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Winemaking: Basics and Applied Aspects
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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 finally, innovative approaches aimed at optimising the process efficiency.

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 deacidification 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 fulfilling 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 flavour. 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-flavour. 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 fruit. 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 profile • 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 modification • Barrel flavour in the wine • 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 filtration 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 fining • 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 water • Quick withdrawal of lees residues from wine • Introduction in chilly weather environment of the fining agent • 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 fining • 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 agents • 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 equipment • 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).

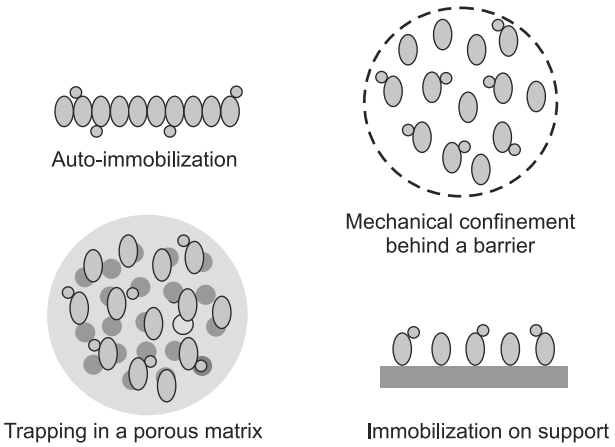

Figure 1. Yeast immobilisation system

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).

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

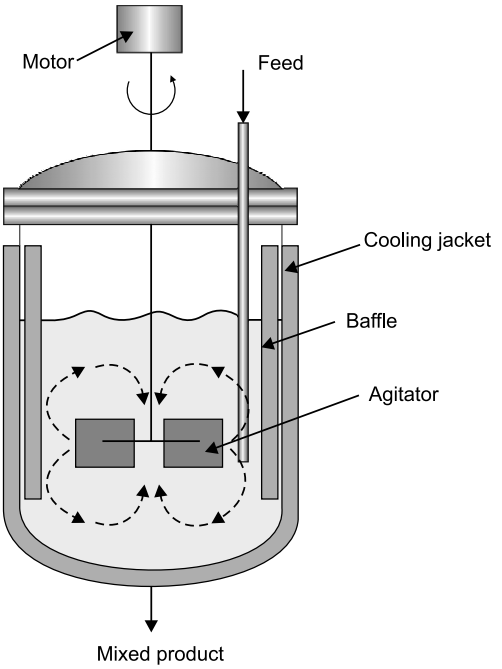

Figure 2. Classical agitated bioreactor

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 efficiency. 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

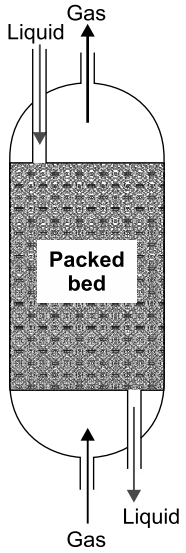

Figure 3. Packed bed bioreactor with the counter current flow

(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).

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 flow. 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).

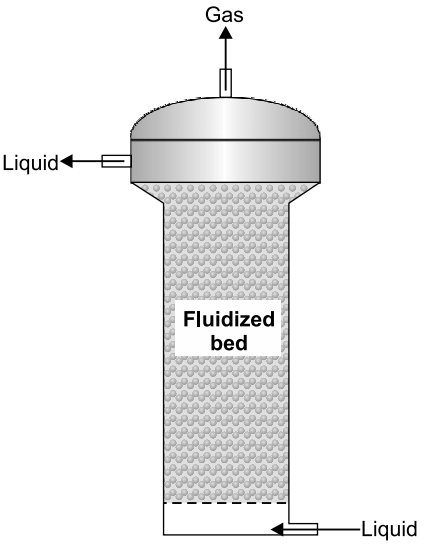

Figure 4. Fluidised bed bioreactor (tower fermenter)

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 efficiency. 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.

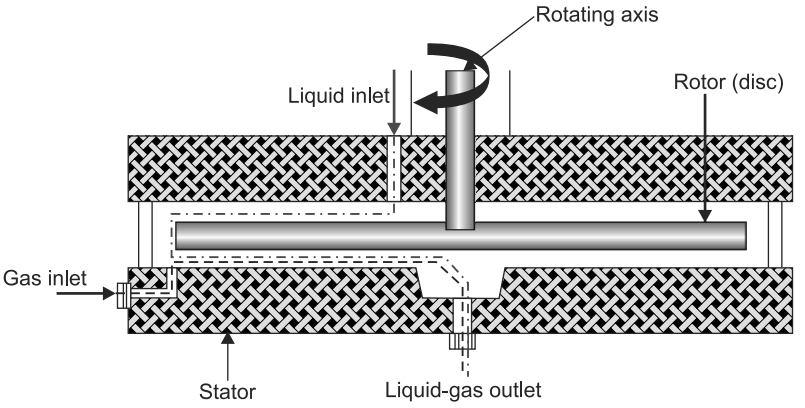

Figure 5. Classical rotating disc bioreactor

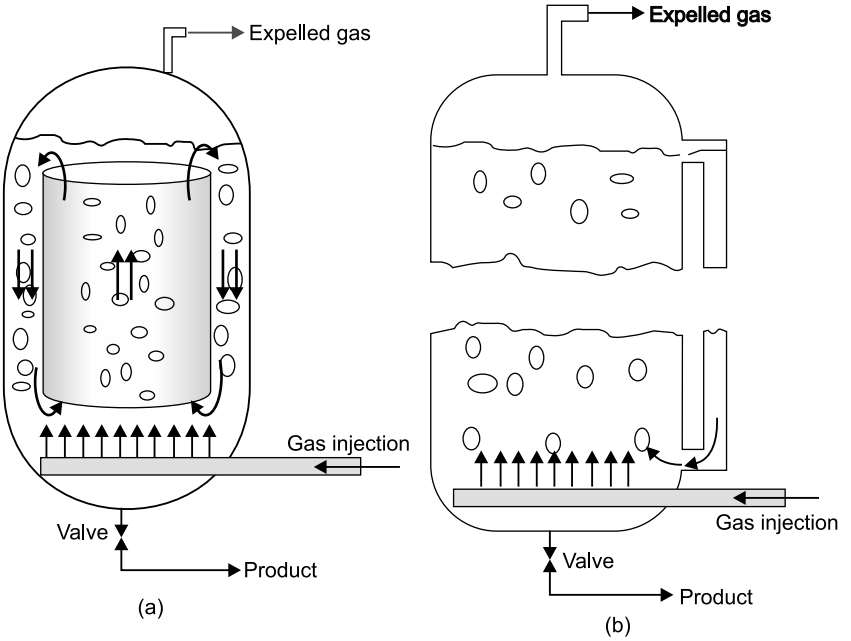

Figure 6. Airlift bioreactor: (a) Classical; (b) External-loop

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

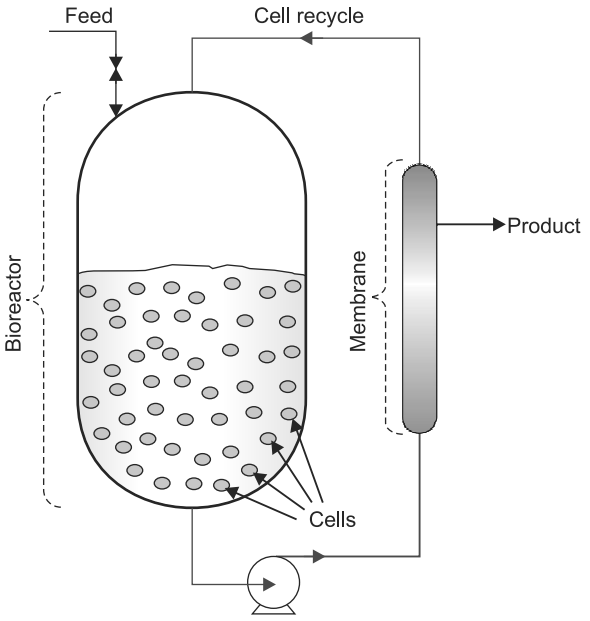

Figure 7. Cell recycle batch bioreactors

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 deacidification. 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*., 1987; Crapisi, *et al*., 1990) 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, *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, *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 mechanized 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 filtration 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 proficient 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 staff to be used all the more fittingly
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 filtration efficiency as summarised in Table 11.

Table 11. Optimisation Aspects of Cross-flow Filtration

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 means.
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 procedures
Water	Cross-stream filtration can be utilised to purify and recover process water

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 efficiency.

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. Specifically, 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.

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