile than the white must and is not trailed by the systems, previously fermentation, since they are performed prior to it. Besides, the contact between peel and juice is appealing in red wines since the phenolic substances should be expelled from the seeds and should persist in the completed wine. The slurry is sent for pressing and the squeezed juice is incorporated in the key squeeze must and the crushed slurry ought to be separated and sent to the winery.

White juice is cleaned in the wake of pressing with a particular but ultimate objective to diminish the suspended grape compounds. Universally, a depletion of particles to less than 0.5 per cent is appropriate. This methodology can be reached by crisp falling or using mechanical methods. Sometimes, the extension or addition of pectolytic enzymes can help in clarification of juice. Starting late, there has been a more noteworthy use of them with a particular objective to quicken the wine clarification, subsequent to fermentation. It is perfect to incorporate the catalysts at this advanced step because the high ethanol contents achieved following fermentation tend to repress the activity of the enzyme (Tucker and Woods, 1996). Particles in juice provide a site to mature yeasts for CO_2 and ethanol release. Extraordinary refining of juice reduces the number of cells in the normal yeast concentration, reducing or annihilating their duty regarding ethanol (Wood, 1998).

Juices are much of the time put away to be utilised as a refreshing part or to raise the time of fermentation. Capacity states must be checked (PCO_2< 3.5 atm, pH: 3.0 to 3.5, T < 2 °C) to hinder the improved decay of microbial cells (Fugelsang, 1997). Juices should be set up in one of the following ways: sulphating, chilling, juice concentration and cross-stream microfiltration (Boulton *et al*., 1996).

2.2. Juice Preparation

Modification of the must before fermentation engages the winemaker to begin fermenting with every juice part. This process much of the time requires no less than one of the backing tasks: nutrient, SO_2 and catalyst incorporation, acidity, oxidation of juice (Boulton *et al*., 1996). The fitness of the additional substances and their estimations need to be mastered (Tartaric acid: 0.5 to 1 g/L, Tannin: 5 g/L, $CaCO_3$: 0.5 to 1 g/L,) (Soufleros, 1997a)

At the point when the juice stabilises, the fermenters are loaded with juice having enough SO_2 and the yeast inoculum is incorporated. Care must however, be taken for the estimation of sulphur dioxide (<200 µg/mL juice), as over-the-top measure of it can realise yeast restraint and give a sulphur dioxide odour to the completed wine (Fugelsang, 1997). It is a direct but essential operation to incorporate an active yeast strain of *Saccharomyces* in the form of inoculum, to finish the alcoholic fermentation instead of relying upon the local microbial population(Lea and Piggott, 1995). The yeast strains might be observed imperceptibly to ensure that the ferments are of the vital sort and not that oxidative ferments and organisms are present (Fugelsang, 1997).

2.3. Fermentation

Fermentation ought to be the ‘centre’ of winemaking as the sugars of grape are transformed into alcohol by *Saccharomyces cerevisiae*. The nearness of increased heat (10-30°C) in the midst of fermentation can provoke destruction of the yeast inoculum and the impact of the all the more thermo-resistant microorganisms to finish the fermentation and plan unwanted side effects (Fugelsang, 1997). Berries, not strongly treated with pesticides in the farm can in addition be a source of the problem (Sala *et al*., 1996). The extraordinary contamination with moulds, lactic and acetic acid organisms on grapes previously accumulated can convey some components that may ruin or obstruct yeast development in the midst of ethanolic fermentation (Wood, 1998). Also, an extreme extension of SO_2 can eradicate the predominant piece of appealing and unwanted cell and present a damaging impact on the wine flavour (Fugelsang, 1997). The nearness of ethyl carbamate concentration (<30 ppb) is a creation threat that might be viewed as critical as it is accepted to be cancer-causing (Fleet, 1994). That chemical is conveyed in the midst of the fermentation when having high heat in the direction of the completion of fermentation. Ferment strains that make a little estimation of urea are introduced and the farm is arranged vivaciously with characteristic compounds (Boulton *et al*., 1996).

2.4. Malo-lactic Fermentation (MLF)

After ethanolic fermentation, wine regularly encounters the malo-lactic fermentation (MLF), that continues around 14 days to a month. Lactic acid organisms, occupant in the wine, are responsible for the MLF; however, various winemakers enable this deacidificati n by incorporation with strains of *Leuconostoc oenos*. The MLF realises a reduction in the taste of wine and an increase in its pH by around 0.3-0.5 units. That fermentation, however, is not helpful to every wine. Wines made of grapes developed in more hotter environments showed the tendency of being not so much acidic (pH > 3.5) and additionally fall in acidity should be malevolent to sensory characteristics. Also, the growth of MLF increases their pH to levels where crumbling microorganisms are more prone to develop (Wood, 1998). In cold climates, deacidification by MLF is desired so as to make the wine drinkable (Lea and Piggott, 1995).

At the point, when aging bubbles have crossed out of a direct recurrence, the novel wine might be racked off the gross stay in clean storage tanks (Vine *et al*., 1997). Beginning hereon, for the term of the wine life, it should be essential to ensure that it is secured in compartments which are finished fully. Preventing air contact with the wine diminishes the first experience with oxygen which is a section for oxidation and the advanced deterioration of living cells (Soufleros, 1997b).

The common tried guidelines in mixing of wine are tantamount to imparting the assorted characteristics of distinctive wines in the wine getting a more extensive and fulfilli g solicitation. Wines might be stirred prior to stabilisation in view of the fact that the various components required for steadiness, once in a while result in stable wines combined to shape a balanced wine (Vine *et al*., 1997).

Just prior to fermenting and packing of wines, they are cleared up by utilising more than one method, which consolidates extension of fining materials (bentonite, egg whites, isinglass, gelatine) layer filtration and centrifugation (Ough, 1992). Frost stabilisation could then begin. It is finished by putting away the wine in a chiller at 3-2°C for not less than 21 days. This operation can generally be reduced by the incorporation of potassium bitartrate powder, that should be separated by using filtration into residue (Vine *et al*., 1997). Wine precariousness can be expedited by numerous substances (synthetic, microbiological) and negatively affects wine quality. Moreover, Cu and the high iron compound can raise medical issues and need to be watched and cut down (Cu < 3 µg/mL wine, Fe < 12 µg/mL wine) by mixing. The genuine issue is metal in wine after the fermentation (Soufleros, 1997b). It can happen from components settling in the wine or vessel comprising these metals. Thus, it is essential to screen the metal substance (Pb <0.3 µg/mL wine, As <0.01 µg/mL wine) (Soufleros, 1997a).

2.5. Maturation

White wines start to mature when the yeast ends fermentation. When these yeasts are eliminated, wines are close to being drinkable. Certain white wines are matured in barrels. This generally is on the side of wines which will be traded at high expenses. Red wine maturation is more expanded than white (Ough, 1992). During maturation, each and every wooden vessel loses a little wine content because of absorption and leakage. It is basic to avoid air entrance to the wine in containers, especially to maintain a strategic distance from oxygen-devouring microbial growth. Each barrel might be precisely analysed at the minimum of four weeks in order to make up to the full capacity of wine. A couple of winemakers prefer ‘’wet-bung’’ barrels prior to filling as a means to remember the ultimate objective of diminishing the risk of bacterial contamination in barrels via the bunghole (Vine *et al*., 1997). Exactly as soon as red wines begin developing in barrels (or something else), the mind should be applied to inspecting for unwanted microbes and changes in shade, smell or flavou . Mix-ups in too little sulphur dioxide can generate wine spoilage by acetic acid bacteria and yeast (Ough, 1992).

Barrels are hard to clean and routinely hard to sanitise in case they appear to be corrupted with unwanted microbes and could be ousted from the winery. However, it is inconceivable since it could be damaging due to ethyl carbamate formation that is tumour-causing. Plus, ethyl carbamate could be formed in the midst of maturation as soon as there are urea build-ups which elevate the temperature. In this way, it must be measured prior to wine bundling (Gump and Pruett, 1993).

2.6. Packaging

The packing procedure is usually a wonder among the most joyful processes. During winemaking, genuine consideration must be given to the observance of hygienic practices (Vine *et al*., 1997). The

bundled wine is relied upon to be free of residual microbes. Wines are clarified through depth filters prior to their entry into the bundling vessel. Almost all issues arose due to the wrong utilisation of hygienic filtration procedure. The filter and notwithstanding the bundling line might be cleaned before the wine output. Air expulsion or counteractive action of the packing line is basic. The essential site where the wine is in connection with air is at the level of the filler bowl. The volume above the liquid in the bottle, in order to cover, could be blown with carbon dioxide or N_2 ahead of plugging (Ough, 1992). New bottles should be flushed frequently with extremely hot water and used jugs ought to have been sanitised when they were depleted, and held topsy turvy. Apparatus could be steam-sanitised. The filling equipment was seen to be the best explanation behind tainting, alongside the corking (Vine *et al*., 1997).

The stopper ought to be accurately treated and the neck of the jug should be of the most ideal size. Attention should be paid that the plugs don't have a bit of fragment or striations which could create spillage. The moistness of the plug is pivotal and might be 5-7 per cent (Ough, 1992). If it is bigger, it will be airtight too quickly. Stopper pollution is regarded as a noteworthy imperfection in packed wine. Stopper disease lead to a foul and off-flavou . It is seen that the most ideal approach to reduce the event of plug imperfection is to restrain the extreme conditions for microbial growth on the stopper by regulating the water activity (Fleet, 1994). Up-to-date stopper suppliers furnish sterile stoppers. In case of vulnerability, plugging might be done prior to being used in a solution of sulphur dioxide concentration of 10 g/hL (Marriott, 1994). Labels are a straightforward piece of trading wine. The paper should be rub-confirm, water-safe and preserved through fast bundling lines. Beyond this, it is basic to be coded in the event that there is an issue in the packed wine (Ough, 1992). Transport and storage of wines are normally not beneath the winemaker's mastery. Noteworthy harm is expected in packed wine as soon as it is predisposed to over abundance of heat or chill (Ough, 1992).

Just before the red wine is involved, de-stemming is vital to be executed cautiously in the production of red wine, as the stalk stores are not cancelled prior to the completion of fermentation and thus have a detrimental impact on the sensory attributes. At whatever point, the stalks are withdrawn from the contact with the pounded grapes by using a broadened time of less than two hours, a 'stemmy' off-nature might occur in wine. Also, the methodologies of skin dissociation and wet mash crushing are realised by following the fermentation method utilised for white wine production (Ough, 1992).

Wine is unreasonably acidic due to the development of pathogens. Various life forms don't survive in lesser pH medium (Speck, 1984). Microbes giving rise to wine deterioration are predominantly primitive yeasts and other bacteria. Basic deterioration yeasts include *Candida*, *Pichia* and different *Saccharomyces* spp. that cause development of films on the top of the wine. Wine-crumbling microorganisms are fundamentally lactic acid and acetobacters bacteria (Forsythe and Hayes, 1998). The best control method is keeping the perishing grapes away.

3. Monitoring Safety and Quality Control

3.1. Gathering/Harvesting

Grape gathering is a Critical Control Point (CCP1) accommodating chemical and physical risks (Table 1). Materially, grapes might be gathered in the absence of ruined parts, principally oxidation and pollution from microorganisms which can quickly grow.

In this way, gathering might be dovetailed with the best feasible precautions and a systematic contamination control method must be executed (Ellison *et al*., 1998; Dibble and Steinke, 1992). Pesticides play an unequivocal part in disturbance administration; in any case they should be taken care of deliberately in the light of the chemical dangers they present (Maner and Stimmann, 1992). At the season of gathering, the grapes should have accomplished proper development when acidity levels and Brix display matureness of wine. Because chemical sediments on top of the berries represent chemical risks, studies suggest a quick and fundamental gas chromatographic technique for their estimation (Oliva *et al*., 1999). The best progress borders for insecticides in wines and grapes are granted by the Codex Alimentarius (Codex, 1998) and OIV (Organisation International du Vin) (OIV, 1994). In the end, mass receptacles utilised for grapes transferral must be successfully sanitised to stay away from any microbial contamination.

Table 1. Activities Concerning Security and Quality Control for Harvesting

		Quality	*Safety*
Harvesting/ Gathering (CCP 1)	Risks/Cause	• Untimely grapes gathering • Overripe grapes gathering • The hurt of grapes due to lack of precautions • Piteous gathering techniques • Mould contagion from affected grapes • *Penicillium* and *Aspergillus* infection of grapes • Growing of *Acetobacter* on grapes • Traces of iprodione, vinclozolin, procymidone in the grapes	• Pesticide trace • Unwanted substance from the soil • Infection of gathering equipment
	Precaution measures	• Quotidian precaution amid gathering • Mature grapes gathering • Gathering workers with experience • Conscientious compliance of MRLs • Control of sugars and acid concentration in grapes • Acceptable cleaning of the gathering machines • Use SO_2 for mould contamination of grape	• Apply attention during gathering • Harvest uncontaminated grapes • Scrupulous conformity of MRLs • Cleanliness rehearses application to stay away from the pollution of grapes
	Severe factors/ limits/ Controls	• Determination of grapes density • Determination of grapes acidity • Checking on grapes integrity • Determination of insecticide residue content of grapes • Check-up of grapes amid harvesting • Investigation of cleanliness application amid collecting	• Determination of insecticide residue concentration • Auditing of hygienic methods amid gathering • Inspection of harvesting equipment hygiene

Source: Adapted from Kourtis and Arvanitoyannis, 2001

3.2. Stemming

Stemming (CCP 2, Table 2) considers the elimination of leaves, grape stalks and stems prior to beating. This system has a few purposes of interest since the entire volume of the disposed items falls by 30 per cent, as needs demand bringing about littler tanks and subsequently increasing the ethanol concentration. Regardless of this, the completion of fermentation and the ethanol concentration of the completed wine rely generally on the sugar concentration of grapes. Stemmers mostly comprise a pierced cylinder for berries to experience yet preserve the area of stems and stalks.

3.3. Blending

Blending/crushing (CCP 3, Table 3) ordinarily instantly takes place in the wake of stemming. Released juice is especially prone to browning due to oxidation and microorganism pollution. The immensely acknowledged squeezing forms incorporate pressing the fruits in contact with a punctured equipment or directing the berries via rollers. It is fundamental to go without pulverising the seeds to protect against polluting the must with oils from the seed. Its oxidation could produce unwanted smells and represent an unpleasant fountainhead of acrid tannins. Essentially, it is fundamental to have the most ideal treatment of the product, since wrong arranging may incite an unexpected start of ethanolic fermentation and therefore lead to highr temperature of fermentation. though a recess may generate microbe pollution and browning (Zoecklein *et al*., 1994).

Table 2. Activities Concerning Security and Quality Control for Stemming

		Quality	*Safety*
Stemming (CCP 2)	Risks/Cause	• Stem residue in grapes (red winemaking) • *Botrytis cinera* infection of grapes • Grapes contamination by foreign matter coming from equipment	• Infection of grapes coming from bad cleaning • Foreign matter of grapes coming from equipment
	Precaution measures	• Destemming maintenance of equipment • Manual elimination of external material from grapes • Prevention of grapes degradation using SO_2 • The utilisation of cold water for adequate cleaning of destemmer	• GMP (Good Manufactured Practice) and sanitation amid destemming • Equipment and environment sanitation in the winery
	Severe factors/ limits/controls	• GMP control (red winemaking) • Convenient expulsion of mold tainted grapes • Sulphur dioxide (40 mg/L) estimation of the grapes • Monitoring of destemmer refreshing	• Mastery of GMP and hygiene amid destemming • Mastery of hygienic techniques for traces of microorganisms and traces of clearing in the destemmer

Source: Adapted from (Kourtis and Arvanitoyannis, 2001

Table 3. Activities Concerning Security and Quality Control for Crushing/Blending

		Quality	*Safety*
Crushing/ blending (CCP 3)	Risks/Cause	• Oxidation of must • The increment in the measure of mass in the must • Contamination of must with metal compound coming from apparatus	• Infection of must via insufficient clearing (deposits of microbes, traces of chemicals) • Must contamination by external matter coming from apparatus
	Precaution measures	• Application of GMP during crushing • Sufficient space between crushing cylinders • The absence of air amid squashing	• GMP and sanitation amid crushing • Utilisation of authorised cleaning agents
	Severe factors/ limits/controls	• Monitoring and application of GMP amid crushing • The environment of crushing air control • Crushing equipment cleaning and control	• Control of GMP and hygiene amid destemming • Must supply time in the blenders <2 h • Cleaning of blending equipment at the end of two days • Dissociation of blending equipment: maximum possible • Sanitation mastery and GMP request amid blending

Source: Adapted from Kourtis and Arvanitoyannis, 2001

3.4. Maceration/Squeezing/Pressing

Maceration is the dislocation of grapea by mashing them. As long as maceration is continually required in the underlying period of red wine fermentation, the long-time practice has led to less soaking in the manufacture of white wine. Span and temperature of mashing depend on wine and grape cultivar.

Conventionally for rose wines and white wines, the time of maceration is below 24 hours – red scheduled for early use, is macerated during three to five days and red for fermentation, is soaked between 120 hours to 21 days. Fermentation all the more regularly occurs in the midst of this or in the direction of the termination of maceration. The quantity of the antimicrobes to be utilised, generally in addition to the musts of white wine which is most sensible to oxidation, relies on the gathering prosperity and maceration heat. SO_2 has an extraordinary favoured viewpoint above alternative antimicrobial substances, as a consequence of the comparative passiveness of the wine ferments to its activity. Notwithstanding this, it is moreover deadly, or hindering, to nearly all yeasts and microorganisms (*Hansenula, Pichia* and *Candida*) in little amounts (Farkas, 1984) and has a fairly reduced retentiveness limit following the clarification stage (Gnaegi *et al*., 1983). The juice is permitted to stay in the press for a time, in the midst of which juice flows out under its own gravity. Being dependent on the press, the obtained must and wine portions differ in regards to their physico-chemical characteristics. Joining various wine parts, the winemaker influences the wine character. In any case, a potential peril might exist in the reaction of oxidation if there is an interference in the procedure (Lichine, 1985).

3.5. Ethanolic Fermentation

Ethanolic fermentation is ordinarily completed by *Saccharomyces cerevisiae* strains since this type is particularly resistant to the large amounts of sugar, ethanol and SO_2 and besides,to lesser pH (3.2-4) for grape juice. The strains of *Saccharomyces cerevisiae* are one constituent of the endogenous microbial population or might be to some degree included in attaining a density of approximately 10^5-10^6 cells/mL in the juice (CCP 4, Table 4) (Constanti *et al*., 1997).

Feasible pollution of juice with 'killer' yeasts (quality generally displayed in undomesticated *Saccharomyces* strains, furthermore in the alternative genus of yeast, for instance, *Cryptococcus, Torulopsis, Pichia, Kluyveromyces, Hansenula, Debaryomyces* and *Candida,*) could lead to bad fermentation (Van-Vuuren and Jacobs, 1992). Thought should be paid to the extra measure of SO_2 (175-225 µg/mL for white and red wine, independently) remembering the true objective is to prevent, if not to eradicate, the majority of wild yeast masses of grapes (Sudraud and Chauvet, 1985) and furthermore acidity management, and to Brix and tannin amount of the must. In fermentation, the accomplished chemical risks contain toxic metals (As <0.2 µg/mL, Cd <0.01 µg/mL, Cu <1 µg/mL, Pb <0.3 µg/mL), methanol amounts (300 µg/mL and 150 µg/mL for red wine and white wine, exclusively), EC amounts, insecticide traces and detergents (non-attendance) and ethylene glycol (non-appearance).

Attention should be paid with respect to the EC amount, in light of the fact that there is no enactment opposed to it in Europe, but it is so in USA (<60 ppb and <15 ppb for dessert and table wines, exclusively). The latter is confirmed from the chemical reaction of ethanol with materials rich in amino acids, basically, amino acids and urea like citrulline and arginine. Its management including gas chromatography (GC) measurement and evasion can be done by preventing concentrated fertiliser treatment of vines, elevated temperatures for conclusion or after ethanolic fermentation, utilising yeast strains for smaller ethyl carbamate and urea creation, using an enzyme and testing urea when prolonged storage is required.

The temperature of fermentation is noteworthy among the most basic factors affecting the metabolism of yeast, both clearly and in a roundabout way. For red and white wines, the appealing temperature vacillates to the extent of 8-15°C and 25-28°C, separately. Any existence of leftover sugars (fructose, glucose, sucrose) before the completion of fermentation is a risk that may create microbial destabilisation of wine.

The system of fermentation needs no oxygen. Nonetheless, residual oxygen towards the beginning of the exponential stage of yeast development quickens the fermentation, considering that the yeast cell number rises and the ordinary cell gets viability augmented. The pH (<3.0) may impact the procedure exactly at extraordinary levels where the advancement of fermentation yeasts is quelled (Zoecklein *et al*., 1994).

At long last, the fungicide in the must may accept improvement of yeast inhibition and hinder the sensory characteristics of wine by affecting biosynthetic metabolisms (Pilone, 1986; Cabras *et al*., 1988; Fatichenti *et al*., 1984).

Table 4. Activities Concerning Security and Quality Control for Fermentation

		Quality	*Safety*
Fermentation (CCP 4)	Risks/Cause	• Development of troublesome bacteria in the fermenters • Stuck fermentation • Loss of wine aroma profil • Acetic acid and H_2S production • Oxidation because of air entrance in the fermenters • Sugar fermentation into lactic acid • Glycerol lactic fermentation • Tartaric acid lactic fermentation • Augmentation of wine viscosity • Abnormal proceeding amid fermentation • Fermentors breaking because of high temperature or CO_2	• EC production • Cleaning chemicals residues in fermentors • Other residues from pre-fermentation phases (yeasts, bentonite) • Extreme injection of SO_2 in the fermented must
	Precaution measures	• Use of SO_2 to prevent wine spoilage • Application of authorised SO_2 limitations • Injection of favoured ferment strains into preceding inoculation • Introduction of yeasts nutrients • Maintain fermentation range temperature by utilising the automatic cooling system • Clean fermentors • Stabilise fermentation temperature • Pump-over process (for the manufacture of red wine)	• GMP and sanitation amid destemming • Insertion of sulphur dioxide < 200 µg/mL fermented juice • Sanitation of fermenters • Setup of small temperature in bioreactors • injection of special yeasts inside the preceding inoculation
	Severe factors/ limits/ controls	• White wine fermentation temperature: 10-21°C • Red wine fermentation temperature: 20-30°C • Must aeration amid the first two days of fermentation • Monitor yeast injection • Authorised SO_2< 200 mg/L must • Juice gravity control amid fermentation • Monitoring of pump-over process	• Mastery of GMP and cleaning amid destemming • EC content: <30 ppb in the fermented must • Authorised sulphur dioxide < 200 µg/mL fermented juice • Fermentor cleaning management • Yeast purity control and safety • Temperature control amid fermentation

Source: Adapted from Kourtis and Arvanitoyannis, 2001

3.6. Malo-lactic Fermentation (MLF)

Early beginning and achievement of MLF incite development of SO_2 and stockpiling at chill temperatures and clearing. It is driven, using lactic acid (LA) organisms (*Oennococcus oenos*) that clearly decarboxylate the L-malic acid to L-lactic acid. This change achieves acidity reduction and pH increase, that are linked to the extended drinkability and creaminess of red wines (Davis *et al*., 1985; Guzzo *et al*., 1998). The underlying pH, the sulphite capture (Vaillant *et al*., 1995), the anthocyanin and the phenolic amount

(Vivas *et al*., 1997) of must/wine unambiguously impact in the case, giving rise of MLF. Phages could truly interrupt MLF by affecting the *Oennococcus oenos* along these lines, creating destabilisation of wine microflora (Gnaegi and Sozzi, 1983). In this way, to ensure the progression of MLF, winemakers inject the fermented juice with no less than one *Oennococcus oenos* strains (CCP3, Table 5) (Nielsen *et al*., 1996; Nault *et al*., 1995). After fermenting, the wine's accepted total acidity is believed to differ inside to the extent of 0.55-0.85 per cent. At any point, total acidity beats the breaking points and fermentation and deacidification techniques are set up (Jackson, 1998)

Table 5. Activities Concerning Security and Quality Control for MLF

		Quality	*Safety*
Malolactic fermentation (CCP 5)	Risks/Cause	• Augmentation of wine pH • Reduction of wine acidity • Degradation of wine taste	• Microbiological contamination
	Precaution measures	• Injection (inoculation) of malolactic yeasts	• Certified suppliers, strictly following instructions
	Severe factors/limits/ controls	• Controlling the pH of the wine • Controlling the acidity of the wine • Wine pH <3.5	• Microbial analysis

Source: Adapted from Kourtis and Arvanitoyannis, 2001

3.7. Maturation/Aging

The maturation step regularly keeps going from six months to one year in oak barrels. Amid maturation, a score of chemical and physical interactions occur inside the barrel, the encompassing environment and the wine in maturation, prompting a change of savour and characteristics of wine (Martinez *et al*., 1996). At this level, we have a CCP (CCP 6, Table 6) regarding the oak vessel, which is expected to be flaw-free and ought to have been subjected to disinfecting processing.

The wood likewise should be exempted from noticeable or unpleasant smells, which pollute the fermented must (Mosedale and Puech, 1998). During the aging period, a few compounds of the wood are deleted to tannin of wine (Viriot *et al*., 1993; Towey and Waterhouse, 1996). Since oak tannins could essentially increase wine savour, white wines are generally aged in oak for a smaller time than red wines and in prepared oak containers to discharge a smaller amount of extractable tannin (Popock *et al*., 1984; Quinn and Singleton, 1985).

One more CCP is marked with the restraint of air infiltration along wood or amid racking and inspection of wine. In spite of the fact that a little oxidation is alluring, a more substantial one could generate different sensory modifications, for example, oxidised smell, browning, colour loss in red wines, yeast activation and bacteria spoilage, ferric casse development and tannin precipitation (Ranken *et al*., 1997). Restrains on free and total sulphur dioxide amounts in completed wine vary from nation to nation.

3.8. Clarification

Clarification includes physical methods for evacuating the floating particles. Must clarification by filtration, centrifugation, or racking frequently enhances the savour improvement in white wine and supports the avoidance of spoilage by microorganisms. Assuming that an adequate period is given, fining and racking could create stable, completely clear wines; however, now that premature packaging in months or 14 days following fermentation is utilised, filtration and centrifugation are done to facilitate the required clearance amount (Ribereau-Cayon *et al*., 1998). Pollution of wine by microorganisms amidst the previously stated techniques causes a possible issue for its steadiness (Ubeda and Briones, 1999). Racking is likewise powerful on insecticide traces and lessening of wine (Gennari *et al*., 1992).

Table 6. Activities Concerning Security and Quality Control for Maturation/Aging

		Quality	*Safety*
Aging/ Maturation (CCP 6)	Risks/ Cause	• Wine sensory characteristics modificatio • Barrel flavour in the win • Oxidation of wine • *Dekkera, Brettanomyces, Pechia, Candida,* development in the fermented must • *Acetobacter* development in the fermented must	• DMDG wine residue • EC in wine • Wine contamination by the development of microorganisms in barrels • Wine contamination from the dirty winery
	Precaution measures	• Prevention of wine spoilage by adding SO_2 • The use of N_2 to remove O_2 from wine • The barrels must be kept totally full • Barrels must be carefully cleaned • Tight-bunged barrel • Maturation of wine using always wetted bung • Maturing wine temperature (<12°C)	• Attentive barrel clearing • Utilisation of new oak vessels • Attentive winery clearing • Keeping small temperature amid maturation
	Severe factors/ limits/ controls	• Monitoring of SO_2 concentration (>3 µg/ mL wine) • Monitoring of keeping temperature (<12°C) • Monitor odour of empty barrels • Monitor oxygen absence amid wine maturation • Monitoring spoilage bacteria in wine • Monitoring barrel cleaning methods	• EC in wine measurement • Monitoring of barrel clearing methods • Mastery of the suitability of the barrels • Monitoring of winery cleaning methods • SO_2 measurement in wine (>3 mg/L)

Source: Adapted from Kourtis and Arvanitoyannis, 2001

3.9. Fining/Stabilisation

The purpose behind fining is the creation of a lastingly clear and flavoured flaw-free wine. Nearly all essential strategies incorporate a) fining using tartrate by cooling the matured wine to close to its freezing temperature and afterward filtra ion or centrifugation is executed to evacuate the solids, b) protein fining with fixing, neutralisation, or degradation by bentonite is carried out (Blade and Boulton, 1988), c) polysaccharide expulsion is done with enzymes which hydrolyse the macromolecule, perturbing its defensive colloidal activity and membrane stopping characteristics (Ribereau-Cayon *et al*., 1998), and d) stabilisation of metal casse (Fe, Cu) (CCP 7, Table 7) is initiated.

Ferric casse is monitored using the expansion of bentonites and proteins by adjusting the aggregation of ferric complexes which are insoluble, though wines with Cu content more noteworthy than 0.5 µg/mL are especially vulnerable to Cu casse development (Langhans and Schlotter, 1985). Legitimate remaining Cu levels in completed wines fluctuate and not all strategies for Cu evacuation are authorised in all the countries.

3.10. Bottling

Wine is packed in glass containers covered with stopper. The container might pass a sanitising stage and an examination to ensure the non-appearance of any inadequacy (CCP 8, Table 8) and the steadiness of the wine until its gobbling (Cooke and Berg, 1984).

The stopper must be well sized, 6-7 mm higher than the inside neck diameter of the bottle, to abstain from any feasible leaks. In packaging, all three risks might be found. In special, stopper microorganism, heavy metals traces, SO_2, insecticides and detergents, and non-appearance of cracks, scrapes and fissures in the lute speak for physical, chemical and microbiological risks.

Table 7. Activities Concerning Security and Quality Control for Stabilisation/Fining

		Quality	*Safety*
Fining/ Stabilization (CCP 7)	Risks/Cause	• Fining chemical residue in the wine • The residue of lees in the wine • Wine over finin • Agents of adsorption in the wine • Brown cloudiness of wine • Cloudiness of wine due to microbes • Cloudiness of wine due to Fe^{2+} • The turbidity of wine due to Cu^{2+} • The turbidity of wine due to colloidal substances	• Impure addition compounds in the wine • Traces of stabilisation chemicals in the wine • Traces of poisonous metals in wine • Residues of chemical substances in wine
	Precaution measures	• Use of dosage pump to add a fining agent • Dissolution of fining chemical in wate • Quick withdrawal of lees residues from wine • Introduction in chilly weather environment of the fining agen • Prevention of deterioration by adding SO_2 • Storage of wine far from sun and air • Addition of bentonite	• Authorized substances addition according to legislation • Addition of authorised substances for wine stabilisation • Authorised substances for addition
	Severe factors/limits/ controls	• Monitoring of the addition of agent solution in the wine • Monitoring of lees traces in the wine • Control of over treatment of trub in the wine • Control of weather environments amid finin • Monitoring of fining chemical traces in the wine • Oxidase measurement in wine • Microscopic check-up of wine for microbes • Fe^{2+} <12 µg/mL wine • Cu^{2+} <3 µg/mL wine	• Monitor the purity of fining agent • Monitor the authorised substances • Monitor the residues of fining chemicals in the wine • Monitoring of authorised additives • Metal limits estimation (As <0.01 µg/mL, Cu <0.1 µg/ mL, Pb <0.3 µg/mL wine)

Source: Adapted from Kourtis and Arvanitoyannis 2001

Although cork is important for its non-reactive property when touching the wine, it could generate unwanted flavours when polluted (Simpson *et al*., 1986; Simpson, 1990) or when winemakers are not executing functional quality control (Neel, 1993). The control for the stopper is non-appearance of yeast and LAB and which could be verified by microbial test. When a long maintenance period of wine is predicted, higher and denser stoppers are favoured since a long exposure bit by bit influences the stopper integrity. When forcing the cork into the bottle neck, attention should be paid to stop the development of microbes inside the equipment (Malfeito-Ferreira *et al*., 1997; Ubeda and Briones, 1999) and the lead transfer to wine through the wine-stopper-capsule method (Eschnauer 1986), and the oxidation during packing by washing out the glass containers with CO_2. Stopper placing might also happen under vacuum. The empty space occupied by oxygen could impact the item quality by giving rise to the disease of the 'bottle'. The containment limit for sulphur dioxide is 175-225 µg/mL respectively for red wine and white wine. Nearly <0.2 µg/mL, Cd <0.01 µg/mL, Cu <1 µg/mL, Pb <0.3 µg/mL traces of insecticides and pesticides in the completed item, are given by Office International de la Vigne et du Vin (OIV, 1994).

Table 8. Activities Concerning Security and Quality Control for Bottling

		Quality	*Safety*
Bottling (CCP 8)	Risks/Cause	• Deterioration microbes in wine bottles • The growth of moulds in wine bottles • Leakage of wine from bottles • Oxidation of wine enhancing loss of sensory characteristics • Foreign substances in wine coming from bottles	• Undesirable substances in the wine and coming from glass containers and filling equipmen • Residues of clearing agents in the fermented must • Pollution of wine from the winery • Development of microbes in glass containers polluting the wine • Development of microbes in filling equipment pollute the wine
	Precaution measures	• Mechanical and chemical cleaning of bottles • Bottling as stated to legislation • SO_2 addition in wine before bottling • Removal of air in wine using N_2	• Cleaning of bottles • Sanitation of bottles line • Sanitation of winery
	Severe factors/ limits/controls	• Monitoring of wine cleaning methods • Control of bottles visually and microbiologically • GMP monitoring application during the bottling of wine	• Cleaning of bottles methods • Monitoring of GMP during the bottling of wine • Hygiene control measurement for bottles line, bottles and environment • Microbial control measurement for bottles line, bottles and environment

Source: Adapted from Kourtis and Arvanitoyannis, 2001

3.11. Storage

Storage and shipping of wine at high temperatures could induct fast modifications in wine flavour and colour. Straight subjection to sunlight reflects the influence of hot storage temperature. It impacts the reaction speeds implicated in maturation, for instance, the speeding up of the terpene fragrance loss and aromatic ester hydrolysis (De-la-Presa-Owens and Noble, 1997). Temperature can influence the volume of wine, alleviating the stopper seal, generating oxidation, leakage and eventually microbial growth due to bottled wine spoilage (CCP 9, Table 9).

Table 9. Activities Concerning Security and Quality Control for Storage

		Quality	*Safety*
Storage (CCP 9)	Risks/Cause	• Alteration of cartons and labels of wine bottles due to a humid area • High temperature provoking wine leakage	
	Precaution measures	• Storage in low humidity environment • Storage at environment temperature between 12-15°C	
	Severe factors/ limits/controls	• Control of storage condition	

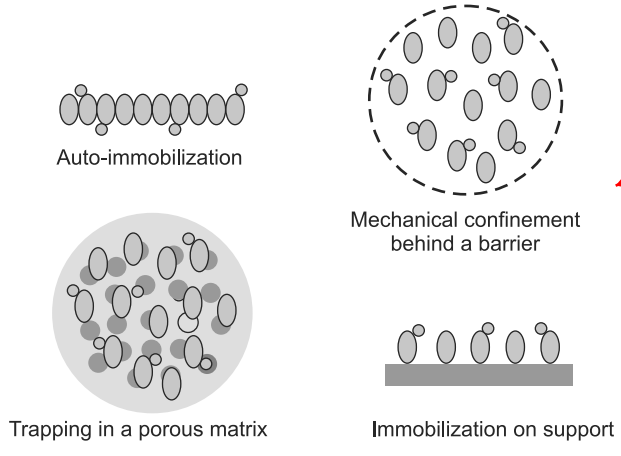
Source: Adapted from Kourtis and Arvanitoyannis, 2001

4. Bioreactors Typology, Technology and Uses

Winemaking innovation has seen amazing progressions all through the most recent 20 years, upgrading the nature of wines and furthermore formulating it to deliver wines with an extensive extent of traits. On this ground, some innovative progressions like enzymatic actions, use of picked yeasts, modification of microbe starters and immobilisation are of key importance (Fig. 1). These headways have influenced all aspects of winemaking, with wine remaining the last consequence of a mechanical chain that joins the handling and must treatment, fermentation, aging and packing. This inventive advance has upgraded the nature of the wines made. Quality wine is evaluated by intensity, fineness, advancement in smell and taste, and physic-chemical and microbiological stability (Dubourdieu, 1986; Noble, 1988; Rapp and Mandey, 1986; Schreier, 1979).

4.1. Bioreactors Shape and Size

Fermenters of a broad collection of forms are straight-tube, barrel, V, square vessels, external forms etc. are utilised for wine manufacture (Boulton *et al*., 1996). Forms of different fermenters used in fermented beverages (Maule, 1986; Moresi, 1989) are shown in Fig. 2. In most of the fermenters, floor inclining is done in the direction of the front. Bioreactors with domed or hemispherical bases are used in winemaking. Despite positive conditions in mash discharge in red winemaking, the usage of the funnel-shaped-based bioreactors has not sharpened. One of the most exorbitant and freshest advancements in the fermentation of red wine are the turning stainless-steel bioreactors that are uncommonly gainful with respect to the degree of energy and time anticipated that would build perfect skin introduction in the aging wine and inconsequential oxygen open to deterioration microbes. Despite having focal points, the usage of rolling and barrel-shaped vessels as a differentiating alternative to standard fermenters has found affirmation in red wines (Peyron and Feuillat, 1985).



Au: There is no reference of fig. 1 in the text

Figure 1. Yeast immobilisation system

There is a noteworthy distinction in measure, shape, outline and advancement materials used as a piece of fermentation tank in the manufacture of wine, inciting a fluctuated grouping of matured wines (Moresi, 1989). Any non-porous and non-perilous tank could be used as a bioreactor. Each tank could be ordered in two fundamental classes (tanks and vats). Vats are open at the top, although tanks are closed at the top. Earlier vats were used for red wine manufacture in view of the fact that a prompt access to the highest point of skins and seeds is desired in the midst of aging. White wines could be manufactured in tanks and are in a position to disallow air from the maturing juice. Most of the bioreactors outlined are rudimentary and a problem in planning occurs since their volume is extended. The development in volume moreover decreases the surface area for heat transfer. In red wine manufacturing, the unpredictability of the tank technology depends on the method used for the top submersion. Usually, the batch fermentation technique is used in wineries. Continuous bioreactors are moreover open but rarely used. As of now,

fermentations used to be finished in 2.25-2.28 hL tanks or 6-12 hL vats (Diviès, 1988). The wooden or concrete vessels used earlier have now been replaced with especially planned stainless-steel bioreactors. A diagram demonstrating particular fragments of a stainless-steel bioreactor is shown in Fig. 2. Small fermenters are often used in red wine aging as a result of the problem in achieving an agreeable top submersion (Jackson, 1999). Business wineries are using bioreactors of 20 m^3 or more prominent limits. They are sensible to the extent of capital cost, computerisation and automation.

4.2. Types of Bioreactors

Efficiency in the fermentation of wine can be increased by utilising elevated yeast cell density by expanding the operative cell density or size by accumulation or cell immobilisation on a certain support. These methods are called high-cell-density reaction techniques. In addition, these methods are insensitive to unforeseen changes in working conditions or other characteristics of the must. Thus the total amount of organisms is maintained, the fermentation activity being restored once the problem is solved. The flow propels the procedures of immobilisation and have led to the improvement of proficient immobilised fermenters to completely make use of the benefits of biocatalysts and cell immobilisation (Fig. 2). The utilisation of the procedure of immobilisation for fermentation of wine accordingly, needs the improvement of a deliberately planned and reasonably constructed fermenter. Non-stop alcohol fermentation methods utilising immobilised cells have been widely reviewed (Gôdia *et al*., 1987) and inferred that immobilised systems have many preferences over the customary suspended cell systems. In the bioreactors, the collection of ethanol inhibits the productivity (Goma, 1978). Thus, it is useful to complete in consecutive bioreactors the fermentation or in a gradient of concentration in reactors. A continuous procedure for the must fermentation to utilise serially associated fermenters was licensed in USA (Epchtein, 1984). A bioreactor with multistage systems, utilising expendable fixed bioplates, has likewise been produced for fermentation of wine in a continuous way (Ogbonna *et al*., 1989). An overview of bioreactor technologies created demonstrated that developments in the last vious couple of years has occurred primarily in three zones: outlines, double phasic responses and environmental fermenters (Deshusses *et al*., 1997). There are two noteworthy methods (heterogeneous and homogeneous) for immobilisation cell or limiting biomass (Diviès *et al*., 1994). The harmonised method comprises identical dispensation of biomass as

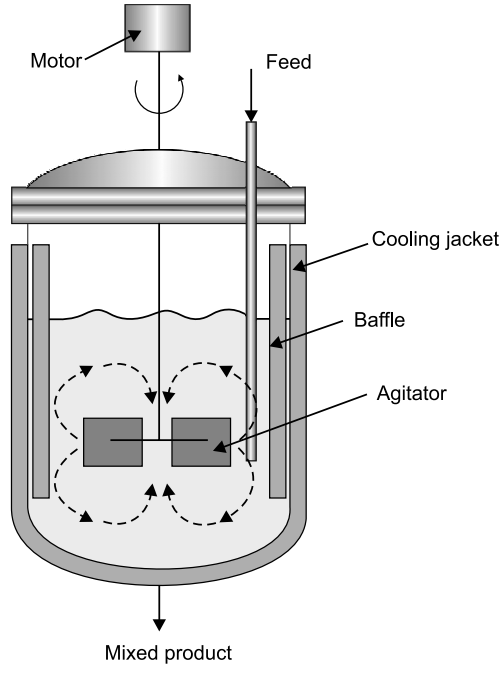


Figure 2. Classical agitated bioreactor

free organisms in the milieu. Rehashed utilisation of weight of organisms could be done by flocculation, centrifugation of yeast with outside or inside decanter or membrane bioreactor where the cells are introduced. Then again, the heterogeneous technique has two different stages, like fluid milieu that is supposed to be changed and a particulate phase having the cells. In this technology, biomass is restricted by way of support, auto flocculation and entrapment in gels

4.2.1. Heterogeneous Bioreactors

In heterogeneous bioreactors, microbes are immobilised by using bonding. The essential and vital thing to do is to augment the concentration of cells and keep their life in recycled or in a continuous method.

4.2.1.1. Continuous Stirred Tank Bioreactor (CSTB)

Stirred tank bioreactors (Fig. 2) comprise of a stirred tank where crisp milieu is continuously introduced and compared, the volume of the fluid substance is evacuated. They are well blended by the utilisation of impellors. The fluid component of the reactor is equivalent in the constitution, like the convergence of the surge. With the immobilisation of cells, high liquid speeds are expected to accomplish a steady provision of product and substrate expulsion. CSTBs or back-mix bioreactors, as they are occasionally named, are inexpensive, adaptable and particularly satisfactory when fluid phase reaction is required. The gas provision, temperature and pH control are simple. New agents can be effectively introduced to the tank and particulate substrate materials can be endured without a problem. In any case, the moderately strong-power input needed to give effective stirring in CSTB is obviously a weakness and it might cause erosion or destruction of the immobilised cell in view of the high cutting forces at the impellor surface.

In any case, the continuous stirred tank bioreactor provides the finest blending qualities and air exchange. The medium density in a continuous stirred tank bioreactor is normally smaller than the fluidised bed and packed bed bioreactors used in smaller average speeds. But bringing down the concentration of substrate might be favourable for hindered organism culture. Quick mixing speeds in the continuous stirred tank bioreactor in elevated shear stresses increase organism spillage from alignate (Margaritis and Wallace, 1982), or carrageenan beads (Jain *et al*., 1985), cell separation from ion exchange resins (Bar *et al*., 1987) and floc disruption (Fein *et al*., 1983).

4.2.1.2. Packed Fixed Bed Bioreactor (PBB)

The packed (fixed) bed bioreactor is oftentimes utilised in immobilisation of the cell reactor for alcohol production (Gôdia *et al*., 1987). The immobilised cells are loaded in a column at its most extreme density between which the milieu solution moves and the level of conversion of the substrate increments with the length of the column occurs (Fig. 3).

If the fluid momentum profile is completely flat, the packed (fixed) bed bioreactor works as a seal-flow bioreactor, which has a perfect behaviour. The efficiency of the packed (fixed) bed bioreactor for a specific biocatalyst relies upon the kind of fixation. High cell loadings are frequently accomplished by entrapment, bringing about enhanced productivity. The particle size for cell attachment likewise impacts efficienc . On a basic level, it is conceivable to accomplish full transformation into an item so that these bioreactors are perfect where full expulsion of a medium is required (detoxification).

The packed (fixed) bed bioreactor has the benefit of effortlessness operation and low cost-effective flow through the bed. It additionally can be flimsy amid long-term procedures in the light of non-stop biomass amassing, mass exchange restrictions and CO_2 holdup resulting in channelling and formation of dead spaces (Ghose and Bandyopadhyay, 1980) and even matrix disruption (Webb *et al*., 1990). Gas developed may likewise lead to back blending, bringing a deviation from perfect seal-flow trend. Horizontal packed (fixed) bed bioreactor was utilised to help gas evacuation. Consequently, decreased channelling and gas fixation occur in the non-stop system (Shiotani and Yamane, 1981). The horizontal packed

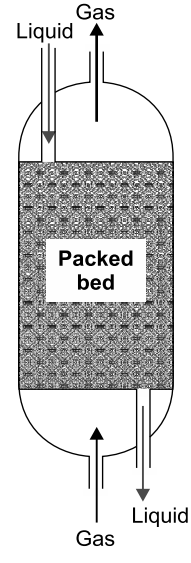


Figure 3. Packed bed bioreactor with the counter current flow

(fixed) bed bioreactor has been 1.5 times more profitable than the vertical packed (fixed) bed bioreactor. A lessening in channelling by CO_2 can likewise be acquired by partitioning the column into isolated stages with perforated plates (Grote *et al*., 1980).

4.2.1.3. Fluidised Bed Bioreactor (FBB)

Fluidised bed bioreactor gives conditions which are middle to the one of the CSTB and packed (fixed) bed bioreactor. Blending is of higher quality in the packed (fixed) bed bioreactor yet it brings down amounts of shear when contrasted with CSTB. FBB comprises a column in which the cell particles are kept suspended in respect to every other by a non-stop flow of the medium or gas at the highest flow speeds (Fig. 4). The benefits of FBB can be seen in numerous studies. The high concentration of yeasts that aggregate in the reactor makes the system suitable for working at high productivities. As indicated by the literature, the fluid flow (must) at the inlet of the FBB might be near that of the outlet and is regulated by the working conditions utilised. This can be viewed as an extraordinary favourable advantage, particularly for reactions repressed by the product, as for alcoholic fermentation (Gôdia *et al*., 1987; Gôdia and Solâ, 1995; Viegas *et al*., 2002).

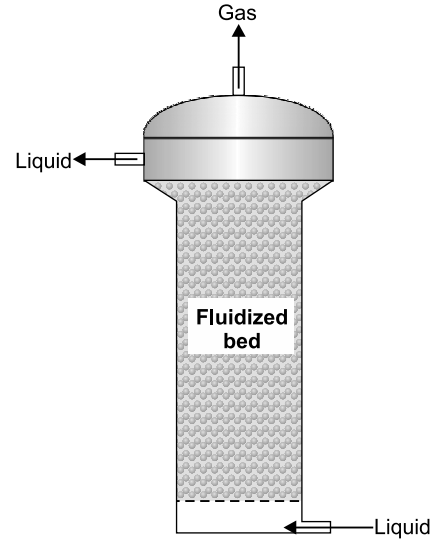


Figure 4. Fluidised bed bioreactor (tower fermenter)

The reduced pressure of the liquid flow underpins the mass of the bed. The FBB provides higher efficiency than CSTB in light of the fact that fluid estimates plug flow like the packed (fixed) bed bioreactor. But, the FBB is more profitable for fermentation with medium hindrance than the packed (fixed) bed bioreactor as a result of the blending created by liquid flo . These reactors advance great mass exchange. The dead organisms are expelled in the process (Andrews, 1988) and expansive volumes of CO_2 are discharged without channelling (Keay *et al*., 1990) and limits pressure decrease. Fluidisation abstains from such issues as pollution, damage of shear and constraints to scaling up, related to impellor shafts and sharp edges in mixed tanks (Dempsey, 1990). FBB can extend to suit developing organism mass so that they are less sensible to plugging and more helpful for cultures where oxygenation is required. FBB needs less energy (four times) contribution than a mechanically-agitated bioreactor. However, it is more energy consuming than the packed (fixed) bed bioreactor (Brodelius and Vandamme, 1987).

4.2.1.4. Rotating Disc Bioreactor (RDB)

It is made up of fixed cell units, for example, polyurethane froth sheets (Amin and Doelle, 1990) or fibre discs (Parekh *et al*., 1989) appended to a pivoting shaft (Fig. 5). It is gradually blended, thus permitting complete blending and expulsion of dead organisms, residues and the developed CO_2. The energy needed for RDB is not as much as that for STB as a result of its moderate blending speed. This bioreactor can take industrial media-holding particle suspensions to attain high efficienc . No problem occurs with the elevated solid milieu in this sort of reactor (Parekh *et al*., 1989).

4.2.1.5. Air (gas) Lift Bioreactor (ALB)

In ALB (Fig. 6), the liquid volume of the tank is separated into two joined areas by means of a bewilder – one area is sparged with air and another area that gets no gas is called down-comer. Bubbles convey the fluid, causing a lessening in fluid specific gravity. Gas runs away from the summit and the fluid fails in the down-comer. An outer loop method might substitute the internal bewilder for the distribution of fluid in some reactors. Stirring in the ALB because of gas move derives little shear with effective blending and mass transfer. The dimension of the bewilder impacts the hydrodynamics of the bioreactor. ALB are exceedingly energy productive in respect to mixed bioreactors.

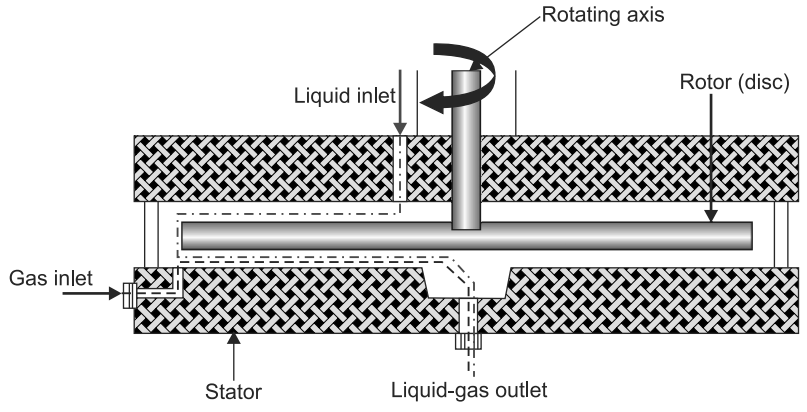


Figure 5. Classical rotating disc bioreactor

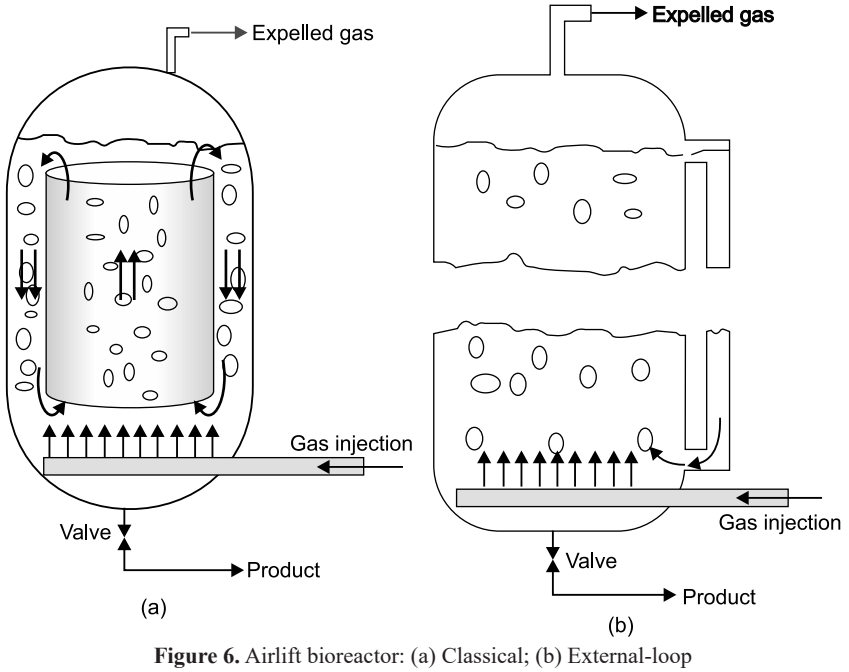


Figure 6. Airlift bioreactor: (a) Classical; (b) External-loop

4.2.2. Cell Recycle Batch Bioreactors (CRBB)

The CRBB (Fig. 7), whose main development is the numerous progressive utilisation of the identical microbe starter in various batch fermentations remains the roughly adequate non-ordinary method in wine production. Not like continuous, the CRBB doesn't need the entire modifications in the winery methods nor undertakes it in the new machine. Indeed, yeast to get reused can be recuperated via natural settling or by membrane separation or centrifugation with equipment effectively existing in nearly all wineries. Five distinct procedures were studied (Guidoboni, 1984); the majority of them utilise a centrifugation stage which accompanies a unique bioreactor for reuse of yeast.

Increase in cell weight and also in efficiency was attained by utilising a fractional vacuum technique (Cysenski and Wilke, 1978). The principal disservices of centrifugation method are the reduction in life of the microbial biomass because of the tension as they are exposed to centrifugation equipment. The utilisation of membrane reactor is an optional technique to realise centrifugation in CRBB, where the yeast cells are held in the fermenter possessing a membrane with pore size of under 0.45 mm.

The medium is directed by the membrane reactor and the changed item moves downstream from the membrane. The productivity of the change can be expanded by reusing the item by the reactor (Diviès

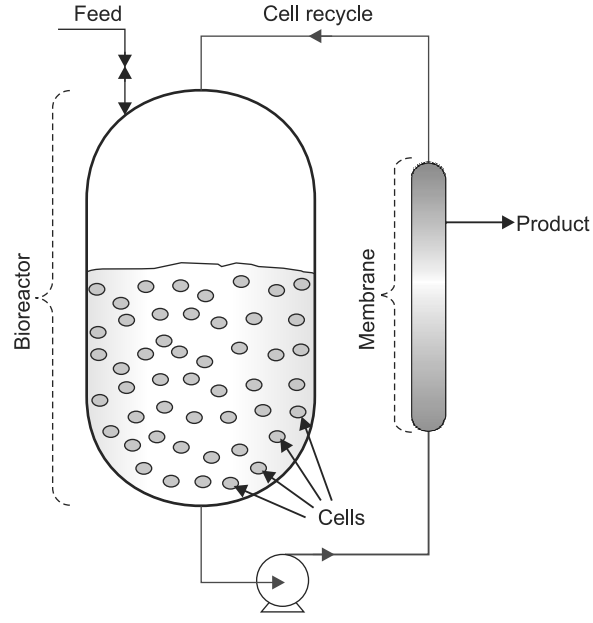


Figure 7. Cell recycle batch bioreactors

et al., 1994). The principal restriction of this is the stopping and the membrane unclogging (Mehaia and Cheryan, 1990).

In order to examine the general legitimacy of nearly all proficient methods of fermentation to diminish the wine production costs, an off-skin fermentation of clear *Trebbianotoscano* juice was done by utilisation of a non-regular cell reuse batch fermentation system (Rosini, 1986). The procedure decreased the fermentation length and also changed the ethanol efficiency and yield. It can be advantageously used in the production of conventional table wines.

Numerous investigations have exhibited the likelihood of controlling MLF by utilising a bioreactor with cell immobilisation or enzymes. Utilisation of bioreactor introduces various benefits in the ordinary wine deacidifica ion. Starter microbes could be reutilised. The diminished development of auxiliary fermentation and products could be ended and initiated at the right moment by the wine producer. But, contamination by phage, a transient decline in activity and a little change in the sensory characteristics of the treated wine cannot be precluded always (Maicas, 2001).

The utilisation of cell immobilisation in fermentation procedures over the utilisation of free organisms offers a few benefits, like increment in efficiency or giving a more protective condition and enhancing the resulting separation of the cell. The concentration of catalytic activity in a decreased volume enables the winemakers to lessen the dimension of the fermenters and recoup the final items more effectively in batch or continuous production methods. In spite of the fact that the characteristics of cell immobilisation were similar to the one of free cells, however, the immobilised cells are interestingly simple to recoup and reuse. The fixation and attachment/adsorption are the two principal immobilisation systems used to prompt MLF in wine. However, entrapment is a well-known strategy because of utilisation of non-dangerous chemicals in agreement with food manufacture (Cassidy *et al*., 1996). The change of immobilisation strategies for deacidification of wine was long examined by utilising alginates (Shieh and Tsay, 1990), polyacrylamide (Clementi, 1990), ê-carrageenan (Crapisi *et al*., 1990; Crapisi, Nuti *et al*., 1987) and κ-carrageenan, etc. For example, an increase was noted in the operational stability of immobilised cells of *Lactobacillus* sp. in a κ-carrageenan matrix (Crapisi, Nuti *et al*., 1987). The combined use of bentonite silica and this polymer has produced an effective bioreactor to develop the MLF of wine. The immobilised cells have shown great efficacy in decreasing L-malic acid, the conversion rate and reduction of titratable acidity being about 60 per cent. These studies have been extended to several species of lactic acid bacteria, including *O. oeni* and *Lactobacillus* (Crapisi, Spettoli *et al*., 1987).

The decision of the immobilised matrix must be done as per the long-term protection of cell life and for beverage manufacture because of its acknowledgment as GRAS (Generally Recognized as Safe). Alginate is just an appropriate matrix in both the considerations, has the size to reduce the diffusion limitation for the media and the items, and to increase the biomass dissemination. However, it is reversible and the existence of chelating compounds in the milieu could prompt leakage and incomplete matrix dissolution of the packed biomass. Bioreactor technologies comprising the high density of MLF microorganisms immobilised in alginate supports or carrageenan or packed between membranes was developed (Colagrande *et al*., 1994). In MLF microscopic organisms react as biocatalyst and without development, quickly convert malic acid to lactic acid in wine that has gone through the bioreactor on a non-stop basis (Gao and Fleet, 1994).

4.2.3. Continuous Bioreactors for Winemaking

The continuous reactor is 'open'. There is a constant flow consisting of entry of the substrate on one hand and output of the product on the other. The main specificity of the continuous reactor is the opportunity to achieve dynamic equilibrium, that is to say that the system operates on the basis of the equilibrium state. Continuous reactors are widely used in chemical and food industries among others. Most operating reactors are multiphasic, including fixed bed, fluidised bed, bubble column and to lift air (Verbelen *et al*., 2006). Multiphase reactors are structured in three phases: gas (air or other), solid (support) and liquid (the medium). In terms of the production of wine, inert gas (CO_2 or N_2) may replace the air to avoid oxidation of the wine. The continuous fermentation technique appears as an option that would reduce manufacturing costs and increase the ethanol yield (Ribéreau-Gayon *et al*., 2006). According to the literature, it is proposed to use higher levels of SO_2 in continuous fermenters to stop contamination. The advantages of continuous fermentation are higher and faster substrate conversion rate; increased homogeneity of the wine; lower losses; best environmental management practices; better control of fermentation; and consistency in the quality of finished wines (Clement *et al*., 2011; Genisheva *et al*., 2014; Ribéreau-Gayon *et al*., 2006).

5. Optimising Winery Unit Operation

Wineries nowadays are confronted with the increasing expenses of trading. In the course of recent years, the cost of gas and electricity for manufacturing has expanded and this expanding pattern is probably going to proceed. These expanded utility costs put additional pressure on business. The outcome is an industry confronting more tightly net revenues and an increased significance on the selection of procedures and technologies that empower quality wine to be manufactured at lower cost. Optimisation should be therefore a business mentality concentrating on executing procedures and innovations to lessen costs, increase speed and improve asset utilisation. Numerous enterprises have effectively embraced optimisation as a foundation for staying focused in nearby and worldwide markets.

5.1. Computerisation

Computerisation can take different structures inside a winery. It can be as essential as computerising areas of a refrigeration framework, or as elaborate as a completely mechaniszed winery. Computerisation is useful as it permits the change of each of the procedure productivity measures, i.e. production, work, materials, water and energy. It is accomplished by advancing procedure gear, permitting round-the-clock operations, enhancing quality and decreasing human mistakes. The computerisation can optimise the process in the winery by the means shown in Table 10.

5.2. Cross Flow Filtration

Cross stream (flow) filtration has developed as a productive filtrati n method, with differing application possibilities for both the quick moving customer merchandise enterprises and the wine factory. Several wineries have actualised this innovation; however many others have not executed this innovation yet. Cross-stream filtration is customised and can include various applications inside a winery. It can be basically more energy proficien than conventional winery filtration while permitting fast-filtration

Table 10. Optimisation Aspects of Computerisation

Process optimisation	*Effect of chance on process effectiveness measure*
Production rate	Critical increments to fabrication speed and improvement of process apparatus
Work	Reductions difficult work enabling sta f to be used all the more fittingl
Materials	Gives more noteworthy process control and accordingly decreases material waste
Energy	Gives large amounts of control and can fundamentally lessen energy– particularly in the systems of refrigeration for wineries
Water	Computerisation can give extra water productivity relying upon the particular use of the robotisation system

speeds. Cross-stream filtration can enhance material effectiveness by removing the requirement for added substances (e.g. filter aid) and lessening wine misfortune caused by development through numerous filtration exercises. The way cross-stream (flow) filtration could optimise the optimisation of filtration efficiency is summarised in Table 11.

Table 11. Optimisation Aspects of Cross-flow Filtratio

Process optimisation	*Effect of chance on process effectiveness measure*
Production rate	Augment filtration speeds by enabling numerous filtration operations to be embraced in one wine development. Can finished filtration in one stage rather than numerous mean
Materials	Can diminish wine development and decline wine waste. Can recuperate wine from dregs expanding production. Can diminish the utilisation of bentonite
Energy	Cross stream filtration is to a greater extent energy-saving per litre of wine obtained in contrasted to other filtration procedure
Water	Cross-stream filtration can be utilised to purify and recover process wate

5.3. Frosty Adjustment Methods

A typical issue in the wine factory amid vintage is the absence of enough fermentation vessels. A quicker essential fermentation rate enables more tanks to be reutilised amid vintage. Moderate or blocked fermentation not just decreasess the manufacture speed, it can expand material use by expecting added substances to ‘restart’ aging and require extra energy for the control of temperature. Expanding fermentation productivity includes both grape juice attributes, remedying for any basic differences (i.e. potassium accessibility, pH, etc.) and choosing yeast strains that are most appropriate to the juice characteristics. This guaranteed fermentation is attempted in a controlled and optimised manner, increasing the manufacture efficienc .

5.4. Continuous Processing

Continuous manufacture systems have more prominent efficiencies in contrast to batch procedure systems. The batch procedure system requires an extensive manufacture chain to stop until the the group bottleneck is prepared for the following cycle. In the wine factory, batch squeezing delays the destemming, receival and pulverising stages. This can prompt temperature changes and extended oxidation. Screw squeezing permits the receival procedure motion to progress from a batch procedure to a continuous procedure. This can reduce bottlenecks all through the receival chain. Presses using screws have gradually been supplanted by press systems utilising membranes because of their capacity to diminish extraction of phenolic substances. Innovation in a screw press, for example, utilising bigger screw blades and moderating upheavals, can lessen quite a bit of this phenolic compound while optimising the speed of production.

6. Conclusion and Future Thrust

Winemakers are confronting increasing rivalry due to the enlarging gap between wine manufacture and wine utilisation, the trend for customer inclination far from fundamental ware wine to top quality wine and financial globalisation. Thus, there is a requirement for a global transformation in the realm of wine. One of the requirements is the usage of HACCP method in the beverages factory that has been of a colossal help. Despite the fact that alcoholic drinks are relatively more secure than different foods and beverages due to their high ethanol content, recognition of potential dangers and recommencement of inhibitory and restorative activities (at whatever point needed) are of essential significance. Foundation of basic control restrains in co-occurrence with suitable and viable checking methods completed by capable staff have figured out how to limit the episodes of occurrences that are perilous and malicious for human well-being. The way towards changing the wine factory from a manufacture to an oriented market industry is an increased reliance on biotechnological advancements and HACCP method. A great part of the procedure proficiency technology utilised in agro-industry factories is promptly accessible for use in the wine factory. A few wineries have executed this innovation while yet others are yet to do as such. Specificall , cross-flow filtration and computerisation-procedure efficiencies are yet being executed. These deferrals in usage are not because of the accessibility of innovation, but rather are expected partially to capital accessibility, the absence of information on proficient practices, or vulnerability regarding what the advantageous prices are for expanding the process productivity. In spite of a substantial number of results on wine, the characteristic course of the fermentation of wine is not completely investigated and fermentation procedures are not really completely managed to require the comprehension of the biochemical conduct of yeast and other organisms in the wine milieu. The overall spread of wine manufacture has prompted novel vineyards delivering quality wine by receiving tried systems, like centrifugation, filtration, stainless steel tanks for fermentation, monitoring of temperature and chosen yeasts, and so forth. A portion of the biotechnological developments, like specific yeasts, change of starters, treatment using enzymes, bioreactor planning and cell immobilisation are of key significance in wine production. The improvements in reactor innovation as for fruit wines other than grape are rare. Mastering ongoing technique efficiencies ought to be viewed as key to enhancing business productivities. Assuring these means can prompt noteworthy cost reserve funds for the business, especially with respect to assets, materials and manufacture rates. This will need an adjustment in worldview for some wineries, yet it is important to guarantee that they stay beneficial in the changing business condition.

References

Amin, G. and Doelle, H.W. (1990). Production of high ethanol concentrations from glucose using *Zymomonas mobilis* entrapped in vertical rotating immobilised cell reactor. *Enzyme and Microbial Technology* 12: 443.

Andrews, G.F. (1988). Design of fixed film and fluidised bed bioreactors. pp. 765. *In*: L.E. Erickson and D.Y.C. Fung (Eds.). Handbook on Anaerobic Fermentations. Marcel Dekker, New York, USA.

Blade, W.H. and Boulton, R. (1988). Absorption of Protein by Bentonite in a Model Wine Solution. *American Journal of Enology and Viticulture* 39: 193-199.

Boulton, R., Singelton, V., Bisson and Kunkee, R. (1996). Principles and Practices of Winemaking. Chapman & Hall, New York.

Brodelius, P. and Vandamme, E.J. (1987). Immobilised cell systems. pp. 405. *In*: H. Rehm and G. Reed (Eds.). Biotechnology, VCH, Weinhein, Germany.

Cabras, P., Meloni, M., Pirisi, F.M., Farris, G.A.O. and Fatichenti, F. (1988). Yeast and pesticide interaction during aerobic fermentation. *Applied Microbiology and Biotechnology* 29: 298-301.

Cassidy, M.B., Lee, H. and Trevors, J.T. (1996). Environmental applications of immobilised microbial cells: A review. *Journal of Industrial Microbiology and Biotechnology* 16: 79.

Clement, T., Perez, M., Mouret, J.R., Sablayrolles, J.M. and Camarasa, C. (2011). Use of continuous multistage bioreactor to mimic winemaking fermentation. *International Journal of Food Microbiology and Immunology* 150: 42-49.

Au: Pl. check

Clementi, F. (1990). Fluidbed dried immobilised cells of *Lactobacillus casei* used for L-malic acid degradation in must. *Italian Journal of Food Science* 1: 25.

Codex (1998). Report of the thirtied session of the codex committee on pesticide residues. alinorm 99/24. FAO/WHO. The Hague, 20-25 April 1998.

Colagrande, O., Silva, A. and Fumi, M.D. (1994). Recent applications of biotechnology in wine production. *Biotechnology Progress* 10: 2.

Constanti, M., Poblet, M., Arola, L., Mas, A. and Guillamon, J. (1997). Analysis of yeast population during alcoholic fermentation in a newly established winery. *American Journal of Enology and Viticulture* 48: 339-344.

Cooke, G.M. and Berg, H.W. (1984). A re-examination of varietal table wine processing practices in California, II: Clarification, stabilisation, aging and bottling. *American Journal of Enology and Viticulture* 35: 137-142.

Crapisi, A., Lante, A., Nuti, M.P., Zamorani, A. and Spettoli, P. (1990). Efficiency of bioreactors with bacterial cells immobilised on different matrixes for the control of malo-lactic fermentation in wine. pp. 349. *In*: P. Ribéreau-Gayon and A. Lonvaud (Eds.). Actualités oenologiques 89, Comptes rendus 4 Symp. International d' Oenologie, Bordeaux, 1989. Paris, France: Dunod.

Crapisi, A., Nuti, M.P., Zamorani, A. and Spettoli, P. (1987). Improved stability of immobilised Lactobacillus sp. cells for the control of malo-lactic fermentation in wine. *American Journal of Enology and Viticulture* 38: 310-312.

Crapisi, A., Spettoli, P., Nuti, M.P. and Zamorani, A. (1987). Comparative traits of *Lactobacillus brevis*, *Lactobacillus fructivorans* and *Leuconostoc oenos* immobilised cells for the control of malo-lactic fermentation in wine. *Journal of Applied Bacteriology* 63: 513-521.

Cysenski, G.R. and Wilke, C.R. (1978). Process design and economic studies of alternative fermentation methods for production of ethanol. *Biotechnology and Bioengineering* 20: 14-21.

Davis, C.R., Wibowo, D., Eschenbruch, R., Lee, T.H. and Fleet, G.H. (1985). Practical implications of malo-lactic fermentation: A review. *American Journal of Enology and Viticulture* 36: 290-301.

De-la-Presa-Owens, C. and Noble, A.C. (1997). Effect of Storage at Elevated Temperatures on Aroma of Chardonnay Wines. *American Journal of Enology and Viticulture* 48: 310-316.

Dempsey, M.J. (1990). Ethanol production by *Zymomonas mobilis* in a fluidised bed fermenter. pp. 137. *In*: J.A.M. de Bont, J. Visser, B. Mattiasson and J. Tramper (Eds.). Physiology of Immobilised Cells. Elsevier Science Publishers, Amsterdam, UK.

Deshusses, M.A., Chen, W., Mulchandani, A. and Dunn, I.J. (1997). Innovative bioreactors. *Current Opinion in Biotechnology* 8: 165.

Dibble, J.E. and Steinke, W.E. (1992). Principles and techniques of vine spraying. *In*: D.L. Flaherty, L.P. Christensen, W.T. Lanini, J.J. Marois, P.A. Phillips and L.T. Wilson (Eds.). Grape Pest Management. University of California. Division of Agriculture and Natural Resources, Oakland.

Diviès, C. (1988). Les Microorganisms immobilisés. Cas des bactéries lactiques et des levures en oenologie. pp. 449. *In*: G.H. Fleet (Ed.). Wine Microbiology and Biotechnology. Harwood Academic Publishers, Chur, Switzerland.

Diviès, C., Cachon, R., Cavin, J.-F. and Prévost, H. (1994). Immobilised cell technology in wine fermentation. *Critical Reviews in Biotechnology* 14: 135.

Dubourdieu, D. (1986). Wine technology: Current trends. *Experientia* 42: 914.

Au: Incomplete

Ellison, P., Ash, G. and McDonald, C. (1998). An expert management system for the management of *Botrytis cinerea* in Australian vineyards. I. *Dev. Agric. Syst*. 56: 185-207.

Epchtein, J. (1984). Continuous process for the fermentation of must to produce wine or ethanol. US Patent No. 4487785.

Eschnauer, E. (1986). Lead in wine from tin-leaf capsules. *American Journal of Enology and Viticulture* 37: 158-162.

Farkas, J. (1984). Technology and Biochemistry of Wine. Gordon & Breach, New York.

Fatichenti, F., Farris, G.A., Deiana, P., Cabras, P., Meloni, M. and Pirisi, F.M. (1984). The effect of *Saccharomyces cerevisiae* on concentration of dicarboxymide and acylanilide fungicides and pyrethroid insecticides during fermentation. *Applied Microbiology and Biotechnology* 20: 419-421.

Fleet, G.H. (1994). Wine: Microbiology and Biotechnology. Harwood Academic Publishers, New York.

Forsythe, S.J. and Hayes, P.R. (1998). Food Hygiene, Microbiology and HACCP. Chapman & Hall, London.

Fugelsang, K. (1997). Wine Microbiology. Chapman & Hall, London.

Gao, C. and Fleet, G.H. (1994). Degradation of malic acid by high density cell suspensions of *Leuconostoc oenos*. *Journal of Applied Microbiology* 76: 632.

Genisheva, Z., Mota, A., Mussatto, S., Oliveira, J.M. and Teixeira, J.A. (2014). Integrated continuous winemaking process involving sequential alcoholic and malo-lactic fermentations with immobilised cells. *Process Biochemistry* 49: 1-9.

Gennari, M., Negre, M., Gerbi, V., Rainondo, E., Minati, J.L. and Gandini, A. (1992). Chlozolinate fates during vinification process. *Journal of Agricultural and Food Chemistry* 40: 898-900.

Ghose, T.K. and Bandyopadhyay, K.K. (1980). Rapid ethanol fermentation in immobilised cell reactor. *Biotechnology and Bioengineering* 22: 1489.

Gnaegi, F., Aerny, J., Bolay, A. and Crettenand, J. (1983). Influence des Traitement Viticoles Antifongiques sur la Vinificatio et la Qualite du vin, Revision Suisse de Viticulture. *Arboriculture et Horticulture* 15: 243-250.

Gnaegi, F. and Sozzi, T. (1983). Les Bacteriophages de Leuconostoc oenos et leur, Importance Oenologique. *Bulletin d'OIV* 56: 352-357.

Gôdia, C., Casas, C. and Solâ, C. (1987). A survey of continuous ethanol fermentation systems using immobilised cells. *Process Biochemistry* 22: 43.

Gôdia, F. and Solâ, C. (1995). Fluidised-bed Bioreactors. *Biotechnology Progress* 11: 479-497.

Goma, G. (1978). Optimisation de la mise en oeuvre des cultures anaérobies. pp. 171. *In*: L. Bolichon and G. Durand (Eds.). Utilisation Industrielle du Carbone d'Origine Végétale par voie Microbienne, Société Française de Microbiologie. Paris, France.

Grote, W., Lee, K.J. and Rogers, P.L. (1980). Continuous ethanol production by immobilised cells of *Zymomonas mobilis*. *Biotechnology Letters* 2: 481.

Guidoboni, G.E. (1984). Continuous fermentation systems for alcohol production. *Enzyme and Microbial Technology* 6: 194.

Au: Name of the publisher and place

Gump, B. and Pruett, D. (1993). Beer and Wine Production, Analysis Characterisation and Technological Advances. American Chemistry Society, Washington DC.

Guzzo, J., Jobin, M.-P. and Divies, C. (1998). Increase of sulphite tolerance in *Oenococcus oeni* by means of acidic adaption. *FEMS Microbiology Letters* 160: 43-47.

Jackson, G. (1998). Practical HACCP in brewing industry. pp. 50-57. *In*: Monograph: European Brewery Convention. Monograph XXVI. Stockholm

Jackson, R.S. (1999). Grape-based fermentation products. pp. 583. *In*: V.K. Joshi and A. Pandey (Eds.). Biotechnology: Food Fermentation. Educational Publishers and Distributors, Ernakulam, India.

Keay, L., Eberhardt, J.J., Allen, B.R., Scott, C.D. and Davison, B.H. (1990). Improved production of ethanol and n-butanol in immobilised cell bioreactors. pp. 539. *In*: J.A.M. de Bont, J. Visser, B. Mattiasson and J. Tramper (Eds.). Physiology of Immobilised Cells. Elsevier Science Publishers, Amsterdam, UK.

Kourtis, L.K. and Arvanitoyannis, I.S. (2001). Implementation of hazard analysis critical control point (HACCP) system to the alcoholic beverages industry. *Food Reviews International* 17: 1-44.

Langhans, E. and Schlotter, H.A. (1985). Ursachen der Kupfer-Trung. *Deutse Weinband* 40: 530-536.

Lea, A. and Piggott, J. (1995). Fermented Beverage Production. Chapman & Hall, London.

Lichine, A. (1985). Alexis Lichine's Encyclopedia of Wines & Spirits. Cassell, London.

Maicas, S. (2001). The use of alternative technologies to develop malo-lactic fermentation in wine. Applied Microbiology and Biotechnology 56: 35.

Malfeito-Ferreira, M., Tareco, M. and Loureiro, V. (1997). Fatty acid profiling: A feasible typing system to trace yeast contamination in wine bottling plants. *International Journal of Food Microbiology* 38: 143-155.

Maner, P.J. and Stimmann, M.W. (1992). Pesticide safety. *In*: D.L. Flaherty, L.P. Christensen, W.T. Lanini, J.J. Marois, P.A. Phillips and L.T. Wilson (Eds.). Grape Pest Management. Publ. University of California. Division of Agriculture and Natural Resources, Oakland.

Marriott, N. (1994). Principles of Food Sanitation. Chapman & Hall, London.

Martinez, R.G., De-la-Serrana, H.L.G., Mir, M.V., Granados, J.Q. and Martinez, M.C.L. (1996). Influence of wood heat treatment, temperature and maceration time on vanillin, syringaldehyde and gallic acid contents in oak wood and wine spirit mixtures. *American Journal of Enology and Viticulture* 47: 441-446.

Maule, D.R. (1986). A century of fermenter design. *Journal of the Institute of Brewing* 92: 137.

Mehaia, M.A. and Cheryan, M. (1990). Membrane bioreactors: Enzyme processes. pp. 67. *In*: H.G. Schwartzberg and M.A. Rao (Eds.). Biotechnology and Food Process Engineering. Marcel Dekker, New York, USA.

Moresi, M. (1989). Fermenter design for alcoholic beverage production. pp. 107. *In*: C. Cantarelli and G. Lanzarini (Eds.). Biotechnology Applications in Beverage Production. Elsevier Applied Science, London, UK.

Mosedale, J.R. and Puech, J.L. (1998). Wood maturation of distilled beverages. *Trends in Food Science and Technology* 9: 95-101.

Nault, I., Gerbaux, V., Larpent, J.P. and Vayssier, Y. (1995). Influence of pre-culture conditions on the ability of *Leuconostoc oenos* to conduct malo-lactic fermentation in wine. *American Journal of Enology and Viticulture* 46: 357-362.

Neel, D. (1993). Advancements in processing Portuguese corks. *Australian Grapegrower and Winemaker* 353: 11-14.

Nielsen, J.C., Prahl, C. and Lonvaud-Funel, A. (1996). Malo-lactic fermentation in wine by direct inoculation with freeze-dried *Leuconostoc oenos* cultures. *American Journal of Enology and Viticulture* 47: 42-48.

Noble, A.C. (1988). Analysis of wine sensory properties. p. 9. *In*: H.E. Linskens and J.F. Jackson (Eds.). Wine Analysis – Modern Methods of Plant Analysis. Springer Verlag, Berlin.

Ogbonna, J.C., Amano, Y., Nakamura, K., Yokotsuka, K., Shimazu, Y., Watanabe, M. and Hara, S. (1989). A multistage bioreactor with replaceable bioplates for continuous wine fermentation. *American Journal of Enology and Viticulture* 40: 292.

OIV (1994). Pesticide Residue: Authorised Limits: Classification by Country, Classification by Pesticide. Office International de la Vigne et du Vin, Paris.

Oliva, J., Navarro, S., Barba, A. and Navarro, N. (1999). Determination of chlorpyrifos, penconazole, fenarimol, vinclozolin and metalaxyl in grapes, must and wine by on-line microextraction and gas chromatography. *Journal of Chromatography* A 833: 43-51.

Ough, C. (1992). Winemaking Basics. Food Products Press.

Parekh, S.R., Parekh, R.S. and Wayman, M. (1989). Ethanolic fermentation of wood-derived cellulose hydrolysates by *Zymomonas mobilis* in a continuous cynamic immobilised biocatalyst bioreactor. *Process Biochemistry* 24: 88.

Peyron, D. and Feuillat, M. (1985). Essais comparatifs de cuves d'automaceration en Bourgogne. *Revue d'Oenologie* 38: 7.

Pilone, G.J. (1986). Effect of Triadimenol Fungicide on Yeast Fermentation. *American Journal of Enology and Viticulture* 37: 304-305.

Popock, K.F., Strauss, C.R. and Somers, T.C. (1984). Ellagic acid deposition in white wines after bottling: A wood-derived instability. *Australian Grapegrower and Winemaker* 244: 87.

Quinn, M.K. and Singleton, V.L. (1985). Isolation and identification of ellagitannins from white oak wood and an estimation of their roles in wine. *American Journal of Enology and Viticulture* 35: 148-155.

Ranken, M.D., Kill, R.C. and Baker, C. (1997). Food Industries Manual. Blackie Academic & Professional, London.

Rapp, A. and Mandey, H. (1986). Wine aroma. *Experientia* 42: 873.

Ribereau-Cayon, P., Glories, Y., Maujean, A. and Dubourdieu, D. (1998). Traité d' Oenologie 2, Chimie du vin. Stabilisation et Traitements. Dunod, Paris.

Ribéreau-Gayon, P., Dubourdieu, D., Donèche, B. and Lonvaud, A. (2006). Handbook of enology. *In*: The Microbiology of Wine and Vinifications. John Wiley & Sons, Chichester.

Rosini, G. (1986). Winemaking by cell-recycle-batch fermentation process. *Applied Microbiology and Biotechnology* 24: 140.

Sala, C., Fort, F., Busto, O., Zamora, F., Alpola, L. and Guasch, J. (1996). Fate of some common pesticides during vinification process. *Journal of Agricultural and Food Chemistry* 44: 3668-3671.

Schreier, P. (1979). Flavour composition of wine: A review. *Critical Reviews in Food Science and Nutrition* 12: 59.

Shieh, Y.M. and Tsay, S.S. (1990). Malo-lactic fermentation by immobilised *Leuconostoc sp*. M-I. *Journal Chinese Agricultural and Chemical Society* 28: 246.

Shiotani, T. and Yamane, T. (1981). A horizontal packed bed bioreactor to reduce CO_2 gas hold up in the continuous production of ethanol by immobilised yeast cells. *European Journal of Applied Microbiology and Biotechnology* 13: 96.

Simpson, R.F. (1990). Cork taint in wine: A review of the causes. *Australian Grapegrower and Winemaker* 305: 286-296.

Simpson, R.F., Amon, J.M. and Daw, A.J. (1986). Off-flavour in wine caused by guaiacol. Food Technology Association of Australia, 38: 31-33.

Soufleros, E. (1997a). Winemaking. Thessaloniki, Greece.

Soufleros, E. (1997b). Winemaking. Thessaloniki, Greece.

Speck, L.M. (1984). Compendium of Methods for the Microbiological Examination of Foods. American Public Health Association, New York.

Sudraud, P. and Chauvet, S. (1985). Activite Antilevure de l'anhydride Sulfureux Moleculaire. *Connaissance de la Vigne et du Vin* 22: 251-260.

Towey, J.P. and Waterhouse, A.L. (1996). Barrel-to-Barrel variation of volatile oak extractives in barrel-fermented chardonnay. *American Journal of Enology and Viticulture* 47: 17-20.

Tucker, G.A. and Woods, L.F.J. (1996). Enzymes in Food Processing. Chapman & Hall, London.

Ubeda, J.F. and Briones, A.I. (1999). Microbiological quality of filtered and non-filtered wines. *Food Control* 10: 41-45.

Vaillant, H., Formysin, P. and Gerbaux, V. (1995). Malo-lactic fermentation of wine: Study of the influence of some physicochemical factors by experimental design assays. *Journal of Applied Bacteriology* 79: 640-650.

Van-Vuuren, H.J.J. and Jacobs, C.J. (1992). Killer yeasts in the wine industry: A review. *American Journal of Enology and Viticulture* 43: 119-128.

Verbelen, P., De-Schutter, D., Delvaux, F., Verstrepen, K.J. and Delvaux, F.R. (2006). Immobilised yeast cell systems for continuous fermentation applications. *Biotechnology Letters* 28: 1515-1525.

Viegas, M.C., Andrietta, S.R. and Andrietta, M.G.S. (2002). Use of tower reactors for continuous ethanol production. *Brazilian Journal of Chemical Engineering* 19: 167-173.

Vine, R., Harkness, E., Browing, T. and Wagner, C. (1997). Winemaking, From Grape Growing to Marketplace. Chapman & Hall, London.

Viriot, C., Scalbert, A., Lapierre, C. and Moutounet, M. (1993). Ellagitanins and lignins in aging of spirits in oak barrels. *Journal of Agricultural and Food Chemistry* 41: 1872-1879.

Vivas, N., Lonvaud-Funel, A. and Glories, Y. (1997). Effect of Phenolic acids and athocyanins on growth, viability and malo-lactic activity of a lactic acid bacterium. *Food Microbiol* 14: 291-300.

Webb, C., Dervakos, G.A. and Dean, J.F. (1990). Analysis of performance limitations in immobilised cell fermenters. pp. 589. *In*: W.E. Goldstein and H. Pederson (Eds.). Biochemical Engineering. Am. N.Y. Acad. Sci., USA.

Wood, B. (1998). Microbiology of Fermented Foods. Blackie A & P, London.

Zoecklein, B.W., Fugelsang, K.C., Gump, B.H. and Nury, F.S. (1994). Wine Analysis and Production. Chapman & Hall, New York.

Résumé du livre

Winemaking: Control, Bioreactor and Modelling of Process

Desobgo, Z. S. C.* & Nso, E.J.

Wine is one of the oldest forms of alcoholic beverages known to man. Estimates date its origins back to 6000 B.C. Ever since, it's has occupied a significant role in our lives, be it for consumption, social virtues, therapeutic value, it's flavoring in foods, etc. A study of the wine production and the technology of wine making is thus imperative.

The preparation of wine involves steps from harvesting the grapes, fermenting the must, maturing the wine, stabilizing it finally, to getting the bottled wine to consumers. The variety of cultivars, methods of production, and style of wine, along with presentation and consumption pattern add to complexity of wine making. In the past couple of decades, there have been major technological advances in wine production in the areas of cultivation of grapes, biochemistry and methods of production of different types of wines, usage of analytical techniques has enabled us to produce higher quality wine. The technological inputs of a table wine, dessert wine or sparkling wine, are different and has significance to the consumer. The role played by the killer yeast, recombinant DNA technology, application of enzyme technology and new analytical methods of wine evaluation, all call for a comprehensive review of the advances made.

This comprehensive volume provides a holistic view of the basics and applied aspects of wine production and technology. The book comprises production steps, dotted with the latest trends or the innovations in the fields. It draws upon the expertise of leading researchers in the wine making worldwide.

IV.4.15) Sorghum Coffee–Lactose Stout Production and Its Physico-Chemical Characterization

Titre de la revue

beverages

MDPI

Comité de lecture

Beverages — Editors

Editor

Prof. Dr. Edgar Chambers IV
Editor-in-Chief
Distinguished Professor and Director, Sensory Analysis Center, Ice Hall, Kansas State University, Manhattan, KS 66506, USA
Website | E-Mail
Interests: sensory quality; consumer acceptance; health aspects; product development; shelf-life; quality control
Special Issues and Collections in MDPI journals

Editorial Board

Prof. Dr. Kris Berglund
University Distinguished Professor of Food Science and Chemical Engineering, Michigan State University, East Lansing, MI 48824, USA
Website | E-Mail
Interests: New and alternative uses of agricultural and forest raw materials; separation, purification, and crystallization processes for food, pharmaceutical, and chemical industries. Distilled beverage technology

Dr. Antonio Bevilacqua
Department of the Science of Agriculture, Food and Environment, University of Foggia, Italy
E-Mail
Interests: fermentation, probiotic, alternative approaches, shelf life definition, spoiling microorganisms

Dr. Julie Bower
Independent scholar
E-Mail
Interests: alcoholic beverages market structure; competition and merger policy; regulatory capture

Prof. Dr. Angel A. Carbonell-Barrachina
Universi dad Miguel Hernández de Elche (UMH), Escuela Politécnica Superior de Orihuela (EPSO), Spain
Website | E-Mail
Interests: Sensory evaluation of foods; Consumer studies; Food quality; Food safety; Volatile compounds; Pomegranate; Quinces; Unit operations; Rice based-foods; Arsenic and heavy metals; Turrón and nougat; Pistachios and almonds
Special Issues and Collections in MDPI journals:
Special Issue: Flavour Volatiles of Foods

Dr. Antonio Cilla
Nutrition and Food Chemistry Department, Faculty of Pharmacy, University of Valencia, Avn. Vicente Andrés Estellés s/n, Burjassot (Valencia), Spain
E-Mail
Interests: fruit juices; infussions; antioxidant capacity; polyphenols;phytochemicals; storage; in vitro gastrointestinal digestion; bioaccessibility; bioactivity; culture cells (Caco-2; HT-29; HepG2);chemoprevention; oxidative stress
Special Issues and Collections in MDPI journals:
Special Issue: Fruit Beverages: Nutritional Composition and Health Benefits
Special Issue: Fruit Beverages and Human Intervention Studies

Dr. Alessandra Durazzo
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di ricerca per gli Alimenti e la Nutrizione, Via Ardeatina 546, 00178, Rome, Italy

E-Mail
Interests: antioxidants, Bioactive compounds, Food Quality, Nutrition, Biodiversity

Dr. Palanivel Ganesan
Department of Applied Life Science and Biotechnology, College of Biomedical and Health Science, Konkuk University, Republic of Korea
Website | E-Mail
Interests: Food Technology - Value added food product development using underutilized plant foods; Food Processing- Plant foods and its biochemistry; Novel Healthy Foods –Product development using underutilized plant foods

Dr. Joerg Gruenwald
Analyze & Realize GmbH, Waldseeweg 6, 13467 Berlin, Germany
E-Mail
Interests: clinical trials; natural products; herbal medicines; functional beverages

Dr. Solomon Habtemariam
Pharmacognosy Research Laboratories, Medway School of Science, University of Greenwich, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK
Website | E-Mail
Interests: Targeting inflammatory cytokines and adhesion molecules by natural products; Search for anti-microbial agents: antileishmanial, antibacterial and antifungal agents; Identification of potential anti-cancer and immunomodulatory compounds; Search for anticachexic agents from natural sources; Modulation of reactive oxygen species in health and disease; Identification of antidiabetic agents from plant sources; Search of potential natural products that promote weight loss;_ etc.

Dr. James Harbertson
Wine Science Center, School of Food Science, Viticulture and Enology Program, Washington State University, USA
Website | E-Mail
Interests: red wine phenolics; proanthocyanidins; anthocyanins; tannins; winemaking; extended maceration; astringency; bitterness

Prof. Dr. Károly (Charles) Héberger
Hungarian Academy of Sciences, Budapest, Hungary
E-Mail
Interests: liquid phase oxidation; radical processes; inhibition; modeling; computer simulations; determination of rate constants by fast-flow technique LMR detection and by kinetic ESR spectroscopy; linear free energy relationships in radical reactions; quantitative - structure activity relationships; QSAR; QSPR; QSRR; quantitative - structure (gas-chromatographic) retention relationships; chemometrics

Dr. Debra Hector
Physical Activity, Nutrition and Obesity Research Group (PANORG), Prevention Research Collaboration (PRC), School of Public Health, The University of Sydney, NSW 2050, Australia
Website | E-Mail
Interests: prevention; health promotion; evidence-based policy and planning; translational research; evaluation tools and methods; food environment

Prof. Dr. Anet Režek Jambrak
Faculty of Food Technology and Biotechnology, University of Zagreb, Croatia
Website | E-Mail
Interests: alternative food processing; non-thermal techniques; thermodynamics; functional properties

Dr. António Manuel Jordão
Polytechnic Institute of Viseu, Agrarian Higher School - Department of Food Industries, Quinta da Alagoa - Estrada de Nelas 3500-606 Viseu, Portugal
E-Mail
Interests: Wine, grapes, phenolic compounds, enology, winemaking, wood in enology, barrels
Special Issues and Collections in MDPI journals:
Special Issue: Phenolic Compounds in Fruit Beverages

Dr. Kadri Koppel
Assistant Professor, Department of Human Nutrition, Kansas State University. 1310 Research Park Drive, 141 Ice Hall, 66502, Manhattan, KS, USA
E-Mail
Interests: method development and processing effect on sensory and aromatic properties and on consumer acceptance

Dr. Tatiana Koutchma
Agriculture and Agri-Food Canada, GFRC, 93 Stone Road West, Guelph, ON, N1G 5C9, Canada
E-Mail
Interests: novel food processing technologies; ultraviolet light; high hydrostatic pressure; electromagnetic heating; process development and validation; food safety engineering; regulations; technology transfer
Special Issues and Collections in MDPI journals:
Special Issue: Advanced Technology in Beverage Processing

Dr. Dirk W. Lachenmeier
Chemical and Veterinary Investigation Agency Karlsruhe, Weissenburger Strasse 3, 76187 Karlsruhe, Germany
Website | E-Mail
Interests: food toxicology; regulatory toxicology; food safety; epidemiology; risk assessment; chemical contaminants; cancer; alcoholic beverages; ethanol; acetaldehyde; thujone; formaldehyde; furan

Dr. Jeehyun Lee
Associate Professor, Department of Food Science and Nutrition, Pusan National University, Busan, 609-735, Korea
E-Mail
Interests: consumer acceptance; descriptive evaluation; green tea; alcoholic beverages

Prof. Dr. Olga Martín-Belloso
Food Technology Department, Faculty of Agrifood and Forestry Science and Engineering, University of Lleida, Rovira Roure, 191, 25198 Lleida, Spain
E-Mail
Interests: food safety; quality and functionality through nonthermal processing; mainly in fruits and vegetables: pulsed electric fields; intense light pulses; cold plasma; edible films and coatings; combined methods including modified atmosphere packaging (MAP); natural antimicrobials; antibrowning and stabilizing substances among others; Nanoemulsions and nanocoatings; Valorization of by-products from fruits and vegetables processing: obtention and characterization of bioactive compounds; functional food product development; modelling; process condition optimization; kinetics and shelf-life studies

Dr. Miranda Mirosa
Department of Food Science,University of Otago, Dunedin, New Zealand
Website | E-Mail
Interests: Consumer behavior and food/beverage choice; Consumer research methods; Cross cultural research on food/beverage preferences; Asian consumers' food/beverage preferences; The impact of food/beverage choice on consumers' health and wellness; Environmental and sustainability issues around food/beverage choice
Special Issues and Collections in MDPI journals:
Special Issue: Consumer behavior and beverage choice

Dr. Richard Owusu-Apenten
Faculty of Life and Health Sciences, School of Biomedical Sciences, Ulster University, Cromore Road, Coleraine BT52 1SA, UK
Website | E-Mail
Interests: antioxidants assays; phytochemicals; anticancer, antimicrobial effects
Special Issues and Collections in MDPI journals:
Special Issue: Tea Polyphenols and Antioxidants: Analysis, Chemistry and Biotechnological Applications

Dr. Salvatore Parisi
Leader of the Food and Beverage Science and Technology Team, the Science Advisory Board, Arlington, VA, USA
E-Mail
Interests: Food packaging; Predictive calculation of shelf life; Study of evolutive profiles for

different bacteriae; Development of new indirect methods and software for the study of cheeses

Dr. Lisa Ryan
Department of Nutrition and Dietetics, Monash University, VIC 3195, Australia
Website | E-Mail
Interests: analysis and development of novel functional foods for glycaemic control and weight loss; maintenance with a particular focus on the potential role of phytochemicals as functional food ingredients

Dr. James M. Seff
Pillsbury Winthrop Shaw Pittman LLP, Four Embarcadero Center, 22nd Floor, San Francisco, CA 94111, USA
Website | E-Mail
Interests: Alcoholic Beverages; Trade Practices law; Labeling; Tied-house law; Licensing; Regulatory Authorities in the U.S.; Federal Tax and Trade Bureau (TTB)

Dr. Lisa Solieri
Department of Life Sciences, University of Modena and Reggio Emilia, Italy
Website | E-Mail
Interests: Starter culture, stress response, wine, vinegar, yeast genetics, spoilage yeasts, Zygosaccharomyces, Saccharomyces hybrids, mating type, strain diversity, lactic acid bacteria, food carrier, probiotics

Dr. Jodi Stookey
Children's Hospital Oakland Research Institute, 5700 Martin Luther King Jr Way, Oakland CA 94609, USA
E-Mail
Interests: hydration epidemiology; water intake; hydration status; osmolality; acute and chronic health effects in healthy; free-living people

Dr. Christopher Taylor
Beverage Management Program and Fred Parks Wine Cellar; Conrad N. Hilton College of Hotel and Restaurant Management, University of Houston, USA
E-Mail
Interests: Consumer Behavior, Preference Development, Wine Education, Wine Tourism, Pro-environmental Beverages, Pro-environmental Beverage Tourism, Cellar Management

Prof. Dr. José António Couto Teixeira
Departamento de Engenharia Biológica, Universidade do Minho, Campus de Gualtar 4710-057, Braga, Portugal
E-Mail
Interests: new beverages; continuous production; processes; healthy drinks; yeast and bacterial physiology; enzymes and beverages

Dr. Laura Vázquez-Araújo
Responsible of Sensory Research and Development. Hijos de Rivera S.A.U. A Coruña, Spain
E-Mail
Interests: sensory analysis; sensory quality; beer; aromas; volatile composition of foodstuffs
Special Issues and Collections in MDPI journals:
Special Issue: Fruit Beverages: Sensory Evaluation and Consumer Acceptance

Dr. Quan V. Vuong
Nutrition Food & Health Research Group, School of Environmental and Life Sciences, University of Newcastle, Australia
E-Mail
Interests: Identification,extraction and isolation of bioactive compounds from natural resources and waste for further utilization in the food and pharmaceutical industries
Special Issues and Collections in MDPI journals:
Special Issue: Tea: Varieties, Production, Functional Applications and Health Benefits

Dr. Frank Welle
Business Development Manager - Packaging, Fraunhofer Institute for Process Engineering and Packaging (IVV), 85354 Freising, Germany

Website | E-Mail
Interests: beverage packaging; active and intelligent materials; food law compliance testing; packaging recycling
Special Issues and Collections in MDPI journals:
Special Issue: Beverage Packaging

Dr. Danyang Ying
CSIRO Animal, Food & Health Sciences 671 Sneydes Road, Werribee, Melbourne, VIC3030, Australia
E-Mail
Interests: microencapsulation; targeted and controlled release delivery; bioactives; functional foods; probiotics; materials science and process engineering; drying; fluid bed coating; extrusion; biomaterials; biopolymers; water sorption; physical properties; glass transition; reaction kinetics; computer modelling

---

Dr. Dimitrios Zabaras
Nestlé Purina Petcare Australia
Website | E-Mail
Interests: chemical contaminants; natural toxins; mass spectrometry; analytical chemistry; method development & validation
Special Issues and Collections in MDPI journals:
Special Issue: Chemical Contaminants in Beverages: 'Traditional' and Emerging Risks in an Ever-Changing World

---

Table des matières

Table of Contents

Beverages, Volume 5, Issue 1 (March 2019)

- Rethinking Luxury for Segmentation and Brand Strategy: The Semiotic Square and Identity Prism Model for Fine Wines

by Federica Galli, Carl A. Boger and D. Christopher Taylor
Beverages 2019, *5*(1), 26; https://doi.org/10.3390/beverages5010026 - 19 Mar 2019

- Shelf-Life Extension of Wood Apple Beverages Maintaining Consumption-Safe Parameters and Sensory Qualities

by Md. Shakir Moazzem, Md. Belal Hossain Sikder and Wahidu Zzaman
Beverages 2019, *5*(1), 25; https://doi.org/10.3390/beverages5010025 - 12 Mar 2019

- Wine Aging Technologies

by Maria Del Alamo-Sanza and Ignacio Nevares
Beverages 2019, *5*(1), 24; https://doi.org/10.3390/beverages5010024 - 12 Mar 2019

- The Effect of the Tactile Attributes of a Container on Mineral Water Perception

by Paola Risso, Emanuela Maggioni, Roberta Etzi and Alberto Gallace
Beverages 2019, *5*(1), 23; https://doi.org/10.3390/beverages5010023 - 05 Mar 2019

- Coconut Neera—A Vital Health Beverage from Coconut Palms: Harvesting, Processing and Quality Analysis

by Mohankumar Chinnamma, Salini Bhasker, Malavika Binitha Hari, Divyaa Sreekumar and Harish Madhav
Beverages 2019, *5*(1), 22; https://doi.org/10.3390/beverages5010022 - 02 Mar 2019

- Biocatalyst Potential of Cellulose-Degrading Microorganisms Isolated from Orange Juice Processing Waste

by Ioanna Zerva, Nikolaos Remmas and Spyridon Ntougias
Beverages 2019, *5*(1), 21; https://doi.org/10.3390/beverages5010021 - 02 Mar 2019

- Sorghum Coffee–Lactose Stout Production and Its Physico-Chemical Characterization

by Fali Mbeh. Harry, Desobgo Zangué Steve Carly and Nso Emmanuel Jong
Beverages 2019, *5*(1), 20; https://doi.org/10.3390/beverages5010020 - 01 Mar 2019

- An Overview on Biogenic Amines in Wine

by Antonella Costantini, Enrico Vaudano, Laura Pulcini, Tommaso Carafa and Emilia Garcia-Moruno
Beverages 2019, *5*(1), 19; https://doi.org/10.3390/beverages5010019 - 01 Mar 2019

- Partial Replacement of Maltodextrin by Sweet Potato Flour (*Ipomoea Batatas* L. Lamarck) in the Development of a Shake Beverage

by Gisele Kirchbaner Contini, Fabielli Priscila de Oliveira, Alana Martins and Katielle Rosalva Voncik Córdova
Beverages 2019, *5*(1), 18; https://doi.org/10.3390/beverages5010018 - 01 Mar 2019

- Simultaneous Voltammetric Determination of Gallic and Protocatechuic Acids in Mango Juice Using a Reduced Graphene Oxide-Based Electrochemical Sensor

by Refat Abdel-Hamid, Ahmed Bakr, Emad F. Newair and François Garcia
Beverages 2019, *5*(1), 17; https://doi.org/10.3390/beverages5010017 - 06 Feb 2019

- Techno-Functional Role of Exopolysaccharides in Cereal-Based, Yogurt-Like Beverages

by Valery Ripari
Beverages 2019, *5*(1), 16; https://doi.org/10.3390/beverages5010016 - 01 Feb 2019

- Quality Acceptability, Nutritional Composition and Antioxidant Properties of Carrot-Cucumber Juice

by Taiwo Ayodele Aderinola and Kemi Elizabeth Abaire
Beverages 2019, *5*(1), 15; https://doi.org/10.3390/beverages5010015 - 01 Feb 2019

- *Listeria monocytogenes* in Milk: Occurrence and Recent Advances in Methods for Inactivation

by Sarah Hwa In Lee, Leandro Pereira Cappato, Jonas Toledo Guimarães, Celso Fasura Balthazar, Ramon Silva Rocha, Larissa Tuanny Franco, Adriano Gomes da Cruz, Carlos Humberto Corassin and Carlos Augusto Fernandes de Oliveira
Beverages 2019, *5*(1), 14; https://doi.org/10.3390/beverages5010014 - 01 Feb 2019

- Current Trends in Fully Automated On-Line Analytical Techniques for Beverage Analysis

by Karen Mejía-Carmona, Marcela Jordan-Sinisterra and Fernando M. Lanças
Beverages 2019, *5*(1), 13; https://doi.org/10.3390/beverages5010013 - 01 Feb 2019

- Hydrothermal Carbonization of Brewery's Spent Grains for the Production of Solid Biofuels

by Mateusz Jackowski, Damian Semba, Anna Trusek, Mateusz Wnukowski, Lukasz Niedzwiecki, Marcin Baranowski, Krystian Krochmalny and Halina Pawlak-Kruczek
Beverages 2019, *5*(1), 12; https://doi.org/10.3390/beverages5010012 - 01 Feb 2019

- Consumption of Chlorogenic Acids through Coffee and Health Implications

by Adriana Farah and Juliana de Paula Lima
Beverages 2019, *5*(1), 11; https://doi.org/10.3390/beverages5010011 - 01 Feb 2019

- Study of High Power Ultrasound for Oak Wood Barrel Regeneration: Impact on Wood Properties and Sanitation Effect

by Marion Breniaux, Philippe Renault, Fabrice Meunier and Rémy Ghidossi
Beverages 2019, *5*(1), 10; https://doi.org/10.3390/beverages5010010 - 01 Feb 2019

- Acknowledgement to Reviewers of *Beverages* in 2018

by Beverages Editorial Office
Beverages 2019, *5*(1), 9; https://doi.org/10.3390/beverages5010009 - 23 Jan 2019

- Pulsed Electric Field Extraction and Antioxidant Activity Determination of *Moringa oleifera* Dry Leaves: A Comparative Study with Other Extraction Techniques

by Eleni Bozinou, Ioanna Karageorgou, Georgia Batra, Vassilis G. Dourtoglou and Stavros I. Lalas
Beverages 2019, *5*(1), 8; https://doi.org/10.3390/beverages5010008 - 13 Jan 2019

- Wine-Derived Phenolic Metabolites in the Digestive and Brain Function

by Irene Zorraquín-Peña, Adelaida Esteban-Fernández, Dolores González de Llano, Begoña Bartolomé and M. Victoria Moreno-Arribas
Beverages 2019, *5*(1), 7; https://doi.org/10.3390/beverages5010007 - 11 Jan 2019

- Direct Determination of Zn, Cd, Pb and Cu in Wine by Differential Pulse Anodic Stripping Voltammetry

by Juliana V. Maciel, Michele M. Souza, Lisiane O. Silva and Daiane Dias
Beverages 2019, *5*(1), 6; https://doi.org/10.3390/beverages5010006 - 11 Jan 2019

- Improving Fermentation Rate during Use of Corn Grits in Beverage Alcohol Production

by Deepak Kumar, Anna-Sophie Hager, Alberto Sun, Winok Debyser, Bruno Javier Guagliano and Vijay Singh
Beverages 2019, *5*(1), 5; https://doi.org/10.3390/beverages5010005 - 11 Jan 2019

- Fortification of Ground Roasted Coffees with Iron, Zinc, and Calcium Salts: Evaluation of Minerals Recovery in Filtered and Espresso Brews

by Angela Soares, Nathalia M. Barros, Tatiana D Saint'Pierre, Juliana De P. Lima, Verônica Calado, Carmen. M Donangelo and Adriana Farah
Beverages 2019, *5*(1), 4; https://doi.org/10.3390/beverages5010004 - 10 Jan 2019

- Migration of Bisphenol A from Can Coatings into Beverages at the End of Shelf Life Compared to Regulated Test Conditions

by Carina Stärker and Frank Welle
Beverages 2019, *5*(1), 3; https://doi.org/10.3390/beverages5010003 - 07 Jan 2019

- Antioxidant Properties of a Yogurt Beverage Enriched with Salal (*Gaultheria shallon*) Berries and Blackcurrant (*Ribes nigrum*) Pomace during Cold Storage

by Vassilios Raikos, He Ni, Helen Hayes and Viren Ranawana
Beverages 2019, *5*(1), 2; https://doi.org/10.3390/beverages5010002 - 27 Dec 2018

- Comparative Study of a Cell-Based and Electrochemical Biosensor for the Rapid Detection of 2,4,6-Trichloroanisole in Barrel Water Extracts

by Georgia Moschopoulou, Sophie Mavrikou, Diego Valdes and Spyridon Kintzios
Beverages 2019, *5*(1), 1; https://doi.org/10.3390/beverages5010001 - 25 Dec 2018

Pages de l’article

beverages

MDPI

Article

Sorghum Coffee–Lactose Stout Production and Its Physico-Chemical Characterization

Fali Mbeh. Harry [1], Desobgo Zangué Steve Carly [2,*] and Nso Emmanuel Jong [1]

[1] Department of Process Engineering, National School of Agro-Industrial Sciences (ENSAI) of the University of Ngaoundere, P.O. Box 455 ENSAI, Ngaoundere, Cameroon; falimbeh@yahoo.com (F.M.H.); nso_emmanuel@yahoo.fr (N.E.J.)

[2] Department of Food Processing and Quality Control, University Institute of Technology (UIT), University of Ngaoundere, P.O. Box 455 UIT, Ngaoundere, Cameroon

* Correspondence: desobgo.zangue@gmail.com; Tel.: +237-697-16-00-04

Received: 23 June 2018; Accepted: 2 February 2019; Published: 1 March 2019

Abstract: Sorghum (*Safrari*) was valorized into sorghum coffee-lactose stouts using *Vernonia amygdalina* as a bittering ingredient. These sorghum grains and subsequent sorghum pale malt were tested for their acceptability in the brewing field. Results obtained were the germinative capacity of 99.29 ± 0.58%, a germinative energy of 98.56 ± 1.79%, a thousand corns weight 48.08 ± 0.02 g for the grains, and a diastatic power of 187.44 ± 7.89 WK for sorghum malt. The worts and beers produced were characterized and were found suitable. Moreover, alcohol content in stout beers obtained was between 8.8% and 9.4% ABV. Sensory evaluation was implemented on beers using 30 panellists and the best combination was the one using 50% lactose (250 g) and 50% coffee (250 g) in 5 L of wort during wort boiling.

Keywords: *Safrari*; coffee; lactose; stout beer; sensory evaluation

1. Introduction

Sorghum is Africa's fourth most important crop in terms of tonnage after maize, rice, and wheat [1]. In certain parts of Africa and India, sorghum grain has traditionally been used in the production of porridge, alcoholic beverages, and for bread making [2]. More than 300 million people in developing countries rely on sorghum as an energy source [3–5]. This is the case in Cameroon where sorghum is the largest energy source in the northern part [6–8] with a significant annual production of 1,102,000 tons [1]. Given the competition of multinational enterprises, sorghum appears to be the best alternative to lager beer production [8]. Barley has become the basic raw material for brewing for both barley and non-barley-producing countries like Cameroon. The process of brewing lager beer with cereals other than barley is growing to be a common practice, especially in non-barley-producing countries due to various drawbacks related to barley. Barley is a temperate cereal and the African climate is unsuitable for its cultivation. This presents a major problem; barley grain or barley malt must be imported, hence there are skyrocketing prices due to strong global demand and high shipping costs, meaning some valuable foreign exchange and increasing the price of the beer beyond the reach of most Africans. Importation also disadvantages local farmers as it denies them potential markets [9]. This occurs in Cameroon and these force a re-think by industries to invest in other cereals as a malting substitute. Sorghum can be well and efficiently utilized industrially in Cameroon for producing beer. The chemical composition of sorghum reassures it as an alternative cereal to barley in lager style beer production. It was previously believed that beer could not be produced without barley. However, it has been well-documented that cereals like sorghum have the potential to be an alternate substrate for conventional beer brewing. Research studies into sorghum are progressing rapidly and

making a significant impact in brewing despite the earlier misunderstanding that malted sorghum developed insufficient hydrolytic enzymes [6–10]. Differences in malting and mashing temperatures employed in studies of sorghum in the past were an important contributory factor and complicated our understanding of the physiological behavior of sorghum during processing [6–10]. In recent times, the large body of work carried out on sorghum to understand the physiological behavior of sorghum has led to improved malting and mashing processes amongst other findings, such as improved varieties of sorghum suitable for beer brewing, which contributes in producing commercially acceptable sorghum beers both lager and stout [6,7,11–15]. Nigeria, South Africa, Uganda, Tanzania, Zambia, and Zimbabwe successfully brew commercial sorghum lager and stout beer [16]. The utilization of a locally grown crops as a brewing material is cost effective and can potentially boost the regional economy of Cameroon. It would benefit sorghum farmers with guaranteed income and thus reduce unemployment. In addition, the use of a native crop would reduce logistical costs for manufacturers resulting in reduced beer retail prices [17]. Manufacturers would be able to negotiate lower taxes with the government on sorghum-based beer, which would contribute to another significant cost reduction of particular benefit to the consumer. It would help create affordable lager beer for consumers for whom this type of beer is unaffordable. These factors would thus lead to an increased growth in the brewing industry [17]. Sorghum beer is gluten-free and can be used by celiacs [18,19]. In order to valorize sorghum, we came up with producing a coffee–lactose sorghum stout. The choice of coffee and lactose is not trivial. Beer customers showed interest in such a beer as they showed interest to give their impression. Bitter leaf (*Vernonia amygdalina*) was used as a substitute for hop. Bitter leaf has successfully served as a substitute to hop in lager beer. Its properties render it suitable for use [20–24]. We were interested in this paper to present how the production of the coffee–lactose stout from the malting process through and fermentation was undertaken. Thereafter, the results of the analyses conducted on worts and beers are discussed, ending up with discussing the sensory evaluation of the beers.

2. Materials and Methods

2.1. Acquisition of Materials

Safrari sorghum cultivar (Figure 1) used was obtained from the Institute of Research and Agronomic Development (IRAD), Maroua, Cameroon. The *Vernonia amygdalina* leaves (Figure 2) were harvested from farms in the Bini-dang neighborhood of Ngaoundere, Cameroon. *Coffea arabica* (Figure 3) beans used during this work were bought from a local cooperative society in Bafoussam, Cameroon.

Figure 1. *Safrari* cultivar.

Figure 2. *Vernonia amygdalina* (bitter leaf).

Figure 3. Green coffee bean.

The D-Lactose monohydrate was obtained from Sigma-Aldrich, Johannesburg, South Africa. *Saccharomyces cerevisiae* (Safbrew T-58) used for fermentation was obtained from "Malterie du Chateau", Chemin du Couloury 1, 4800 Lambermont, Belgium. The characteristics of the commercial mashing enzymes used are: Hitempase 2XL®, a thermostable α-amylase from *Bacillus licheniformis*, and Bioglucanase TX, from an enzymatic composition of β-glucanase and hemicellulases from *Trichoderma reesei* and their sources, are presented in Table 1. Hitempase 2XL and Bioglucanase TX were obtained from Kerry Bioscience, Kilnagleary, Carrigaline, Co. Cork, Ireland.

Table 1. Characteristics of commercial enzyme preparations used during mashing.

	Commercial Mashing Enzyme	
	Hitempase 2XL	**Bioglucanase TX**
Organism of origin	*Bacillus licheniformis*	*Trichoderma reesei*
Activity	4416.29 ± 19.34 U/mL	750 BGU/mL
Description	α-amylase	β-glucanase
Optimum temperature (°C)	60–95	60
Optimum pH	4–8	4.5–6.5
Recommended application level in adjuncts	60 U/g	0.01 and 0.025% (*v*/*w*)
Form	Solution	Solution

2.2. General Work Overview

Safrari cultivar was sorted to obtain homogenous samples free from foreign materials, and broken and infected grains. The sorted grains were submitted to tests of acceptability and brewing potential, which included: the germinative capacity, germinative energy, moisture content, thousand corns weight, and total ash. The grains were then malted (Figure 4) and different malts were produced by

varying the kilning program. Diastatic power of the pale malt was also determined. Malted grains were mashed with a supplement of exogenous enzymes (Hitempase 2XL and Bioglucanase TX). Coffee and D-Lactose monohydrate (lactose) were added during the boiling process of wort following a mixture design to produce worts of different formulations. Dry bitter leaves (*Vernonia amygdalina*) were used as a substitute to hops. Worts produced were fermented with *Saccharomyces cerevisiae* (Safbrew T-58) at ambient temperature (25 °C). Formulations of worts, as well as the corresponding beers produced, underwent physicochemical analyses. A sensory analysis of the beers was performed. It consisted of a hedonic nine-point verbal scale with 30 panellists.

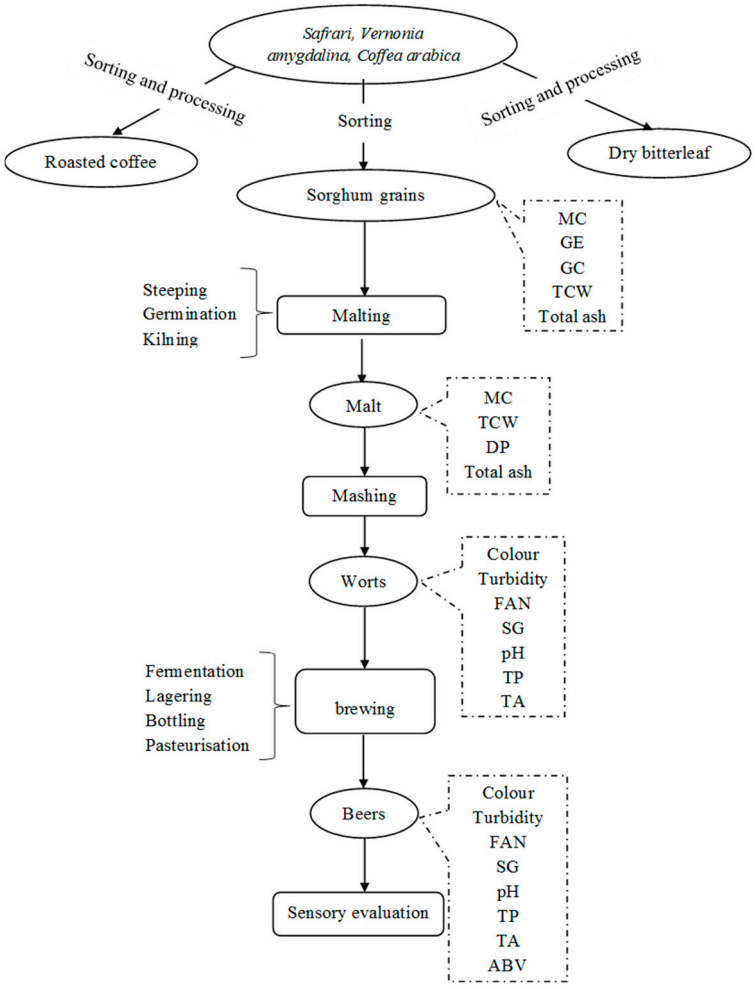


Figure 4. General work overview (MC = moisture content; GE = germinative energy; GC = germinative capacity; TCW = thousand corn weight; DP = diastatic power; FAN = free amino nitrogen: SG = specific gravity; TP = total polyphenols; TA = titratable acidity; ABV = alcohol by volume).

2.3. Processing of Raw Bitter Leaves (Vernonia Amygdalina)

As showed in Figure 5, the leaves were screened to remove foreign bodies and withered leaves. They were thoroughly washed afterwards with tap water, rinsed, and oven-dried at 30 °C for 9 days. Dried leaves were hand crushed and conditioned in glass bottles, in a refrigerator at 4 °C.

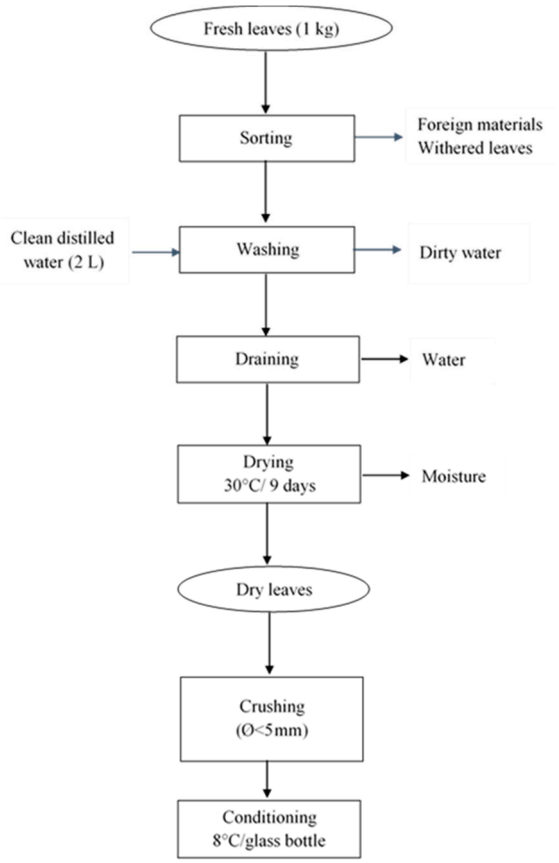


Figure 5. Processing of *Vernonia amygdalina* leaves.

2.4. Processing of Coffee Beans

The coffee beans were bought with their parchment. They were thus dehulled manually to obtain the green beans. The green beans were roasted at 200 °C for 20 min in a Memmert ventilated oven (ULM/SLM 400–800), Germany. They were subsequently cooled before being ground and conditioned in glass bottles. Figure 6 depicts the process used.

2.5. Preparation of Sorghum Grains

Sorghum grains were cleaned by first manually sorting to remove deformed, small, broken, and immature kernels, dust, sand, stones, and other foreign materials.

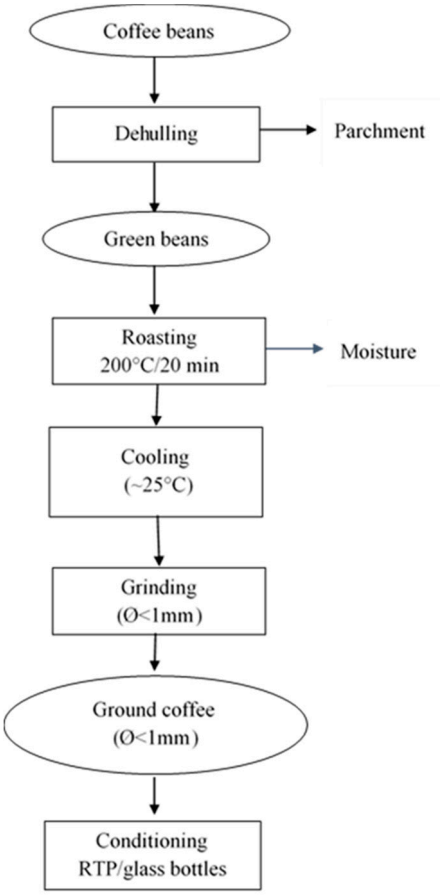


Figure 6. Processing of coffee beans.

2.6. Analysis of Sorghum Grain

2.6.1. Determination of the Germinative Energy of Sorghum

Two filter papers were placed at the bottom of two Petri dishes. A total of 4 mL and 8 mL of distilled water were accurately added [25].

Two lots of 100 corns were placed on the paper so that each made good contact without drowning the embryo by ensuring that the ventral side only touched the paper. After which, the dish was covered to prevent moisture loss, and placed in a dark cupboard. Chitted corns were removed after 24, 48, and 72 h from the beginning of steeping, thus avoiding excessive moisture uptake by those corns that germinated early. The germinative energy was calculated using the formula:

$$GE = 100 - N_{ng} \quad (1)$$

where GE is the germinative energy (%) and N_{ng} is the number of grains that had not chitted.

2.6.2. Determination of the Germinative Capacity of Sorghum

Three lots of 200 corns were obtained after removing foreign matter and half of the corns out of each of the lots of 200 corns was steeped in 200 mL of fresh H_2O_2 solution at a concentration of 7.5 g/L at room temperature (22–25 °C) for 2 days. After a day, the steep liquor was drained off and replaced with 200 mL of fresh H_2O_2 solution at room temperature. After 2 days of steeping the steep liquor was

drained off and corns were separated and counted for those that had not developed both roots and acrospires [25]. The germinative capacity was calculated using the formula:

$$GC = \frac{200 - N_{ng}}{2} \quad (2)$$

where GC is the germinative capacity (%) and N_{ng} is the number of grains that had not chitted.

2.6.3. Determination of the Thousand-Corn Weight of Sorghum

Three lots of 35 g of sorghum was sampled and weighed, and half of the corns and foreign matter was removed and the weight subtracted, after which the corns were counted in each lot. This experiment was repeated thrice to obtain a more precise and accurate value. The thousand-corn weight on the dry matter was calculated using a standard formula [25]:

$$TCW = \frac{1000 \times (100 - M) \times W}{100 \times N} \quad (3)$$

where TCW is the weight of a thousand corns of dry sorghum in g, W is the weight of lot of sorghum taken in g, M is the moisture% (m/m), and N is the number of corns in each lot taken.

2.6.4. Determination of the Moisture Content

Twenty grams of sorghum was finely milled using a hand grinding machine and 5 g of the flour obtained was put in a clean dry dish and dried at of 105 °C for 24 h. The product was later removed from the oven and was immediately allowed to cool in a desiccator and weighed again. The moisture content percentage (%) of the sample was calculated using a standard formula [25]:

$$MC = \frac{100 \times (M_0 - M_1)}{M_0} \quad (4)$$

where MC is the moisture content (%), M_0 is the mass in g of the sample before drying, and M_1 is the mass in g after drying.

2.6.5. Determination of Total Ash

The sample was completely incinerated until obtaining white ash in a muffle furnace calibrated at 550 °C [26]. For that, the porcelain crucibles containing the samples resulting from drying at 105 ± 2 °C (M_2) were placed in the furnace. After incineration for 24 h, the crucibles were removed from the furnace by using grips, then cooled in the atmosphere of a desiccator and weighed (M_3). The ash content per 100 g of DM (dry matter) was calculated using the formula:

$$Total\ ash = \frac{100 \times (M_3 - M_1)}{M_2} \quad (5)$$

where M_1 is the mass of the empty crucible.

2.7. Experimental Procedure for Malting Sorghum

Seven kilograms of *Safrari* sorghum cultivar grains were washed three times using 21 L of distilled water to remove dirt and foreign bodies. Grains were steeped in 21 L of distilled water for 48 h at room temperature (≈25 °C) with three changes of water at intervals of 12 h before steep out. Germination was carried out for 4 days in a Heraeus type incubator (D-63450 Hanau, Germany) at a temperature of 25 °C with water sprinkled on the grains on a daily basis. The green malt was then kilned following different kilning programs to obtain characteristic malts used in the beer recipe. The malt was rubbed-off of its rootlets and stored until further use. Different malts were produced by varying the temperature

and time for kilning the green malt [27]. Four malts were used in the course of this work: base malt, caramel malt, toasted malt, and roasted malt. Figure 7 shows the malting process.

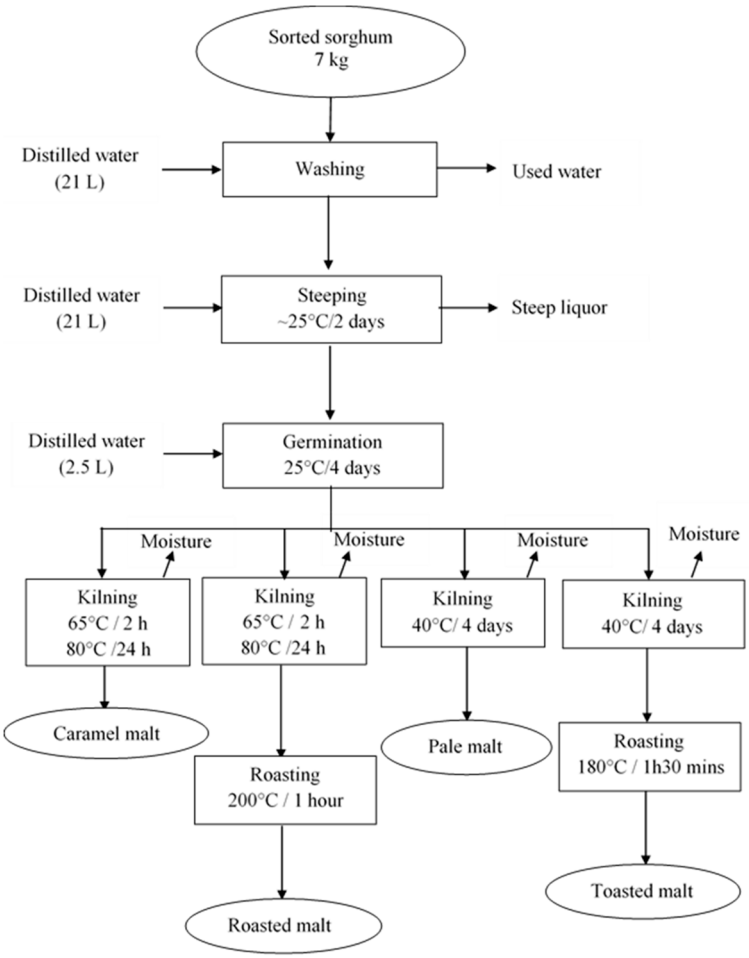


Figure 7. Sorghum malting process.

2.8. Determination of the Diastatic Power of Pale Malt

For the enzyme extraction, a water bath was first set at 40 °C. Ten grams of flour was measured into a beaker and 480 mL of water added. The mixture was mixed to avoid balling. The beaker was placed in the water bath and mashed for 1 h while stirring continuously. The extraction solution was cooled to room temperature. The beaker contents were adjusted to 510 g. The contents of the beaker were stirred and transferred onto a filter. The first 200 mL were discarded and the next 50 mL immediately used for analysis. A hundred mililiters of starch solution was pipetted into a 200 mL volumetric flask. Five milliliters of sodium acetate buffer was added and the flask placed in the water bath at 20 °C and allowed to stand for 20 min. Five mililiters of the flour extract was added using a pipette, then the contents of the flask was shaken thoroughly and replaced in the bath for 30 min. Sodium hydroxide (4 mL) was added to the mix to inactivate the enzymes. The volume was made up to 200 mL with water and mixed well. The alkalinity of the solution was verified using a thymolphthalein solution. The blank was prepared by pipetting 100 mL of starch solution into a 200 mL volumetric flask. NaOH solution (2.35 mL) was then added and mixed thoroughly. The malt extract (5 mL) was then added and the volume made up to 200 mL. The alkalinity was also checked using the thymolphthalein solution. The determination of the reducing sugars was done by transferring a 50 mL aliquot of the digest into a 150 mL Erlenmeyer flask. Into this flask was added 25 mL of iodine solution and 3 mL of sodium hydroxide, and was shaken. The flask was stoppered and allowed to stand for 15 min. Sulfuric

acid (4.5 mL) was added and the unreacted iodine titrated with thiosulphate solution until the blue colour disappeared [25].

$$DP_1 = F \times (V_B - V_T) \quad (6)$$

$$DP_2 = \frac{100 \times DP_1}{100 - M} \quad (7)$$

where, DP_1 is the diastatic power on sample in Windisch–Kolbach (WK) units; DP_2 is the diastatic power on dry malt in Windisch–Kolbach units; V_B is the titration value of the unreacted iodine in the blank test, in mL; V_T is the titration value of unreacted iodine in the test portion, in mL; F is the correction factor to obtain the result per 100g of flour used for the extraction; and M is the moisture content of the flour in percentage (m/m).

2.9. Experimental Procedure for Mashing Sorghum

A decantation mashing program [7] for sorghum was adopted for the study (Figure 8). The quantities and types of malts used are given in Table 2 below. It was done according to preliminary studies.

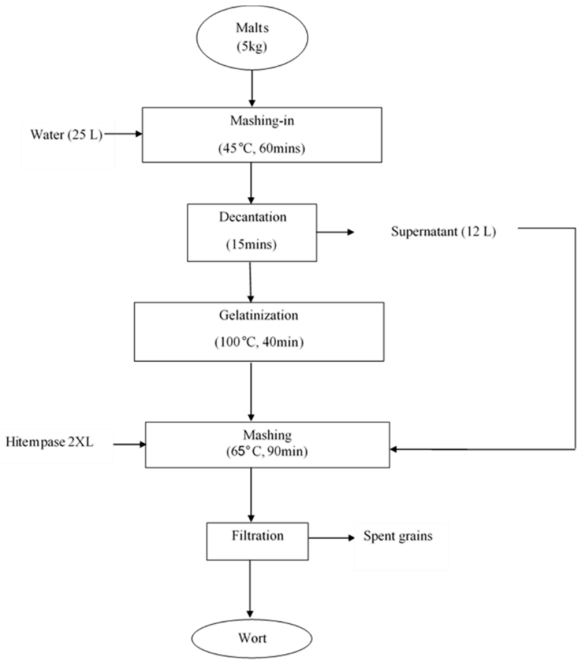


Figure 8. Decantation mashing process.

Table 2. Sorghum malt types and quantities used during mashing.

Sorghum Malt Type	Quantity/kg
Pale malt	3.1
Caramel malt	1.2
Toasted malt	0.3
Roasted malt	0.4

Twenty-five litres of distilled water was put into a stainless-steel pot and 5 kg of a mixture of sorghum malts (flour Ø < 1 mm) as given in Table 2, added with continuous stirring until a homogenous mixture was obtained. This mixture was kept at 45 °C for 1 h with intermittent stirring at intervals of 5 min. The mixture was allowed to decant and 12 L of the supernatant was withdrawn and kept aside. The temperature of the mash was then raised to boiling so as to gelatinize the sorghum starch. This was done for 40 min with intermittent stirring at intervals of 5 min before cooling to 65 °C. The

supernatant withdrawn together with the commercial enzymes (Hitempase 2XL) were added to the mash and held at 65 °C for 1 h 30 min with intermittent stirring at intervals of 10 min. The mash was filtered at 25 °C using Whatmann no. 4 paper to obtain the sweet wort.

2.10. Wort Boiling

The motherwort was divided into five portions of 5 L. Each portion (5 L) of wort was boiled for an hour. During boiling, 35 g of dry bitter leaves per 5 L was added as a substitute for hops. Coffee and lactose (lactose) in a proportion of 10% (w/v) was also added 5 min before the end of wort boiling following a mixture design generated by the software Design Expert ® Version 7.0.0 (Stat-Ease, Inc. 2021 East Hennepin Ave., Suite 480 Minneapolis, MN 55413) as showed in Table 3 below.

Table 3. Experimental matrix.

Std	Run	Block	Proportion		Quantity (g)	
			x_1: Lactose	x_2: Coffee	x_1: Lactose	x_2: Coffee
4	1	Block 1	1.000	0.000	500	0
1	2	Block 1	0.750	0.250	375	125
3	3	Block 1	0.500	0.500	250	250
2	4	Block 1	0.250	0.750	125	375
5	5	Block 1	0.000	1.000	0	500

2.11. Clarification and Fermentation

The bitter worts were then cooled to room temperature, filtered to clarify them, characterized, pitched, and then fermented at room temperature for 9 days. Figure 9 illustrates the fermentation scheme.

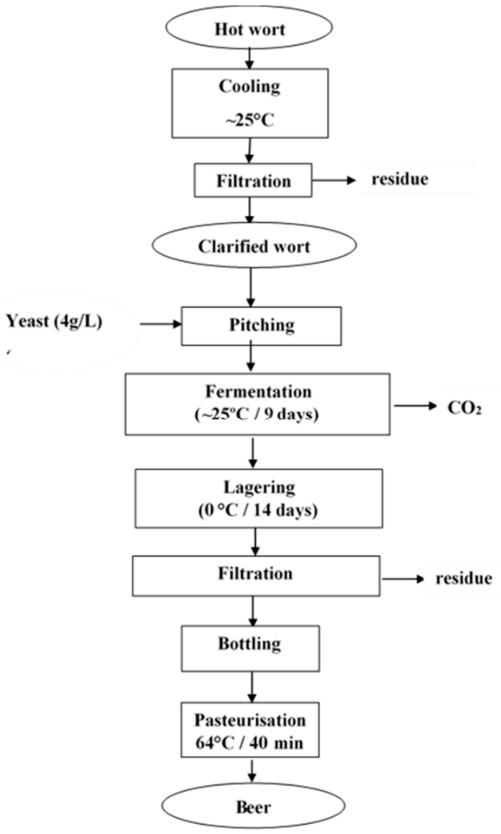


Figure 9. Brewing process.

2.12. Physicochemical Analyses of Worts and Beers

2.12.1. Determination of Specific Gravity (Analytica-EBC, 1998)

A thoroughly cleaned pycnometer was washed and rinsed with distilled water. It was then dried in an oven set at 105 °C for 5 min and then cooled in a desiccator. The initial mass of the pycnometer was weighed and then filled with the sample (wort, beer). The difference in mass between the empty pycnometer and when it was filled with the sample was evaluated. This mass was used to calculate the specific gravity by dividing the value obtained by 25 mL, which corresponds to the volume of the calibrated pycnometer. The specific gravity thus calculated was checked across an extract table for the corresponding concentration in °Brix and °Plato. Results from tables are expressed as °Plato using the Goldiner and Klemann table.

2.12.2. Determination of Color Using Spectrophotometric Method

The wavelength was set at 430 nm. The cell was filled with water and the absorbance set to read 0.00. The cell was then rinsed and filled with the sample (wort and beer) and the absorbance read [25].

$$Color\ (EBC) = A \times d \times 25 \tag{8}$$

where A is the absorbance at 430 nm in 10mm cell and d is the dilution factor

2.12.3. Determination of pH

The electrode of the pH-meter was immersed into the wort and beer samples and the pH was read. The beer was degassed before the pH was read.

2.12.4. Determination of Turbidity

The tube was filled with the sample and wiped carefully and thoroughly. It was then placed in the turbidimeter, closed, and read immediately. Results are expressed in NTU (nephelometric turbidity unit).

2.12.5. Determination of Free Amino Nitrogen (FAN) Content

The samples (wort and beer) were diluted to 1% (v/v); 2 mL of the diluted sample was placed in a test tube into which was added 1 mL of coloured reagent. Tubes were stoppered with aluminium foil, thoroughly homogenized, and placed in a water bath (95 °C) for exactly 16 min and then cooled in cold water (20 °C) for 20 min. After this time, 5 mL of dilution solution was added, mixed, and the absorbance was read at 570 nm against a reference sample prepared from the reagents plus 2 mL of distilled water in place of diluted wort and beer [25]. The free amino nitrogen (FAN) was calculated according to the relation:

$$FAN\ (mg/L) = \frac{A_1 \times 2 \times d}{A_2} \tag{9}$$

where A_1 is the absorbance of test solution at 570 nm, A_2 is the mean absorbance of standard solutions at 570 nm, and d is the dilution factor.

2.12.6. Determination of Titratable Acidity

Titratable acidity was determined according to the standardized method, i.e., AFNOR (1982), with 0.1 N sodium hydroxide (NaOH) in the presence of phenolphthalein indicator. Ten milliliters of the sample was pipetted into a conical flask and 0.1 mL of phenolphthalein (0.05%) was added. Titration

was stopped when the initial color changed to pink and persisted for at least 30 s. The burette reading was noted. The titratable acidity (TA) is expressed in g/L H_2T:

$$TA = 75 \times N \times \frac{V}{T} \quad (10)$$

where V is the volume (mL) of the sodium hydroxide noted at endpoint, N is the concentration of the base, and T is the volume of titre.

2.12.7. Determination of Total Polyphenols

After haven prepared the reagents needed for this experiment, with the help of standard solutions of gallic acid, a scale of standardization was prepared and the samples are titrated.

The test tubes were again agitated and allowed to rest for 2 h at room temperature, after which their relative absorbance was read at 725 nm. The polyphenol mg/L content was obtained using the relationship given in the standard curve after plotting optical density against concentration [28].

2.12.8. Alcohol Determination Using Specific Gravity

The original gravity (OG) and final gravity (FG) were determined using a pycnometer as previously described in Section 2.12.1. The ABV was expressed as follows:

$$ABV\ (\%\ v/v) = \frac{(OG - FG)}{0.0075} \quad (11)$$

2.12.9. Sensory Evaluation of Beers

A hedonic test was conducted. Sensory evaluation was conducted by 30 ordinary consumers (20 males and 10 females) from the town of Ngaoundere. The consumers were selected from different age groups (21–35 years old). The prerequisites for participating in the study were that the individual consumed beer and showed an interest in participating in all test sessions. Evaluations were carried out at the Food Engineering and Technology Laboratory; the beer samples were served in a random way at temperatures of about 8 °C. All the beer samples were coded. Each participant received a series of five beers (30 mL of each formulation) served in opaque cups except when rating appearance, during which they were served in glasses. The degree of liking was rated using a nine-point hedonic scale for five main attributes i.e., smell, taste, bitterness, mouthfeel, and appearance; They were also asked to rate their overall liking for each beer. For each sample, participants were instructed to drink and swallow the beer when rating taste. Consumers were asked to drink mineral water to clean their mouth between tastings to avoid cross-contamination between samples. Also, they were asked not to smoke, eat, or drink anything, except water, 1 h before the tasting session. The panellists were invited to comment on the beers especially with respect to the attributes rated. After tasting, a purchase intent score sheet was filled by all the tasters.

3. Results

3.1. Physicochemical Characteristics of Unmalted and Malted Sorghum

The quality of beer was dictated by the nature of the raw materials. Sorghum (*Safrari*) utilized for this study was characterized in order to assess its brewing potentials. These tests (for acceptability in brewing) helped in determining the potentiality of the *Safrari* cultivar. Table 4 shows the results obtained for characterization of unmalted and malted sorghum.

Table 4. Physicochemical characteristics of unmalted and malted sorghum.

Characteristics	Unmalted *Safrari*	*Safrari* Malt
Water content (%)	8.50 ± 0.01	4.80 ± 0.56
Germinative capacity (%)	99.30 ± 0.58	N.D.
Germinative energy (4 mL) (%)	98.60 ± 1.79	N.D.
Germinative energy (8 mL) (%)	97.00 ± 1.21	N.D.
Thousand corn weight (g)	48.10 ± 0.02	38.00 ± 1.35
Diastatic power (WK)	N.D.	187.40 ± 7.89
Total ash (%)	1.30 ± 0.10	0.90 ± 0.22

N.D. = not determined.

3.1.1. Water Content

The values obtained for the water content of unmalted and malted sorghum were 8.50 ± 0.01% and 4.86 ± 0.56%, respectively (Table 4). In both cases, these values were in the range of those reported by the literature [29,30]. The samples produced were therefore considered to be suitable for storage since it was also reported that grains at a moisture content of up to 11.7% will keep safe without deterioration during storage [31].

3.1.2. Germinative Capacity and Energy

Results obtained for germinative capacity, germinative energy (4 mL), and germinative energy (8 mL), were 99.29 ± 0.58%, 98.56 ± 1.79%, and 97.00 ± 1.21%, respectively (Table 4). They all fell within the specifications of at least 95% [25]. These two properties had a direct bearing on the suitability of cereals for malting since it was mentioned in the literature that a GE $\geq$ 90% is appropriate for malting and brewing [31,32].

3.1.3. Thousand Corn Weight

The thousand-corn weight of unmalted and malted sorghum *Safrari* cultivar were 48.08 ± 0.02 g and 38.05 ± 1.35 g, respectively (Table 4). The literature stated a range of 7–61 g [7,15,33]. The samples, therefore, were one more time suitable for brewing.

3.1.4. Diastatic Power

The diastatic power (DP) of *Safrari* malt was 187.44 ± 7.89 WK (Table 4), less than the average value of 250 WK recorded in barley. This indicated a relatively low enzymatic activity, and thereafter, showed insufficient production of enzymes during malting when compared to barley. These relatively low levels of DP in sorghum may indicate the necessity of the addition of exogenous starch hydrolyzing enzymes since it was stated that the most important characteristics of good malt are high enzyme levels to degrade starch and obtain high extract yield [34].

3.1.5. Ash Content

The ash content of unmalted grains was 1.35 ± 0.01% (Table 4). It fell within the range indicated in the literature, which was between 0.3 and 1.7% [35,36]. A significant decrease in ash content was observed after malting. This was due to the removal of roots and shoots after kilning. *Safrari* malt had an ash content of 0.87 ± 0.22%. Despite the loss in ash content, *Safrari* malt was still within the 0.3 to 1.7% range reported in the literature [35,36]. This is beneficial for lager brewing as the yeast needs minerals for optimum function during wort fermentation [37].

3.2. Analysis of Worts and Beers

3.2.1. Specific Gravities

The specific gravity of the worts produced a range between 1.0508 and 1.0748 (Table 5). These values fall within the range as recorded in the literature [9,10,24]. The lowest value recorded was that of the motherwort. This increase could be explained, amongst other reasons, by the evaporation of water taking place during the boiling process. This evaporation should have contributed to wort concentration; thus, specific gravity increased in the boiled wort [18]. In the beer, specific gravity between 0.9923 and 1.0040 was obtained (Table 6). The lower final gravity could be explained by the fact that sugars were used up by yeast to convert the wort into beer; hence, the final gravity will be much lower as yeasts have consumed much of the sugar, which is denser than water, and have left alcohol in its place, which is less dense than water [18].

3.2.2. pH

The pH of all the worts studied was within the range 5.41 ± 0.00 to 5.79 ± 0.01 (Table 5). All the boiled wort had pH values higher than 5.41 ± 0.00, which was that of the motherwort. This increase could be explained by the fact that the pH of wort was dependent on the residual alkalinity of the water [37]. According to the literature, sorghum wort pH should range between 5.3–6.0 for optimum brewing [3,4,38]. All the worts produced were within this range. Equally, in the beer, pH ranged between 4.47 ± 0.02 and 4.68 ± 0.03 (Table 6). The lower pH values obtained in the beers could be explained by the fact that during fermentation, the pH continued to drop as a result of the yeast cells taking in ammonium ions (which are strongly basic) and excreting organic acids including lactic acid [37].

3.2.3. Turbidity

The proportion of lactose and coffee impacted the turbidity of wort by increasing it (Table 5). This could be due to the fact that coffee contains proteins, polyphenols, and carbohydrates [39], amongst other components that induce the formation of haze [7,8]. High turbidity values were recorded for all wort samples. The wort containing 100% coffee recorded a turbidity value of 91.00 ± 0.00 NTU (Table 5). A turbidity value of 606.00 ± 0.82 NTU was obtained in the sample containing 100% lactose (Table 5). Together with polyphenols, proteins are thought to cause haze formation during wort boiling (hot break) and wort cooling (cold break). The trub in both cases was as a result of the interaction between proteins and polyphenols which forms some complex that clumps. At the end of the boil, as the wort cooled it got more and more cloudy. The clumps of polyphenol and protein in the cold break were much smaller than the hot break. Therefore, they tended to stay in suspension longer, causing the wort to be turbid [7,8]. The lower turbidity values obtained in the beer (Table 6) could be explained by the fact that during maturation, clarification of the beer took place. This was due to natural sedimentation in the cold (lagering at 0 °C) of protein and polyphenol complexes. This ensured that turbidity owing to chemical precipitation or growth of microorganisms did not occur or, in the case of chemical precipitation, did not recur when the beer was clear and stable [7,8].

Table 5. Physicochemical characteristics of worts.

Factors		Responses						
X_1	X_2	SG	pH	Turbidity (NTU)	TP (mgGAE/L)	FAN (mg/L)	Colour (EBC)	TA (g/L H_2T)
1.000	0.000	1.0748	5.79 ± 0.01	606.0 ± 0.8	416.0 ± 0.1	308.0 ± 0.2	186.40 ± 0.12	2.58 ± 0.04
0.750	0.250	1.0728	5.73 ± 0.00	375.0 ± 1.2	487.0 ± 0.1	313.0 ± 0.2	242.50 ± 2.04	2.78 ± 0.10
0.500	0.500	1.0704	5.68 ± 0.01	281.0 ± 0.5	615.0 ± 0.1	317.0 ± 0.5	192.50 ± 0.20	2.84 ± 0.01
0.250	0.750	1.0632	5.63 ± 0.00	149.0 ± 0.5	441.0 ± 0.1	339.0 ± 0.9	146.70 ± 3.00	2.83 ± 0.00
0.000	1.000	1.0592	5.41 ± 0.01	91.0 ± 0.0	442.0 ± 0.0	286.0 ± 0.2	151.30 ± 0.12	2.84 ± 0.00

Table 6. Physicochemical characteristics of beers.

Factors		Responses							
X_1	X_2	SG	pH	Turbidity (NTU)	TP (mg GAE/L)	FAN (mg/L)	Colour (EBC)	TA (g/L H_2T)	ABV (%)
1.000	0.000	1.0040	4.64 ± 0.00	120.0 ± 0.5	108.0 ± 0.6	140.0 ± 0.1	155.00 ± 0.00	4.38 ± 0.02	9.30 ± 0.00
0.750	0.250	1.0027	4.62±0.01	299.0 ± 0.5	127.0 ± 0.7	131.0 ± 0.4	189.70 ± 0.20	4.37 ± 0.02	9.20 ± 0.09
0.500	0.500	0.9987	4.68 ± 0.03	141.0 ± 0.0	135.0 ± 0.4	120.0 ± 0.5	183.90 ± 0.24	4.18 ± 0.04	9.40 ± 0.01
0.250	0.750	0.9960	4.57 ± 0.00	11.0 ± 0.1	139.0 ± 0.7	112.0 ± 0.1	109.20 ± 1.18	3.97 ± 0.05	8.80 ± 0.02
0.000	1.000	0.9923	4.47 ± 0.02	6.0 ± 0.0	146.0 ± 0.6	110.0 ± 0.2	112.50 ± 0.00	3.92 ± 0.08	8.80 ± 0.02

3.2.4. Total Polyphenols

Total polyphenols ranged between 416.00 ± 0.13 and 615.00 ± 0.06 mg GAE/L (Table 5). These values were higher than the 150 mg/L to 300 mg/L range from the literature [27,33,40]. The proportion of lactose and coffee impacted the total polyphenols of beer. This could be accounted for by the fact that coffee contains polyphenols in their composition [41,42]. Total polyphenols between 108 to 146 mg GAE/L were obtained in the beer (Table 6). Before the end of fermentation and maturation, a large amount of the polyphenolic material and protein had been removed by adhesion and coagulation, and it had then sunk to the bottom of the fermenter, hence the drop in total polyphenols of beer. However, they were still present in the final beer where they contributed in determining its quality since polyphenols contribute to flavor, astringency, the perception of bitterness, haze, oxidative effects, and antioxidative effects [43–45].

3.2.5. Free Amino Nitrogen (FAN)

The FAN of wort varied from 308.00 ± 0.23 mg/L to 339.00 ± 0.93 mg/L (Table 5). This could be explained by coffee, which contains proteins [41,42]. These proteins were broken down by proteases to FAN during mashing. It has been generally agreed that at least 120 mg/L of FAN is required to support proper yeast growth during brewing, though with the high gravity brewing processes employed in most modern breweries, recommended levels are at about 150 mg/L [46]. In beers, the FAN varied from 110.00 ± 0.23 mg/L to 140.00 ± 0.14 mg/L (Table 6). During fermentation, FAN provided nutritional support to the yeast, enabling the optimal yeast growth and efficient fermentation necessary for good head retention and foam quality. This further explained the decrease in FAN recorded compared to wort [47,48].

3.2.6. Color

The color values of the worts produced were within the range 146.75 ± 3.00 EBC to 242.50 ± 2.04 EBC (Table 5). This could be due to the fact that color depends on the grain used as raw materials and bitter leaf, as well as on the processes during the brewing. Color components were produced partly in the Maillard and caramelization reactions, and partly by the oxidation of polyphenols [7,49]. The color of beer ranged between 112.50 to 242.50 EBC (Table 6). The values obtained indicated that the beer produced was in the range of stout given that the appellation of stout with reference to colour starts as from 69 EBC as indicated on the beer colour chart based on the standard reference method.

3.2.7. Titratable Acidity (TA)

The proportion of lactose and that of coffee impact on the TA of beer. This could be accounted for by the fact that both lactose and coffee contained titratable acids in their composition as reported by Fox et al. (2015) and Wang and Ho (2009), respectively. Titratable acidity varied slightly comparatively in the formulation: between 2.58 ± 0.04 and 2.84 ± 0.01 g/L H2T (Table 5). Values of the TA of beer ranged between 3.92 to 4.38 g/L tartaric acid (Table 6).

3.2.8. Alcohol by Volume (ABV) Content of Beer

The ABV of the five beers were very high (Table 6). Three of beer formulations had ABV above 9%. They include formulations 1 to 3. A formulation with higher ABV means more fermentable sugars have been converted into ethanol during fermentation. Beers can contain up to about 12.5% ABV [10,24,37,50,51].

3.3. Sensory Evaluation Results

For beer 1 containing 100% lactose, all attributes had the majority of votes located in "the liking part" of the hedonic scale (Figure 10). Mouthfeel had the highest number of votes. Smell, taste, and

bitterness scored high too. This could be the reason for the high score recorded for the overall liking. However, for this beer, some panellists commented on the appearance, saying it was hazy, making it less attractive. Some also mentioned that the colour was not bad but the haziness gave a poor appearance. They suggested that the beer be more brilliant.

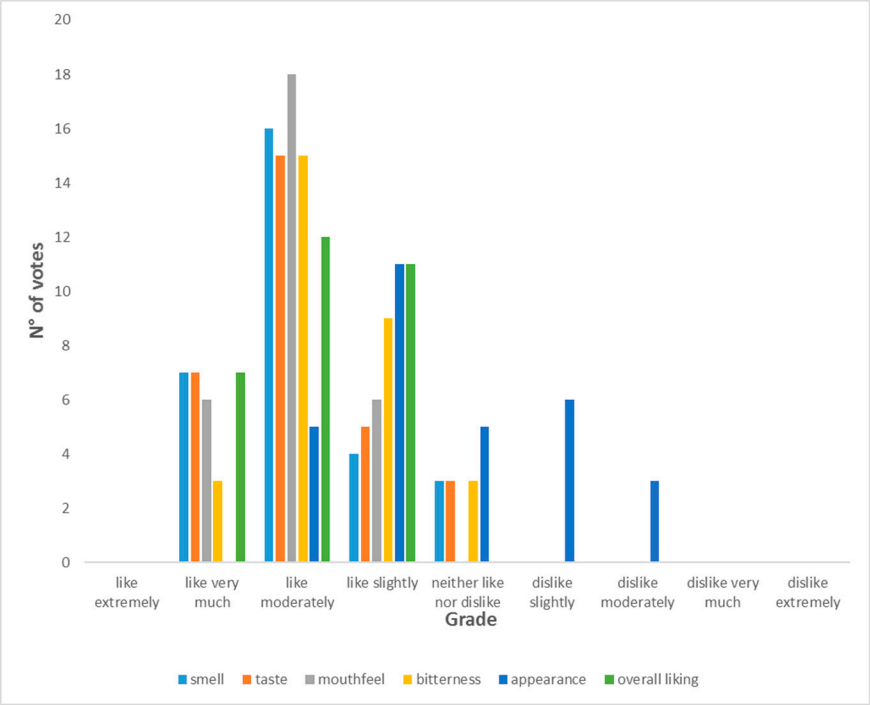


Figure 10. Hedonic nine-point scale grading for beer 1 (100% lactose and 0% coffee).

The bitterness and overall liking scored the highest in beer 2. Likewise for beer 1, for beer 2 containing 75% lactose and 25% coffee, all attributes had the majority of votes located in "the liking part" of the hedonic diagram (Figure 11). Similar comments were made by the panellists with respect to appearance being hazy. According to them, the beer lacked brilliance. They also mentioned that the colour was not bad but the haziness gave a poor appearance. They suggested that the haziness should be removed to make the beer more attractive.

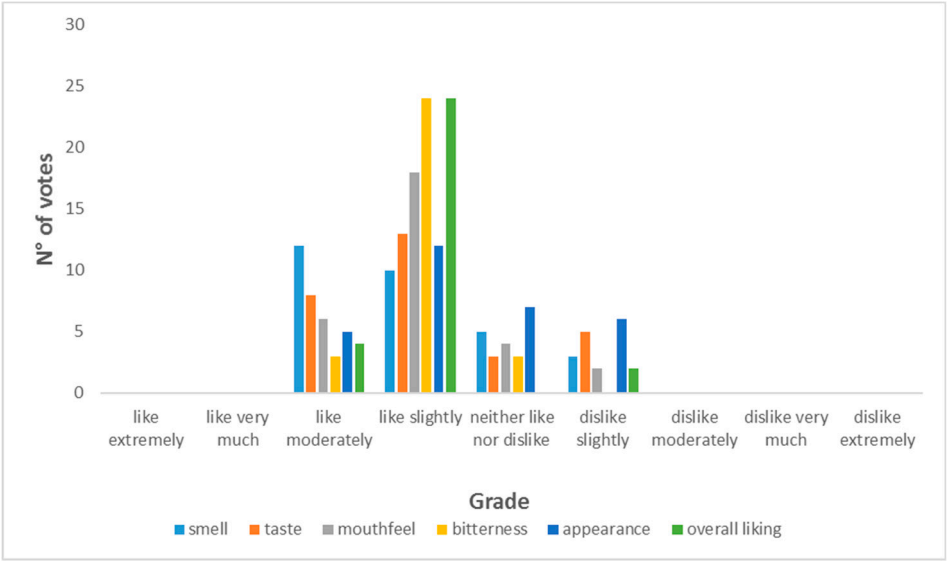


Figure 11. Hedonic nine-point scale grading for beer 2 (75% lactose and 25% coffee).

Concerning beer 3 containing equal proportions of lactose and coffee, all attributes had the majority of votes located in "the liking part" of the hedonic diagram (Figure 12). Though overall liking had the highest number of votes, a panellist said the beer could even taste better if the bitterness was reduced a little and carbonation increased. This explained the votes seen in the dislike part of the diagram. Smell, taste, and mouthfeel were, however, much appreciated in the comments made by panellists. Appearance scored higher than in the previous beer as haziness dropped.

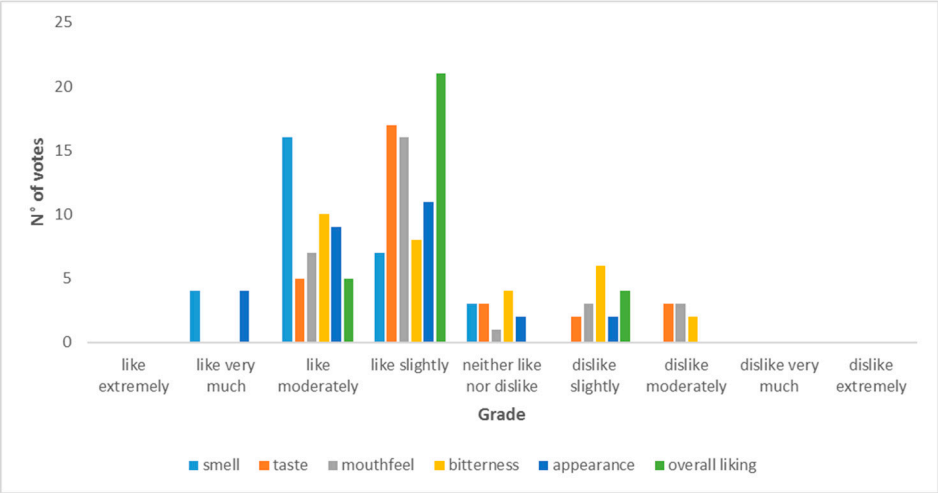


Figure 12. Hedonic nine-point scale grading for beer 3 (50% lactose and 50% coffee).

Except for smell and appearance, beer 4 containing 25% lactose and 75% coffee, had the majority of votes for all other attributes located in "the disliking part" of the diagram (Figure 13). The comments gave a clue on consumers' grading. They commented that the beer was too bitter such that they could not appreciate the flavour of the malts. They suggested much of the bitterness should be reduced. The dark colour with less haze of the beer was much appreciated and gave the appearance its good score.

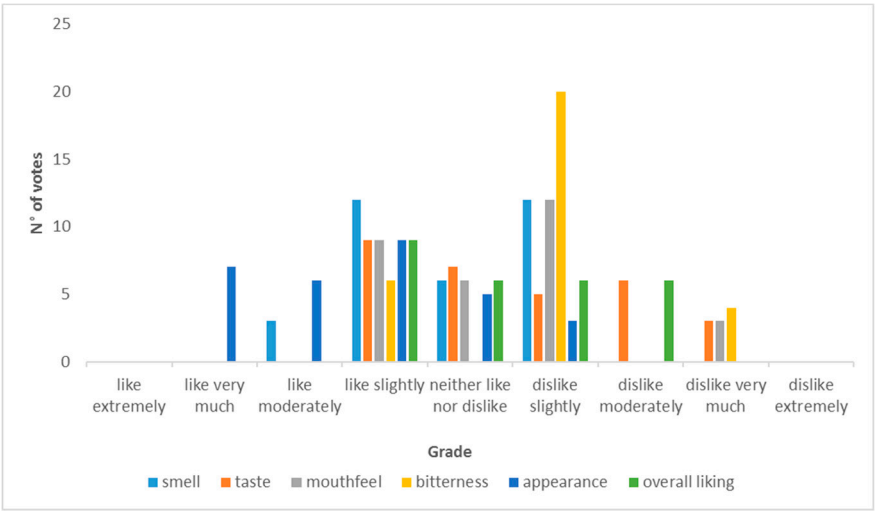


Figure 13. Hedonic nine-point scale grading for beer 4 (25% lactose and 75% coffee).

Beer 5 containing 100% coffee had the majority of votes in the "liking part" of the hedonic diagram, except for bitterness with the majority of votes located in "the disliking part" of the diagram (Figure 14). The appearance was very much liked. The dark colour with the least haze of the beer was highly appreciated as depicted by the votes. Though the bitterness was decried and suggested being reduced in the comments made by consumers, the taste scored well.

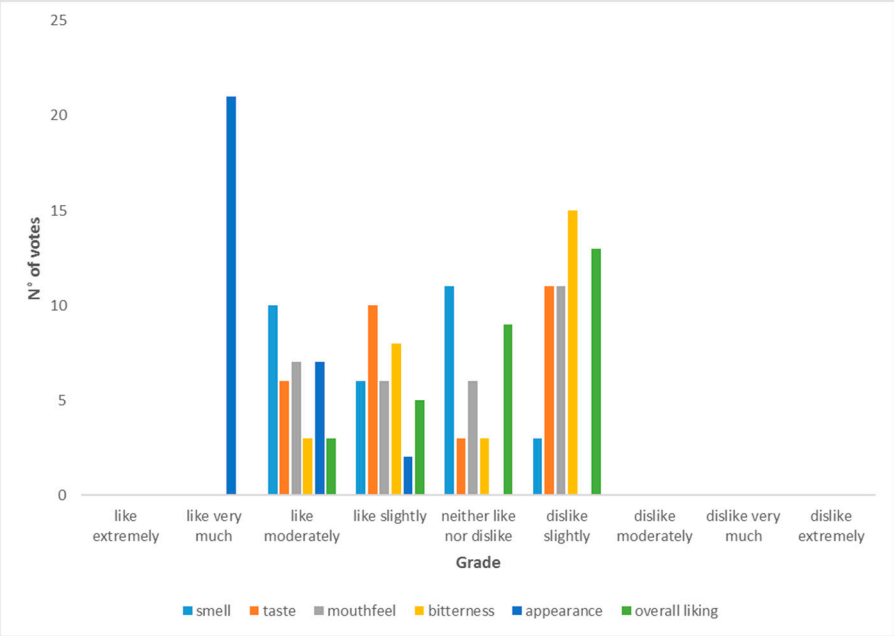


Figure 14. Hedonic nine-point scale grading for beer 5 (0% lactose and 100% coffee).

4. Conclusions

Studies on the physicochemical characterization of a beer stout using coffee and lactose as ingredients and *Vernonia amygdalina* as bittering were made. It emerged from this study after having carried out a mixing plan having given five different beers that the physicochemical characteristics of musts and beers were comparable to the values obtained in the literature. The sensory analysis of these beers revealed those which are appreciated by the panellists during a hedonic test. It is therefore at the end of this work, plausible to consider a feasibility study for a pilot production of this type of beer.

Author Contributions: F.M.H. Performed the experiments. D.Z.S.C. Analyzed the data; Contributed reagents/materials/analysis tools; Wrote the paper. N.E.J. Contributed reagents/materials/analysis tools; Supervised the laboratory work and the paper.

Funding: This research received no external funding.

Acknowledgments: The authors gratefully acknowledge the Departments of Process Engineering of the National School of Agro-Industrial Sciences (ENSAI), The University of Ngaoundere (Cameroon) for providing necessary facilities for the successful completion of this research work.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Food and Agriculture Organization of the United Nations (FAO). *Faostat Database Collections*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2014.
2. Agu, R.C.; Palmer, G.H. Enzymic modification of endosperm of barley and sorghum of similar total nitrogen. *Brew. Dig.* **1998**, *73*, 30–35.
3. Bajomo, M.F.; Young, T.W. The properties, composition and fermentabilities of worts made from 100% raw sorghum and commercial enzymes. *J. Inst. Brew.* **1993**, *99*, 153–158. [CrossRef]
4. Bajomo, M.F.; Young, T.W. Fermentation of worts made form 100% raw sorghum and enzymes. *J. Inst. Brew.* **1994**, *100*, 79–84. [CrossRef]
5. Taylor, J.R.N.; Robbins, D. Factors affecting beta-amylase activity in sorghum malt. *J. Inst. Brew.* **1993**, *99*, 413–416. [CrossRef]
6. Nso, E.J.; Nanadoum, M.; Palmer, G.H. The effect of formaldehyde on enzyme development in sorghum malts. *Tech. Q. Master Brew. Assoc. Am.* **2006**, *43*, 177–182.

7. Desobgo, Z.S.C.; Nso, E.J.; Tenin, D.; Kayem, G.J. Modelling and optimizing of mashing enzymes-effect on yield of filtrate of unmalted sorghum by use of response surface methodology. *J. Inst. Brew.* **2010**, *116*, 62–69. [CrossRef]
8. Desobgo, Z.S.C. *Modélisation de L'action des Hydrolases sur Quelques Caractéristiques Physico-Chimiques des Moûts de Deux Cultivars de Sorgho*; Université de Ngaoundéré Ngaoundéré: Ngaoundéré, Cameroon, 2012.
9. Bubacz, M.; Philip, T.; McCreanor, P.T.; Jenkins, H.E. Engineering of beer: Hard work or too much fun? In *2013 American Society for Engineering Education Southeast Conference*; American Society for Engineering Education: Cookeville, TN, USA, 2013; pp. 1–10.
10. Owuama, C.I. Brewing beer with sorghum. *J. Inst. Brew.* **1999**, *105*, 23–34. [CrossRef]
11. Desobgo, Z.S.C.; Nso, E.J.; Tenin, D. The response surface methodology as a reliable tool for evaluating the need of commercial mashing enzymes for alleviating the levels of reducing sugars of worts of malted sorghum: Case of the *Safrari* cultivar. *J. Brew. Distill.* **2011**, *2*, 5–15.
12. Desobgo, Z.S.C.; Nso, E.J.; Tenin, D. Use of response surface methodology for optimizing the action of mashing enzymes on wort reducing sugars of the *madjeru* sorghum cultivar. *Af. J. Food Sci.* **2011**, *5*, 91–99.
13. Desobgo, Z.S.C.; Nso, E.J.; Tenin, D. Modeling the action of technical mashing enzymes on extracts and free-amino nitrogen yields of the *madjeru* sorghum cultivar. *J. Brew. Distill.* **2011**, *2*, 29–44.
14. Desobgo, Z.S.C.; Nso, E.J.; Tenin, D. Optimisation of the action of commercial mashing enzymes on wort extracts and free amino nitrogen of the *Safrari* sorghum cultivar. *Tech. Q. Master Brew. Assoc. Am.* **2011**, *48*, 77–86.
15. Nso, E.J.; Ajebesone, P.E.; Mbofung, C.M.; Palmer, G.H. Properties of three sorghum cultivars used for the production of *bili-bili* beverage in northern cameroon. *J. Inst. Brew.* **2003**, *109*, 245–250. [CrossRef]
16. Wolgang, K. *Technology Brewing and Malting*, 5th ed.; VLB: Berlin, Germany, 2014; p. 960.
17. Mackintosh, I.; Higgins, B. The development of a sorghum-based lager beer in uganda: A model of co-operating between industry and government in the development of local ingredients for the production of quality lager beer and consequential benefits for the parties involved. *Asp. Appl. Biol.* **2004**, *72*, 235–245.
18. Taylor, J.R.N.; Schober, J.T.; Bean, S.R. Novel food and non-food uses for sorghum and millets. *J. Cereal Sci.* **2006**, *44*, 252–271. [CrossRef]
19. Veith, K.N. *Evaluation of four Sorghum Hybrids through the Development of Glutenfree Beer*; Master of Science; Kansas State University: Manhattan, AR, USA, 2007.
20. Ajebesone, P.E.; Aina, J.O. Potential african substitutes for hops in tropical beer brewing. *J. Food Technol. Afr.* **2004**, *9*, 13–16.
21. Desobgo, Z.S.C.; Naponni, F.Y.; Nso, E.J. Characterization of *Safrari* sorghum worts and beers hopped with *Vernonia amygdalina* and nauclea diderrichii. *Int. J. Innov. Appl. Stud.* **2013**, *2*, 83–91.
22. Okafor, N. Prospects and challenges of the use of local cereals and starchy subtrates in brewing. In *National Symposium on the Brewing Industry, Now and the 21st Century*; Owerri, Nigeria, 1985; pp. 22–25.
23. Okafor, N.; Aniche, G.N. West african hop substitute for sorghum lager. *Brew. Distill. Int.* **1983**, *13*, 200–204.
24. Owuama, C.I.; Okafor, N. Use of unmalted sorghum as a brewing adjunct. *World J. Microbiol. Biotechnol.* **1990**, *6*, 318–322. [CrossRef] [PubMed]
25. Analytica-EBC. *European Brewery Convention*; Fachverlag Hans Carl: Nürnberg, Germany, 1998.
26. AFNOR. Association française de normalisation. In *Recueil des Normes Françaises des Produits Dérivés des Fruits et Légumes. Jus de Fruits*, 1st ed.; AFNOR: Paris, France, 1982.
27. Briggs, D.E. *Malts and Malting*, 1st ed.; Blackie Academic & Professional: London, UK, 1998.
28. Marigo, G. Méthode de fractionnement et d'estimation des composés phénoliques chez les végétaux. *Analysis* **1973**, *2*, 106–110.
29. Ogu, E.; Odibo, F.; Agu, R.C.; Palmer, G.H. Malting studies of some selected brewing sorghum varieties. *MBAA TQ* **2004**, *41*, 386–389.
30. Okon, E.U.; Uwaifo, A.O. Evaluation of malting sorghum i: The malting potentials of nigerian varieties of sorghum. *Brew. Dig.* **1985**, *60*, 24–27.
31. Agu, R.C.; Palmer, G.H. A reassessment of sorghum for lager-beer brewing. *Bioresour. Technol.* **1998**, *66*, 253–261. [CrossRef]
32. Agu, R.C.; Palmer, G.H. Effect of mashing with commercial enzymes on the properties of sorghum worts. *World J. Micro-Biol. Biotechnol.* **1998**, *14*, 43–48. [CrossRef]

33. Briggs, D.E.; Boulton, C.A.; Brookes, P.A.; Stevens, R. *Brewing Science and Practice*; Woodhead Publishing Limited: Cambridge, UK; CRC Press LLC: Boca Raton, FL, USA, 2004.
34. Gupta, M.; Abu-Ghannam, N.; Gallaghar, E. Barley for brewing: Characteristic changes during malting, brewing and applications of its by-products. *Compr. Rev. Food Sci. Food Saf.* **2010**, *9*, 318–328. [CrossRef]
35. Pontieri, P.; Di-Maro, A.; Tamburino, R.; De-Stefano, M.; Tilley, M.; Bean, S.R.; Roemer, E.; De-Vita, P.; Alifano, P.; Del-Giudice, L.; et al. Chemical composition of selected food-grade sorghum varieties grown under typical mediterranean conditions. *Maydica* **2010**, *55*, 139–143.
36. Pontieri, P.; De-Vita, P.; Boffa, A.; Tuinstra, M.R.; Bean, S.R.; Krishnamoorthy, G.; Miller, C.; Roemer, E.; Alifano, P.; Pignone, D.; et al. Yield and morpho-agronomical evaluation of food-grade white sorghum hybrids grown in southern italy. *J. Plant Interact.* **2012**, *7*, 341–347. [CrossRef]
37. Bamforth, C.W. *Brewing: New Technologies*; Woodhead Publishing: Cambridge, UK, 2006; p. 500.
38. Bajomo, M.F.; Young, T.W. Development of a mashing profile for the use of microbial enzymes in brewing with raw sorghum (80%) and malted barley or sorghum malt (20%). *J. Inst. Brew.* **1992**, *98*, 515–523. [CrossRef]
39. Walstra, P.; Wouters, J.; Geurts, T. *Dairy Science and Technology*; CRC Press: Boca Raton, FL, USA, 2006.
40. Briggs, D.E.; Hough, J.S. *Malting and Brewing Science*, 2nd ed.; Chapman and Hall: London, UK, 1981.
41. Fox, P.F.; Uniacke-Lowe, T.; McSweeney, P.L.H.; O'Mahony, J.A. *Dairy Chemistry and Biochemistry*, 2nd ed.; Springer International Publishing: Basel, Switzerland, 2015; p. 584.
42. Wang, Y.; Ho, C.-T. Polyphenolic chemistry of tea and coffee: A century of progress. *J. Agric. Food Chem.* **2009**, *57*, 8109–8114. [CrossRef] [PubMed]
43. Kondo, K.; Kurihara, M.; Miyata, N.; Suzuki, T.; Toyoda, M. Scavenging mechanisms of (-)-epigallocatechin gallate and (-)-epicatechin gallate on peroxyl radicals and formation of superoxide during the inhibitory action. *Free Radic. Biol. Med.* **1999**, *27*, 855–863. [CrossRef]
44. Liu, Z.; Ma, L.P.; Zhou, B.; Yang, L.; Liu, Z.L. Antioxidative effects of green tea polyphenols on free radical initiated and photosensitized peroxidation of human low density lipoprotein. *Chem. Phys. Lipids* **2000**, *106*, 53–63. [CrossRef]
45. Yilmaz, Y.; Toledo, R.T. Major flavonoids in grape seeds and skins: Antioxidant capacity of catechin, epicatechin, and gallic acid. *J. Agric. Food Chem.* **2004**, *52*, 255–260. [CrossRef] [PubMed]
46. Beckerich, R.P.; Denault, L.J. Enzymes in the preparation of beer and fuel alcohol. In *Enzymes and Their Role in Cereal Technology*; Kruger, J.E., Lineback, D., Stauffer, C.E., Eds.; American Association of Cereal Chemists: St. Paul, MN, USA, 1987; pp. 335–354.
47. Lekkas, C.; Hill, A.; Taidi, B.; Hodgson, J.; Stewart, G. The role of small wort peptides in brewing fermentations. *J. Inst. Brew.* **2009**, *115*, 134–139. [CrossRef]
48. Lekkas, C.; Stewart, G.; Hill, A.; Taidi, B.; Hodgson, J. The importance of free amino nitrogen in wort and beer. *Tech. Q.-Master Brew. Assoc. Am.* **2005**, *42*, 113.
49. Shellhammer, T.H. Beer color. In *Beer: A Quality Perspective*; Bamforth, C.W., Russell, I., Stewart, G.G., Eds.; Academic Press: London, UK, 2008; pp. 221–226.
50. Bamforth, C.W. Beer, carbohydrates and diet. *J. Inst. Brew.* **2005**, *111*, 259–264. [CrossRef]
51. Bamforth, C.W. *Chemistry of Brewing*; Elsevier Science Ltd.: Amsterdam, The Netherlands, 2003.

© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).

Résumé de l’article

Sorghum Coffee–Lactose Stout Production and Its Physico-Chemical Characterization

Fali Mbeh. Harry, Desobgo Zangué Steve Carly*, and Nso Emmanuel Jong

Sorghum (*Safrari*) was valorized into sorghum coffee-lactose stouts using Vernonia amygdalina as a bittering ingredient. These sorghum grains and subsequent sorghum pale malt were tested for their acceptability in the brewing field. Results obtained were the germinative capacity of 99.29 ± 0.58%, a germinative energy of 98.56 ± 1.79%, a thousand corns weight 48.08 ± 0.02 g for the grains, and a diastatic power of 187.44 ± 7.89 WK for sorghum malt. The worts and beers produced were characterized and were found suitable. Moreover, alcohol content in stout beers obtained was between 8.8% and 9.4% ABV. Sensory evaluation was implemented on beers using 30 panellists and the best combination was the one using 50% lactose (250 g) and 50% coffee (250 g) in 5 L of wort during wort boiling.

Keywords: *Safrari*; coffee; lactose; stout beer; sensory evaluation

IV.5) Rapport pédagogique confidentiel établi par le Chef de Département Génie Alimentaire et Contrôle Qualité (GACQ)

IV.6) Rapport administratif confidentiel établi par le Chef d'Etablissement (Directeur IUT de Ngaoundéré)

V) AUTRES

V.1) Participation aux séminaires, colloques nationaux et internationaux

V.1.1) University of Johannesburg Winter Beverage Symposium. 20 June 2013, Sedibeng Brewery, South Africa.

University of Johannesburg - Inaugural Winter Beverage Symposium.

Hosted by Sedibeng Brewery.

Thursday 20 June 2013.

Welcome

On behalf of the University of Johannesburg, the Symposium organising team and Sedibeng Brewery, welcome to the inaugural UJ Winter Beverage Symposium.

The intent behind this Symposium is to stimulate interest in the South African beverage industry amongst the university science and engineering communities and to profile some of the current and future challenges and possible solutions which the industry faces.

On your behalf, we have compiled a busy 1-day programme with several educational and informative technical presentations from UJ and industry speakers followed by a tour of Heineken's state-of-the-art Sedibeng brewery.

Please enjoy your day and make the most of this opportunity to satisfy your 'thirst' for beverages!

Regards

Bob

Bob Stafford.

Professor: Brewing & Beverage Engineering.

The University of Johannesburg.

(rstafford@uj.ac.za)

Programme

0930-1000	Registration - coffee and tea available.
1000-1030	Safety induction: Mr Zweli Mbatha.
1000-1035	Welcome to UJ Winter Beverage Symposium: Prof. Bob Stafford, UJ.
1035-1100	Welcome to Sedibeng: Mr Frans Rozemeier, Production Manager, Sedibeng brewery.
1100-1125	"The use of UV light in brewing." Mr Craig Groeneveld, Surepure Inc.
1125-1140	Coffee
1140-1205	"Cereal breeding." Dr Eduard Venter, UJ.
1205-1225	"Brewery energy usage." Mr Thuthuka Buthelezi, UJ.
1225-1250	"Beverage mycotoxins." Dr Patrick Njobeh, UJ.
1250-1310	"Dairy aflatoxins." Dr Suretha de Kock, UJ.
1310-1350	Lunch
1350-1410	"Introduction to experimental design in brewing science." Dr Steve Carly Desobgo, UJ.
1410-1430	"Data mining the Sedibeng mash filter performance." Mr Lukas Swart, UJ.
1430-1450	"Challenges in clarifying beverages." Prof Bob Stafford, UJ.
1450-1455	Technical session close.
1455-1555	Brewery tour.
1555-1630	Refreshments.
1630	Buses depart.

Speaker Biographies

Mr Craig Groeneveld: Surepure Inc.

Craig Groeneveld is an IBD qualified Master Brewer with 15 years' experience in beverage production and is a Chartered Scientist.

He currently works as a Technical Brewing Consultant for SurePure inc. delivering innovative solutions to ambient liquid purification.

His interests include: new brewery design and commissioning, process optimisation and quality improvement; new product and process development; craft brewing (and tasting!) and Gauteng Lions Rugby.

Dr Eduard Venter: Dept of Botany & Plant Biotechnology, University of Johannesburg.

Eduard Venter completed a PhD in Genetics at the University of Pretoria on host-pathogen interactions using pitch canker on pines as a model system. He then focused on late blight of potato during post-doctoral research at the James Hutton Institute (then the Scottish Crop Research Institute). After completion of this post-doc he joined the Department of Botany and Plant Biotechnology at the University of Johannesburg to develop and teach the Plant Biotechnology module. He established a research programme in cereal genetics and genomics that studies the interaction between cereal hosts and pests. One of the aims of the programme is to develop markers linked to economically important traits to enhance cereal breeding. This research is performed in collaboration with commercial breeding companies in South Africa, national and international collaborators. Eduard is also a member of several societies and organisations to further genetics and science in South Africa.

Dr Suretha de Kock: Dept of Food Technology, University of Johannesburg.

Sue did all her studies at the University of Pretoria. She obtained her degree, honours, masters and doctorate all in the field of Food Science. Whilst doing her post grad studies, she received the prestigious Koepen Memorial scholarship. She is currently employed by the University of Johannesburg where she has taught in the Department of Food Technology for many years. Her passion (apart from students) lies in food chemistry and her area of research expertise falls within cereals and baking science. She has supervised and co-supervised a number of master students on various topics though, and has published in accredited journals. Today she is presenting some of the work of one of her masters students who graduated last year.

Dr Steve Carly Desobgo: Post-Doctoral Research Fellow, Faculty of Engineering & Built Environment/Faculty of Science, University of Johannesburg (UJ).

Dr. DESOBGO ZSC started his master course in 2003 and has occupied a Research Assistant position at the department of Process Engineering in the National School of Agro-Industrial Sciences of The University of Ngaoundere, Cameroon up to 2004. He worked at the University Institute of Technology of The University of Ngaoundere since 2008 as Assistant Lecturer. After his Ph.D in 2012, he became a Senior Lecturer in the same school.
His research interest is in food technology, especially brewing process and other engineering process. He has several papers on these subjects. He has participated to his school program renewal. He lectures malting and brewing sciences, fruits and vegetables technologies, wine and spirit technology etc… He currently has several master students and three Ph.D students in the National School of Agro-Industrial Sciences of The University of Ngaoundere, Cameroon.

Mr Lukas Swart: Dept of Electrical & Electronic Engineering Science, University of Johannesburg.

Lukas is originally from Pretoria but grew up in Paraguay. He graduated from University of Pretoria BEng Chem Eng in 1998 and also later was awarded a BEng Honours Degree in Technology Management. After a few years at SASOL R&D he moved to followed interest in ventures in Argentina.

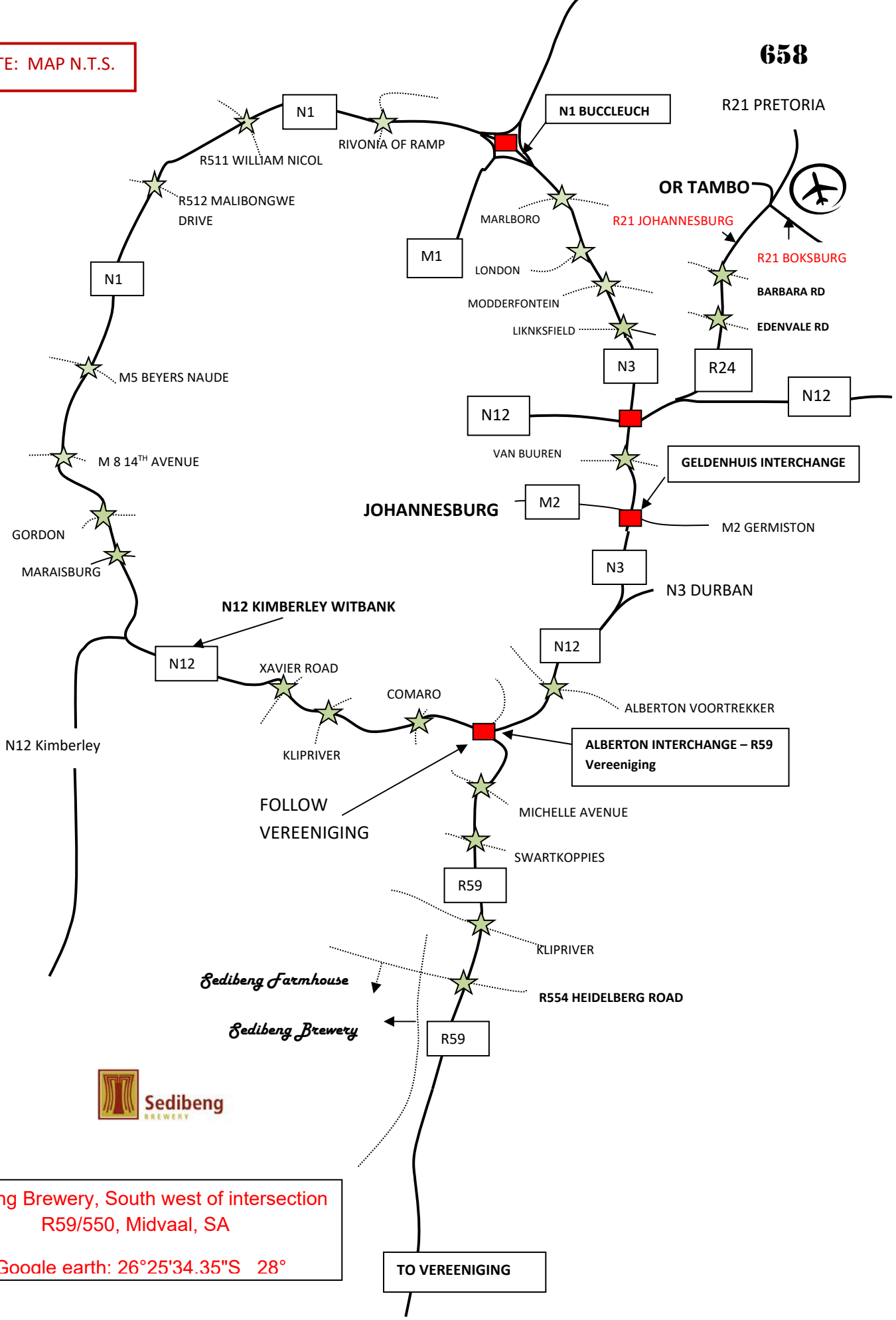
With a keen interest in mathematics, economics and finance, Lukas finds opportunities to exploit many facets currently within an Actuarial Consulting company, Solveco Pty Ltd. Currently he is studying towards a Masters in data-mining techniques and applications at the University of Johannesburg.

Still, Lukas is very much a hands-on person. He enjoys restoring old motorbikes and cars, especially those that originate from southern state of Bavaria in Germany.

Prof Bob Stafford, School of Mining, Metallurgy and Chemical Engineering, University of Johannesburg.

Bob Stafford is Professor: Brewing & Beverage Engineering at the University of Johannesburg (UJ) and has over 20 years industrial and academic experience both in the United Kingdom and in South Africa. He spent over 8 years working for SAB and SABMiller in a variety of engineering, brewing and R&D consultant roles. Prior to this he was a Process Engineering lecturer at Heriot-Watt University in Scotland where he was instrumental in developing the internationally successful distance learning Masters' program in Malting and Brewing.
He has served for many years on the editorial boards of the Journal of the Institute of Brewing and the Technical Quarterly of the Master Brewers Association of the Americas and is the only African academic to date, to serve on these boards.

PLEASE NOTE: MAP N.T.S.



Gauteng Brewery, South west of intersection R59/550, Midvaal, SA

Google earth: 26°25'34.35"S 28°

University of Witwatersrand

Full name	Contact no	Email address	Degree currently enrolled for	Year of study	Require bus service
1. Nigel Tafadzwa Chikore		nigelchikore@hotmail.com	Bsc: Chemical Engineering	Fourth year	Yes
2. Antony Higginson	27836433151		Biochemical Engineering	Associate lecturer	No
3. Rasivhetshele Tendani	27792652343	rasivhetsheletendani@yahoo.com	BSc (Eng) (Chem)	Fourth year	Yes
4. Thomas Coetzee	27722447258		Chemical Engineering	3rd year	No
5. Kgalaletso Rakau	27836064638	kgalaletsorakau@ymail.com	Chemical Engineering	3rd year	No
6. Tafara Chitsiga	27718064754	chitigatafara@gmail.com	Chemical Engineering	Fourth year	Yes
7. Ayanda Makupula	27812630817	305350@students.wits.ac.za	Bsc: Chemical Engineering	Fourth year	Yes
8.Seipati Tenyane	27780421458	570769@students.wits.ac.za	Bsc: Microbiology and Biotechnology		Unspecified
9. Hildeguard Pontsho Khoza		ladyseptic@hotmail.com	Bsc: Microbiology and Biotechnology	3rd year	Yes
10. Velinjani Mthethwa	27738956356	392458@students.wits.ac.za	MSc: Chemical Engineering	Final year	Yes
11. Langa Moyo	27738502999		MSc: Chemical Engineering	Final year	Yes
12. Lebogang Sentle	27786150566	lebsentle@gmail.com	Chemical Engineering	Fourth year	Yes
13. Mpendulo Ncongwane	27713224377	Mpendulo.Ncongwane@students.wits.ac.za	MSc: Chemical Engineering		Yes
14. Ralph Muvhiiwa	27764263654	416759@students.wits.ac.za	MSc: Chemical Engineering		Yes
15. Siyabonga Gift Nhlabathi	2778 874 6269	gnhlabathi@gmail.com	BSc (Eng) (Chem)	Fourth year	Yes
16. Kamogelo Modise	0713517120/0117170991	470064@students.wits.ac.za	Bsc: Chemical Engineering	Fourth year	Yes
17. Vujaha Teddy Mabunda	0849896376/0117170678	468899@students.wits.ac.za	Bsc: Chemical Engineering	Fourth year	Yes
18. Thabiso Thomas Chautsane	27717009302	474556@students.wits.ac.za	Bsc: Chemical Engineering	Fourth year	Yes
19. Itumeleng Masobela	27785922716	450339@students.wits.ac.za	Bsc: Chemical Engineering	Fourth year	Yes
20. Benjamin A Obuala	27781491023	benjaminobuala@yahoo.com			Yes

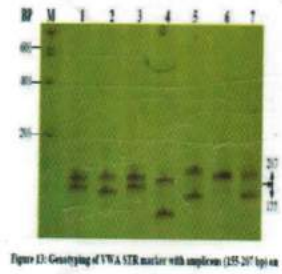
University of Johannesburg

Full name	Contact no	Email address	Degree currently enrolled for	Year of study	Require bus service
1. Dr. Pieter Henning		pfjhenning@uj.ac.za	Mech Eng Science	HOD	No
2. Denise Metcalfe		dmetcalfe@uj.ac.za	Food Technology	HOD	No
3. Anthony Bosch	27715549115	boschrobin94@gmail.com	Chemical engineering	Second year	Yes
4. Sepudumo TP	27827400405	malpotrading@gmail.com	Btech:Chemical Engineering	Fourth year	Yes
5. Tokologo Ngoasheng	27817737656	tokologo.ngoasheng@gmail.com	Btech: Food Technology	Fourth year	Yes
6. Datrium Mhlanga	27783564538	datty.mhlanga@gmail.com	Chemical engineering	S3	Yes
7. Selepe Maloma	27785275467	selepemaloma@gmail.com	Chemical engineering	Second year	Yes
8. Eric Van Zyl		ericvz@uj.ac.za	Biotechnology	HOD	No
9. Phumelelo Nxumalo		201220000@student.uj.ac.za	Chemical engineering	Second year	Yes
10. Maluleke Constance	2778 090 5986	constancemapulemaluleka@gmail.com	Chemical engineering	3rd year	Yes
11. Thokozani Makinda	27742159986	thokozanimakinda@yahoo.com	Chemical engineering	Final year	Unspecified
12. Jimmy Mashapa	27769351149	jimmymashapa@hotmsil.com	Chemical engineering	Second year	Yes
13. Sithole Z.B	27737103485	zanelesithole@rocketmail.com	Chemical engineering	Second year	Yes
14. Klaas SK Maphanga	27832295085	201011208@student.uj.ac.za	Chemical engineering	Fourth year	Yes
15. Thulane Paepae	27784774015	paepaethulane@gmail.com	Chemical engineering	Fourth year	Yes from VUT
16. Tibelo Nelson Mohapi	2773 204 6691	mohapitn@gmail.com	Chemical engineering	Fourth year	Yes
17. Tshiamo Modise	2773 2206 301	201011540@student.uj.ac.za	Chemical engineering	NDip	Yes
18. Dr Steve Carly Desobgo		desobgo@yahoo.fr	Post-Doctoral Research Fellow		Yes
19. AMELIA SEODI MMUSHI	27768054597	amelia.mmushi@gmail.com	Chemical engineering	3rd year	Yes
20. Mampholo Segopotso	27786712907	segopotso.m2@gmail.com	Chemical engineering	Final year	Yes
21. Bongisisa Dlambewu	083 587 1088	sisero25@gmail.com	Chemical engineering	Fourth year	Unspecified
22. Tebogo Mabitsela	072 531 0689	tebogo.mabitsela@webmail.co.za	Chemical engineering	Fourth year	Yes

23. Rachoene Raesibe Grace		201103021@student.uj.ac.za	Chemical engineering	Second year	Yes
24. Ntiti eseu Moshia	27790265754	eseumoshia@gmail.com	Btech: Chemical Engineering	Fourth year	Yes
25. Maile O.I.	27720789798	ireen.dizo@gmail.com	Btech: Chemical Engineering	Fourth year	Yes
26. Noxolo Sibiya	27728618854	sibiyanoxolo@gmail.com	Btech: Chemical Engineering	Fourth year	Yes

V.1.2) Cameroon Bioscience Society, 24th Annual Conference. University of Buea

24th Annual Conference



Book of Abstracts

"Bioscience Research for Cameroon's Emergence"

banque atlantique

University of Buea, Cameroon

November 28 – December 02, 2017

inqaba biotec™

University of Buea
KNOWLEDGE WITH WISDOM

DOUANES CAMEROUNAISES
CAMEROON CUSTOMS

DAAD
Deutscher Akademischer Austauschdienst
German Academic Exchange Service
DAAD Scholarships for Developing Countries

THE UNIVERSITY OF BAMENDA
UNIVERSITE DE BAMENDA
Knowledge Probity Entrepreneurship

www.camerounbiosciences.org

CBS17-ORA-111

CHIASSA

Performances d'incubation artificielle des œufs de pintade commune (Numida meleagris) en zone d'altitude d'Afrique centrale

Chiassa Librich Carrel* ; Meutchieye Félix* ;DongmoDjiotsa Francis; Massawa Jean
*Unité de recherche de Biotechnologie et de Bio-informatique, Département des Productions Animales, FASA ; * Auteurs pour correspondance; Université de Dschang B.P. 188, Dschang-Cameroun : librichkarrel@yahoo.com / fmeutchieye@univdschang.org*

La maitrise des techniques de reproduction permet une meilleure exploitation du potentiel des espèces avicoles non conventionnelles. Celles-ci constituent une ressource alternative de revenus et de protéines pour de nombreuses familles. La présente étude s'est proposée de caractériser quelques performances d'incubation artificielle des œufs de pintades dans la Région des Hautes Terres de l'Ouest Cameroun entre Août et Septembre 2017. Un total de 150 œufs issus des élevages de Guidiguis (Commune de la Région Soudano Sahélienne du Cameroun) a été collecté, transporté, caractérisé (poids, couleur, longueur, diamètre), désinfectépuis incubé à la ferme d'application et de recherche de l'Université de Dschang. Il est ressorti des résultats que les œufs de l'échantillon avaient un poids moyen de 37,04 ± 0,32g, couleurs variables (rose entier, rose mouchetée, blanc et brun), une longueur de 47,22 ± 0,35mm et ungrand diamètrede 37,78 ± 0,15mm. Le poids et le grand diamètre sont fortement corrélés (r = 0,84; P<0,05). Le taux de fertilité était de 58% contre 21,83% pour le taux de mortalité embryonnaire, alors que la mortalité intra coquille était de 66,67%. Le taux d'éclosion était de 11,50%. Les œufs infertiles avaient un poids moyen de 36,85±0,38g. Il est nécessaire d'inclure dans les investigations futures les effets : de provenance, de transport de conditions et temps de stockage en vue de l'optimisation de la production en masse des pintadeaux par incubation artificielle, l'évaluation de quelques paramètres génétiques de croissance.

CBS17-ORA-112

Presnter : DESOBGO ZANGUE

Optimisation de quelques paramètres de fermentation de la sève de raphia (Rafia farinifera) par Lactobacillus fermentum et Bifidobacterium bifidum

Mbarga, M.J.A.[1] ; Desobgo, Z.S.C[1]*. ; Tatsadjieu, N.L. [1]
[1]Département de Génie Alimentaire et Contrôle Qualité, Institut Universitaire de Technology, Université de Ngaoundéré Address for correspondence, Tel: 237-697160004 Email: desobgo_zan_steve@yahoo.fr

Dans l'optique de contribuer à la diversification de la gamme des produits probiotiques limités jusqu'ici aux matrices laitières et de valoriser les matières premières locales, l'objectif du présent travail était de trouver les conditions de fermentation de la sève fraiche de Rafia farinifera par deux ferments probiotiques à savoir Lactobacillus fermentum et Bifidobacterium bifidum. La caractérisation de la sève de raphia a été réalisée et les valeurs suivantes ont été obtenues : 3,8% de matière sèche, 7,04g de cendre par 100 g de matière sèche, 10,78g de sucres réducteurs par litre, acidité titrable de 4,44 équivalent gramme d'acide lactique par litre , pH de 4,12, composés phénoliques totaux 2,91 g/litre, masse volumique de 1,158 g/L et un °Brix de 4,2. Le suivi de la viabilité des ferments dans cette sève a montré une évolution de celle-ci traduisant la possibilité de fermenter cette sève avec les deux souches. Par ailleurs, l'optimisation des paramètres physicochimiques grce au modèle de Box-Behnken après avoir maximisé le °Brix, les sucres réducteurs et les protéines et fixé le pH à 4, l'acidité lactique à 9 g/L, la quantité de probiotiques à 1,00x1010 UFC/mL, ainsi que les diamètres d'inhibition à 14 mm pour Salmonella et 12 mm pour les 3 autres souches testées (L. monocytogenes, E. coli et B. cereus) a conduit aux conditions opératoires suivantes : des taux d'ensemencement de B. bifidum et L. fermentum respectifs de 10 % et 2,82 % , une température d'incubation de 37 °C et un temps d'incubation de 14 h. Ainsi, ces conditions ont permis d'obtenir une boisson ayant une acidité titrable de 8 g d'acide lactique/L, un pH de 3,87, une teneur en protéines de 574,6 mg/L, un °Brix de 5,47 et une quantité de probiotiques de 1,13x108 UFC/mL. Au-delà de cette optimisation, une analyse sensorielle réalisée sur le produit optimisé a montré que celui-ci était acceptable sur le plan organoleptique.

V.1.3) Cameroon Bioscience Society, 25th Annual Conference. University of Ngaoundere

CAMEROON BIOSCIENCE SOCIETY

(CBS)

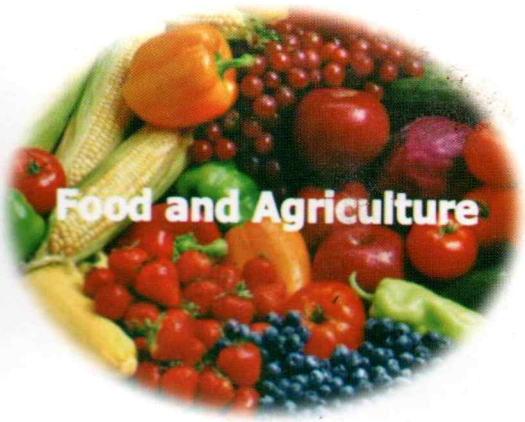
25th Annual Conference

November 27th- December 1st, 2018-University of Ngaoundere-Cameroon

THEME:

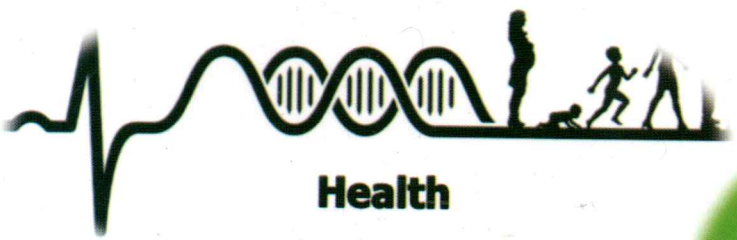
BIOSCIENCE, KNOWLEDGE VALORISATION AND ENTREPRENEURSHIP

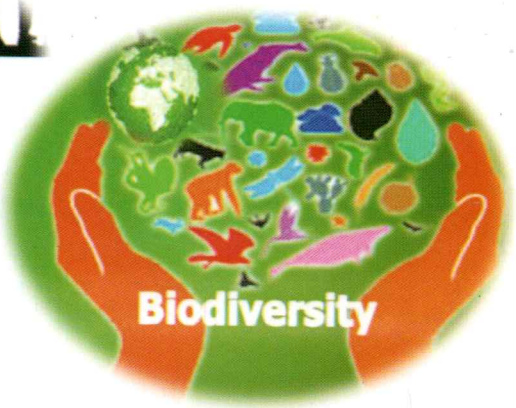
PROGRAMME & ABSTRACTS BOOK



DAAD

Deutscher Akademischer Austauschdienst
German Academic Exchange Service





EDITFRIC
Maison d'édition

CBS18_FAA_ORA 25

A screening method for the expression of total amylase activity during malting of sorghum

NGUEMOGNE A.-C., **DESOBGO Z.-S.-C.***, NSO E.-J.

Department of Food Processing and Quality Control, University Institute of Technology (UIT), The University of Ngaoundere, P.O. Box 455 Ngaoundéré, Cameroon
**Email: desobgo.zangue@gmail.com*

Introduction: The most important feature of the brewing quality of malt is the level of total amylolytic power involved in the conversion of starch into fermentable sugars.

Methodology: A fractional factorial design ($n = 2^{11-7}$ experiments) with a level of confidence of $P < 0.05$ was performed to determine the factors which have an influence on total amylase activity of a Cameroonian sorghum cultivar Safrari, during the malting process. Eleven factors identified in the literature were studied: grains disinfection, alkaline steeping and renewal of steeping liquor, steeping time and temperature, steeping with air-rest periods, germination time and temperature, kilning time and temperature and finally, grinding malt with roots and shoots. The determination of total amylase activity was done by measuring the initial velocities of enzyme-substrate reactions as a decrease of starch-iodine colour with time.

Results: A multiple regression equation relating total amylase activity to the factors studied gave a good fit to first order equation without interactions ($R^2 = 0.98$). Only five factors were shown to be statistically significant: the renewal of the steep liquor, germination time, kilning time and temperature and grain disinfection. Grain disinfection being the only one with a negative impact.

Conclusion: Factors which significantly influence enzymes synthesis during the malting process of sorghum might vary with variety used.

Impact of the study: Results can be used as data base to optimise amylolytic enzymes synthesis during the malting process of *Safrari* sorghum cultivar for brewing purposes.

Key words: Sorghum; Malting; Screening; Total amylase activity.

V.2) Sociétés savantes dont le candidat est membre

academicJournals

Open Access Journals

http://www.academicjournals.org

African Journal of Biotechnology

April 27, 2015

Food Processing and Quality Control University Institute of Technology (University of Ngaoundere), Cameroon.

Dear Dr. Desobgo Zangue Steve Carly,

Appointment as an Editorial Board Member

I am pleased to inform you that your application for membership of the editorial board of the African Journal of Biotechnology (AJB) has been evaluated and accepted.

Your responsibilities will be:

- To act as a reviewer for submitted manuscript
- To evaluate and determine if reviewed and revised manuscript(s) are to be accepted, modified or rejected.
- To communicate, issues affecting the growth and development of the journal directly with her editorial office and to resolve any conflict(s) that may arise after the publication of a given manuscript as well as evaluating the relative importance of the issues raised by reviewers and giving recommendations to authors.

Please find attached:

1. COPE - Code of Conduct and Best Practice Guidelines for Journal Editors
2. COPE - Code of Conduct for Journal Publishers
3. Memorandum of Understanding for Editors and Editorial Board Members

Kindly read the attached documents and return a signed copy of the Memorandum of Understanding for Editors and Editorial Board Members to us.

Also provide us with your ORCID ID and Scopus ID (if available).

Your appointment takes effect from April 27, 2015. Kindly note that yours is a voluntary position and there will be no financial remuneration.

As soon as we receive your response, we will update the journal's website with your details and start forwarding manuscripts to you for evaluation.

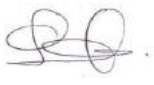
Thank you once again for your interest in serving on the board of our journal.

You can login to our portal as an editorial board member ms.academicjournals.org

User name: desobgo@yahoo.fr
Password: deso2015

Accept my congratulations.

Yours faithfully,



Clement Onou
Academic Journals

ASBC Membership

Boîte de réception x

Cheryl Kruchten <CKruchten@scisoc.org> 27/06/2017

À moi

anglais
français

Traduire le message

Désactiver pour : anglais

Dear Dr. Desobgo Zangue,

Thank you for joining the ASBC! Your membership application has been processed. We are pleased that you have made the decision to become a part of a member-driven organization focused on scientific and technical research in the brewing and related industries.

The ASBC Website is where you can access and update your member record, access your subscription to the *Journal of the ASBC*, register for an event, purchase a book or online product, or search for a colleague or contact in the membership directory. The ASBC Website is designed to interface directly with our database. By signing in, the system will know who you are and will automatically provide corresponding member pricing and options. All transactions are completely safe, secure, and instantaneous.

Please use the link below to access the ASBC website.

www.asbcnet.org

CERTIFICATE

OF EDITORIAL BOARD MEMBERSHIP

DESOBGO ZANGUE Steve Carly

has been appointed as one of the

Editorial Board Members

In

SCIREA Journal of Food

http://www.scirea.org/journal/Food

Science Research Association

Date: March 2019

Arvind Chhabra

672

Editorial Board Membership Certificate

Journal of Food Stability

THIS IS TO CERTIFY THAT

Dr. Desobgo Zangué Steve Carly

IS A HONORABLE ASSOCIATE EDITOR OF THE

JOURNAL OF FOOD STABILITY

FTD RESOURCES PUBLISHER

JOURNAL OF FOOD STABILITY

www.foodstability.com/editorial.php

V.3) Reviewer pour les journaux internationaux

Routledge Taylor & Francis Group
African Journal of Science, Technology, Innovation and Development
Editorial Manager

Completed Reviewer Assignments for Z.S.C. Desobgo, Ph.D.

Page: 1 of 1 (1 total assignments) Display 10 results per page.

Action	My Reviewer Number	Manuscript Number	Article Type	Article Title	Final Disposition	Date Reviewer Invited	Date Reviewer Agreed	Date Review Due	Date Review Submitted	Days Taken	Editor's Name
View Reviewer Comments Send E-mail	1	RAJS-2017-0127	Original Article	Assessment of heavy metals in foods and adult dietary intake estimates.		Aug 24, 2017	Aug 31, 2017	Oct 02, 2017	Feb 28, 2018	181	Ignace TCHWAKET KAMGA, PhD

Page: 1 of 1 (1 total assignments) Display 10 results per page.

<< Reviewer Main Menu

You should use the free Adobe Reader 10 or later for best PDF Viewing results.

Get ADOBE READER

Completed Reviewer Assignments for Desobgo Zangué Steve Carly, Ph.D

Page: 1 of 1 (2 total assignments)

Display 10 results per page.

Action	My Reviewer Number	Manuscript Number	Article Type	Article Title	Status Date	Current Status	Date Reviewer Invited	Date Reviewer Agreed	Date Review Due	Date Review Submitted	Days Taken	Editor's Name	Corr. Author
Action Links	3	BITE-D-17-00829	Original research paper	Functional bacterial and archaeal diversity revealed by 16S rRNA gene pyrosequencing during potato starch processing wastewater treatment in an UASB	Mar 23, 2017	Completed - Accept	Feb 08, 2017	Feb 08, 2017	Mar 01, 2017	Mar 13, 2017	33		Jianzheng Li
Action Links	2	BITE-D-16-02396	Original research paper	The feasibility of an up-flow partially aerated biological filter (U-PABF) for nitrogen and COD removal from domestic wastewater	Jun 25, 2016	Completed - Accept	May 08, 2016	May 08, 2016	May 29, 2016	May 29, 2016	21		Chuanping Feng

Page: 1 of 1 (2 total assignments)

Display 10 results per page.

<< Reviewer Main Menu

You should use the free Adobe Acrobat Reader 6 or later for best PDF Viewing results.

Get Acrobat Reader

Copyright © 2018 Elsevier B.V. All rights reserved.
Cookies are set by this site. To decline them or learn more, visit our Cookies page.

Food and Bioprocess Technology

Completed Reviewer Assignments for Steve Carly Desobgo Zangue, Ph.D

Page: 1 of 1 (9 total assignments) Display 10 ▼ results per page

Action	My Reviewer Number	Manuscript Number	Article Type	Article Title	Final Disposition	Date Reviewer Invited	Date Reviewer Agreed
View Reviewer Comments	1	FABT-D-16-01061	Original Research	Optimization of sesame oil extraction by screw-pressing at low temperature		Oct 21, 2016	Oct 22, 2016
View Reviewer Comments View Attachments	1	FABT-D-15-00824R2	Original Research	Combined Effect of High Pressure and Conventional Heating on Pectin Extraction from Passion Fruit Peel	Accept	Jan 04, 2016	Jan 14, 2016
View Reviewer Comments View Attachments	1	FABT-D-15-00824R1	Original Research	Combined Effect of High Pressure and Conventional Heating on Pectin Extraction from Passion Fruit Peel	Accept	Nov 08, 2015	Nov 09, 2015
View Reviewer Comments View Attachments	1	FABT-D-15-00824	Original Research	Combined Effect of High Pressure and Conventional Heating on Pectin Extraction from Passion Fruit Peel	Accept	Aug 19, 2015	Aug 19, 2015
View Reviewer Comments View Attachments	4	FABT-D-14-01502R2	Original Research	Changes of antioxidant compounds in a fruit juice-Stevia rebaudiana blend processed by pulsed electric technologies and ultrasound	Accept	Jun 22, 2015	Jun 27, 2015
View Reviewer Comments View Attachments	4	FABT-D-14-01502R1	Original Research	Changes of antioxidant compounds in a fruit juice-Stevia rebaudiana blend processed by pulsed electric technologies and ultrasound	Accept	Apr 24, 2015	Apr 24, 2015
View Reviewer Comments	3	FABT-D-15-00135R1	Original Research	Extraction of Oat (Avena sativa L.) Antifreeze Proteins and Evaluation of Their Effects on Frozen Dough and Steamed Bread	Accept	May 05, 2015	May 13, 2015
View Reviewer Comments	3	FABT-D-15-00135	Original Research	Extraction of Oat (Avena sativa L.) Antifreeze Proteins and Evaluation of Their Effects on Frozen Dough and Steamed Bread	Accept	Feb 15, 2015	Feb 15, 2015
View Reviewer Comments View Attachments	4	FABT-D-14-01502	Original Research	Changes of antioxidant compounds in a fruit juice-Stevia rebaudiana blend processed by pulsed electric technologies and ultrasound	Accept	Jan 11, 2015	Jan 16, 2015

Page: 1 of 1 (9 total assignments) Display 10 ▼ results per page

<< Reviewer Main Menu

You should use the free Adobe Reader 10 or later for best PDF Viewing results.

Completed Reviewer Assignments for Steve Carly Desobgo Zangue, Ph.D

Page: 2 of 2 (13 total assignments) |< << 1 2 Display 10 results per page.

Action	My Reviewer Number	Manuscript Number	Article Type	Article Title	Final Disposition	Date Reviewer Invited	Date Reviewer Agreed	Date Review Due	Date Review Submitted	Days Taken	Editor's Name
View Reviewer Comments	3	FABT-D-15-00135R1	Original Research	Extraction of Oat (Avena sativa L.) Antifreeze Proteins and Evaluation of Their Effects on Frozen Dough and Steamed Bread	Accept	05 May 2015	13 May 2015	02 Jun 2015	13 May 2015	8	
View Reviewer Comments	3	FABT-D-15-00135	Original Research	Extraction of Oat (Avena sativa L.) Antifreeze Proteins and Evaluation of Their Effects on Frozen Dough and Steamed Bread	Accept	15 Feb 2015	15 Feb 2015	15 Mar 2015	31 Mar 2015	44	
View Reviewer Comments View Attachments	4	FABT-D-14-01502	Original Research	Changes of antioxidant compounds in a fruit juice-Stevia rebaudiana blend processed by pulsed electric technologies and ultrasound	Accept	11 Jan 2015	16 Jan 2015	08 Feb 2015	09 Feb 2015	29	

Page: 2 of 2 (13 total assignments) |< << 1 2 Display 10 results per page.

<< Reviewer Main Menu

You should use the free Adobe Reader 10 or later for best PDF Viewing results.

Get ADOBE READER

Pending Reviewer Assignments for Steve Carly Desobgo Zangué, Ph.D.

678

Page: 1 of 1 (1 total assignments) Display 10 results per page.

Action	My Reviewer Number	Manuscript Number	Article Type	Article Title	Current Status	Date Reviewer Invited	Date Reviewer Agreed	Date Review Due
Action Links	3	JFST-D-18-00478	Original Article	Pro-oxidant vs anti-oxidant effects of seeds aglycone extracts of Lepidium sativum and Eruca vesicaria Linn., in vitro, and on neutrophil nitro-oxidative functions	Under Review	26 Jul 2018	26 Jul 2018	25 Aug 2018

Page: 1 of 1 (1 total assignments) Display 10 results per page.

<< Reviewer Main Menu

You should use the free Adobe Reader 10 or later for best PDF Viewing results.

Get ADOBE READER