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# An overview of current status of Kenyan fish feed industry and feed management practices, challenges and opportunities

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## Abstract
The profitability of commercial fish farming operation is of paramount importance to all farmers. However, farmers must have access to well-balanced and cost effective feeds coupled with optimal on-farm feed management practices as a prerequisite to profitable production. This paper presents an audit of the current status of the Kenyan fish feed industry and on-farm feed management practices including opportunities and constraints from the fish farmer's perspective. The Kenyan fish feed industry has been boosted with the development of fish feed standards, which is expected to ensure quality fish feeds for all farmers. Much of the aquafeeds used in Kenya are either produced on-farm or by small-scale semi-commercial feed manufacturers, and improvements to the quality and preparation of these feeds are likely to bring about improved productivity and cost savings. Since feed management practices significantly impacts the economic performance of production systems, adopting appropriate feed management strategies is instrumental to maximize returns. In a few instances, innovative farmers have reported developing their own feeding strategies such as spreading feeds at fixed points at same time daily, bag and restrictive feeding techniques, break feeding schedules and promoting natural pond productivity. Provision of species-specific feeds addressing the nutritional requirements of the different life stages of fish is still an issue. Other challenges include inadequate access to finance, a lack of technical innovations, absence of feed formulation and processing knowledge and poor feed handling and storage techniques. The potential to develop public-private partnerships with farmer groups to improve access to information should be considered. Programs that use the local media to provide farmers with extension messages must be encouraged. The government should frequently carry out spot checks on feeds supplied to Agrovets to ascertain its quality. Fish farmers should also be trained on feed formulation, transportation and storage to maintain a constant feed supply and save on costs.

**Keywords:** Kenya, Fish feeds, Management, Challenges, Opportunities.

## 1. Introduction
According to estimates of the Food and Agriculture Organization (FAO), to feed the world in 2050, agricultural output originating from fisheries and aquaculture must increase by over 60 percent [1]. Meeting this target is a formidable challenge for the international community considering that an alarming number of people, mostly in developing countries still suffer from hunger and poverty. To meet the demand for food fish of an increasing and wealthier global population by the year 2030, it appears that the aquaculture production rate needs significant acceleration as capture fisheries production is expected to stagnate [2].

Due to this development, nations around the world have continuously developed aquaculture technologies especially on feed and feed management practices to increase production efficiencies for a range of aquatic organisms in environment of limiting natural resources [2]. Despite significant inter-country differences in production capacities, aquaculture has collectively achieved the highest average growth rate and is the fastest growing food production sector worldwide. In 2010, global aquaculture production reached 79 million tons, growing at an annual rate of 9.7 percent since 1998 (Fig.1) [2]. The technological advances in equipment and feed management have led to an increase in its proportional contribution to total fisheries production, which is now comparable to capture fisheries [2, 3]. However, this increased

contribution is largely an Asian phenomenon, as Asia alone accounted for about 92% of total world aquaculture production in 2010, while the Americas, Africa and Europe combined contributed only 8.3 % [3]. In 1988, aquaculture contributed only 15 % of total global fisheries production, but by 2010, this had risen almost threefold to 47 % [3].

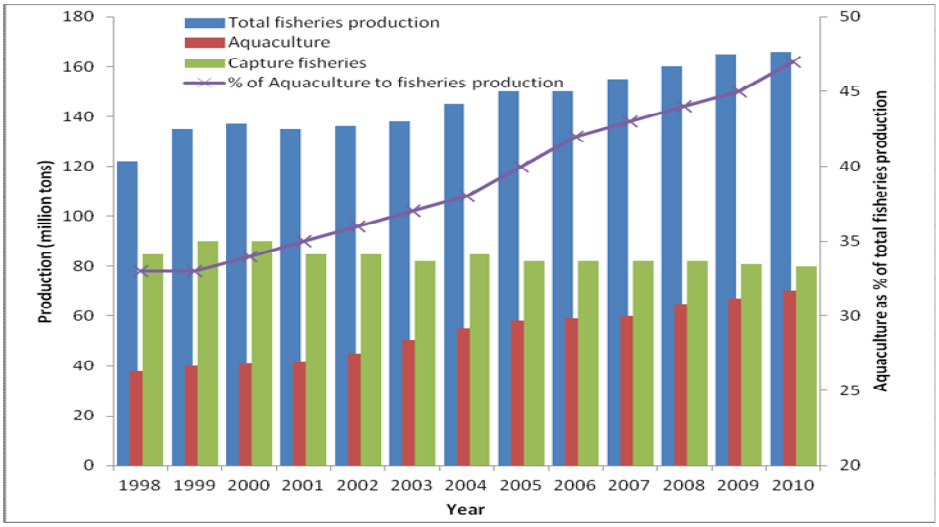


**Fig 1:** Global trends in contribution of aquaculture to fisheries production, 1998–2010, Source: Adapted from [2].

African aquaculture is currently undergoing an exciting phase of growth after numerous false starts, perhaps as a reaction to the high incidence of poverty, malnutrition, and unemployment [4]. Africa has great potential for fish farming with 37% of its surface area suitable for artisanal fish farming and 43% for commercial fish production [5].

The evolution of aquaculture development in Kenya has been rather interesting. Since aquaculture inception in 1950s to 2006, the total annual Kenyan aquaculture production has never exceeded 2,000 MT $yr^{-1}$ (Fig. 2) [6]. Before the beginning of the government funded fish farming project, there were about 7,500 fish farmers holding about 7,477 production units with an estimated cover area of 722.4 ha [7]. The performance of the aquaculture sector has remained dismal due to a number of constraints such as unavailability of efficient and inexpensive fish feeds for different stages of development, poor feed management skills, limited varieties of the cultured fish species and low quality seed fish [8].

However, the Kenyan aquaculture sector has undergone a remarkable revolution. Over the last ten years, fish production has increased from 1,012 metric tons produced in 2003 to the present production of 21,487 metric tons (fig. 3), thanks to the Kenya government fish farming program [9]. The implementation of the program triggered an immediate short-term demand for about 28 million certified tilapia and catfish fingerlings and over 14,000 MT of formulated fish feeds, which could not be adequately and timely supplied, even by the private sector [10]. The ripple effect of the program led some farmers to dig their own ponds, further increasing the demand for seed fish and feed to over 100 million and 100,000 MT respectively [10, 11]. Thus far, the program is projected to stimulate further aquaculture growth and consequently expected to play a significantly greater role in contributing to food security, poverty alleviation and economic improvement for the poor.

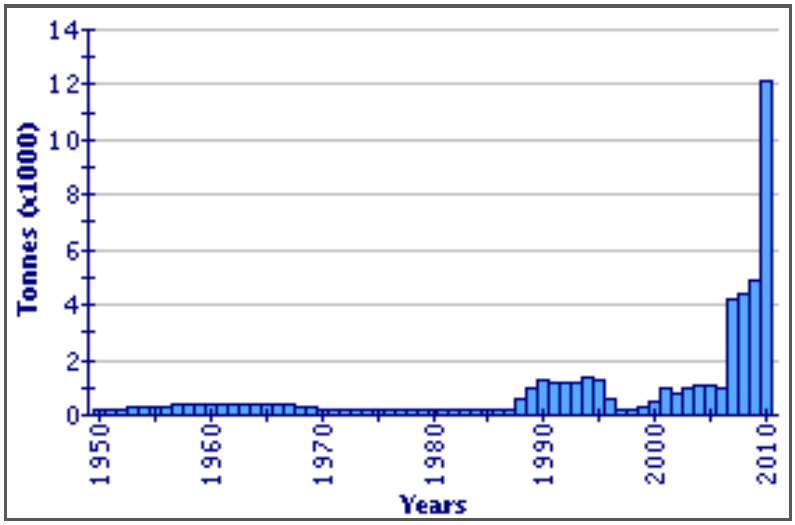


**Fig 2:** Reported aquaculture production in Kenya (from 1950 - 2010) [6]

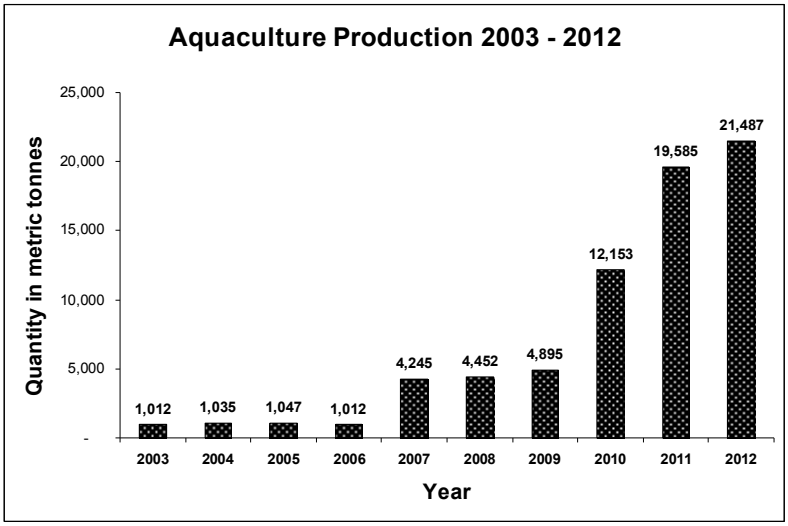


**Fig 3:** Trends in aquaculture production in Kenya [12]

Many authors concur that growth of the aquaculture is positively correlated to the progressive use of quality feeds, which meet the nutritional requirements of the cultured fish [12]. Indeed, the increase in aquaculture production must be supported by a corresponding increase in of designed diets. Most Kenyan fish farmers have mentioned fish feed and feed management as their major challenges (Fig. 4) [13].

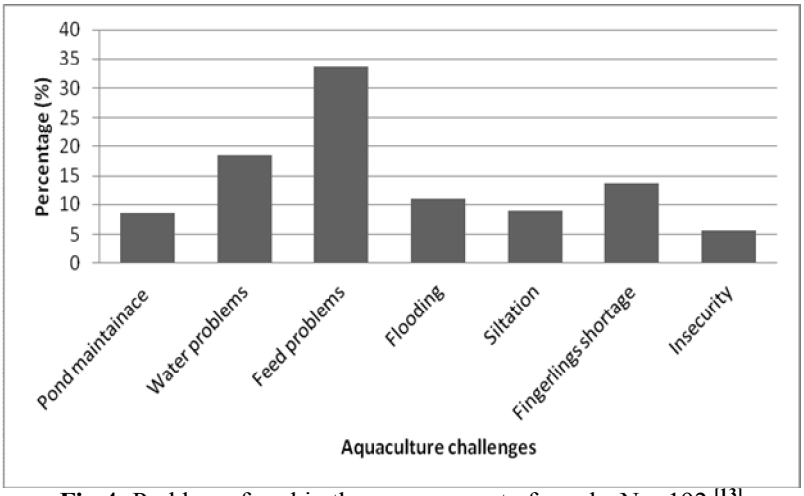


**Fig 4:** Problems faced in the management of ponds, N = 192 [13]

Feed represents the largest expenditure item in both semi-intensive and intensive culture systems and protein is the most expensive macro-nutrient in fish feeds [13]. In semi-intensive tilapia farming where ponds are heavily fertilized, natural food organisms contribute significant amount of nutrient necessary for fish growth. Compounded feeds are used to supplement natural food to maximize yield. For aquaculture to register substantial growth and meet its potential, development of Kenyan fish feed industry must be refocused. There is a need to optimize feed production and employ best on-farm feed management practices to sustain aquaculture growth for small holder fish farmers. Today, the majority of small holder fish farmers does not know how best to manage feed operations, leading to massive losses in their aquaculture ventures. This paper provides an audit of the current status of the Kenyan fish feed industry and on-farm feed management practices including opportunities and challenges from the fish farmer's perspective.

## 2. The current status of Kenyan fish feed industry

In both semi-intensive and intensive aquaculture systems, feed costs typically account for between 40 and 60 % of production costs [14, 15]. The first step towards making the aquaculture industry more profitable and viable is to ensure that farmers have access to the best quality and affordable feeds. Notably, the optimization of feed use by instituting appropriate on-farm feed management practices cannot be overemphasized. Over 90% of cultured fish in Kenya come from earthen ponds sized between 150 to 500 $m^2$ and fed with locally available low cost agricultural by products [16]. Before the availability of compounded diets, most fish farmers used locally available materials (rice bran, wheat bran, cassava meal and corn meal) to feed their fish. In extreme traditional systems fish were reared in fertilized ponds (manure) with or without supplementary feed [17]. Single ingredients (brans) are deficient in macro and micro-nutrients while the high content of crude fiber in some brans reduces the digestibility and palatability thus, leading to low fish yields [17]. However, preliminary studies conducted at Sagana fish farm, Kenya have shown that the performance of different brans in promoting fish growth differed considerably, with Maize bran performing better than wheat and rice bran (Fig. 5) [17].

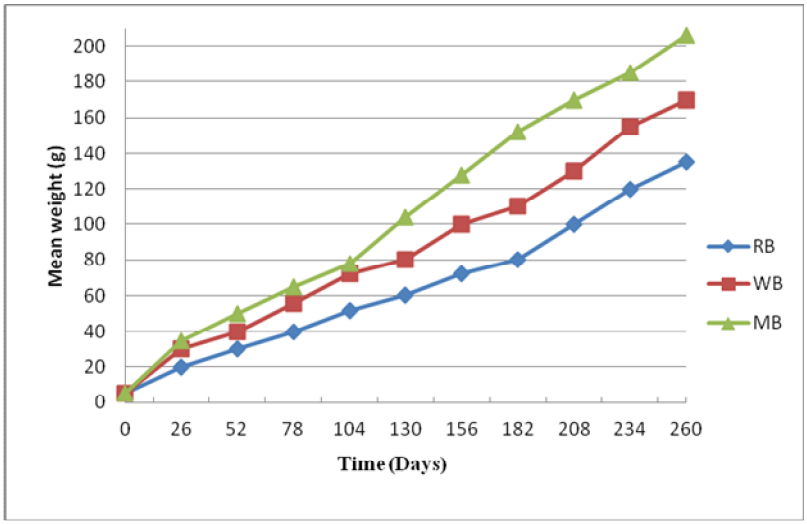


**Fig 5:** Growth curves for *O. niloticus* at 1.7 fish $m^2$ receiving 1.5% body weight of wheat (WB), rice (RB) and maize bran (MB) in fertilized ponds during 250 days culture in Kenya [17]

## 3. Synoptic review of Kenyan on-farm-made fish feeds

Fish feed is formulated by mixing several raw ingredients to make a balanced diet. These ingredients are ground separately and later mixed to ratios before pelletizing to produce semi-floating pellets, which are then sun, dried and stored in gunny bags [18]. The most commonly used feed ingredients include: Ochonga (*Caridina nilotica*), Omena (*Rastrineobola argentea)*, Wheat or rice bran, Sunflower or cotton seed cake and cassava for binding (Fig. 6). The proximate analyses of some of the raw ingredients are presented on table 1.


**Fig 6:** Photos showing some commonly used fish feed ingredients and feed formulation procedures in Kenyan fish feed industry [8, 9]

**Table 1:** Proximate analysis of some commonly used fish feed ingredients in Kenya [8]

| Ingredients | % Nutrient Concentration | | | | | |
|---|---|---|---|---|---|---|
| | Dry matter | Crude Protein | Lipid | NFE | Crude Fibre | Ash |
| Brewer's yeast | 93.0 | 25.0 | 15.4 | 32.0 | 21.9 | 4.7 |
| *Caridina nilotica* | 91.0 | 55-60 | 6.0 | 5.0 | 4.0 | 23.1 |
| Cotton seed Cake | 93.0 | 35.9 | 6.7 | 44.5 | 7.1 | 5.8 |
| Sunflower Cake | 94.0 | 21-25 | 5.5 | 29.2 | 39.6 | 5.0 |
| Wheat bran | - | 14-18 | 6.5 | 59.5 | 16.0 | 4.0 |
| Maize bran | 93.0 | 10-15 | 4.4 | 70.8 | 11.6 | 3.2 |

NFE- Nitrogen Free Extracts

In Kenya today, one of the most pressing challenges in aquaculture is the unavailability of efficient and inexpensive farm made feeds for different stages of fish development. As mentioned previously, the Kenyan fish farming project caused tremendous fish feed shortage. Due to the increased demand for fish feed, unscrupulous dealers took advantage to compromise the quality of fish feed, prompting the government to initiate efforts to establish fish feed standards. The fish feed standards was a culmination of several negotiations between all aquaculture stakeholders (Kenya Marine & Fisheries Research Institute - KMFRI, State Department of Fisheries, Commercial feed companies, fish farmers and Kenya Bureau of Standards KBS). The fish feed standards were created as part of the efforts to streamline the aquaculture sector and ensure high quality fish feed in the market. The aquaculture challenges can be addressed by creating and enforcing standards for fish feed, aquaculture products and maintaining best aquaculture practices amongst others. The standards also help manufacturers to improve quality of their products and reassure consumers thus maintaining high sales. The Kenya fish feed standards are shown in table 2.

**Table 2:** The Kenyan commercial fish feed standards for catfish and tilapia fry, fingerlings, growers and brooders [9].

| Feed parameters | Fry | Fingerlings | Growers | Brooders |
|---|---|---|---|---|
| Feeding rate | 5% b.w | 6 – 8% b.w | 3% b.w | 3% b.w |
| Crude protein % | 40 - 45 % | 35 – 40 % | 30 – 34 % | 40 % |
| Energy MJ/Kg | ≥ 10 | ≥ 10.5 - 11 | ≥ 11.5 – 12.5 | |
| Crude fiber CF | ≥ 4% | ≥ 4% | ≥ 6% | ≥ 6% |
| Lipids | ≥ 8% | ≥ 8% | ≥ 10% | ≥ 10% |
| Lysine | ≥ 12 % | ≥ 12% | ≥ 12% | ≥ 12% |
| Methionine | ≥ 5% | ≥ 5% | ≥ 5% | ≥ 5% |
| Shelf life (months) | ≥ 6 | ≥ 6 | ≥ 6 | ≥ 6 |
| Moisture content | ≤ 12% | ≤ 12% | ≤ 12% | ≤ 12% |
| Enzymes | Needed to improve the FCR | | | |
| Pellet size (mm) | Mash 2 | | 2 – 5 | 2 – 5 |
| Floating pellets (min) | N/A | ≥ 2 | ≥ 2 | ≥ 2 |
| Packaging labels | Company address, Manufacturing and expiry date. | | | |
| Packaging size | 5Kg, 10 Kg, 20 kg, 50kg etc | | | |
| Packaging material | Must be airtight | | | |
| Acidifiers | Preferred | | | |
| Premix (vitamin & mineral) | Mandatory | | | |

Commercial fish feeds for tilapia usually contains 24 - 28% crude protein [19]. However, the cost of these feeds is usually the limiting factor to most farmers. Therefore, farmers prefer locally mixed feeds such as mixture of 76% rice bran and 24% fish meal, mixture of dried freshwater shrimp (*Caradina spp*.) and maize bran, sometimes with some omena (*Rastrineobola argentea*) meal added [19]. Fish fed on maize bran and wheat bran grows significantly faster than those fed with rice bran due to high levels of fibre in rice bran [19]. Lack and cost of commercially produced feeds and low pond management practices has resulted in stagnation of fish farming leading to household food insecurity in Kenya [20]. The proximate crude protein content analysis for various feeds from government parastatals (Lake Basin Development Authority) and private manufactures as at 2001 are shown in table 3. Due to the low quality fish feeds in the Kenyan aquaculture market the Kenyan government in consultation with other aquaculture stakeholders in the country undertook a vetting exercise for all fish feed manufacturers. So far, up to 15 fish feed firms have been approved but further survey efforts are still on course to identify more firms (Table 4).

**Table 3:** Results on Crude Protein content for sampled fish feeds analyzed in KARI laboratories at Kitale, Kenya [13]

| S. No. | Source of fish feed | Crude protein content (%) |
|---|---|---|
| 1 | LBDA Feeds (MASH) | 20.62** |
| 2 | GOWINO Feed industry (MASH) | 18.13** |
| 3 | GOWINO Feed industry (Pellets) | 21.25** |
| 4 | MELL-WIT-61 Mineral Enterprise Ltd | 18.1** |
| 5 | Tilapia pond growers (Pellets) | 21.69** |
| 6 | UGA FISH (PELLETS) | 30.00 |
| 7 | PAC-KISUMU (MASH) | 22.50** |
| 8 | SIGMA FEEDS (PELLETS) | 31.88 |

The asterisk ** represent below optimum crude protein content for the sampled feeds

**Table 4:** Authenticated Feed Suppliers in Kenya [9]

| Company Name | Address | Region/Location | Director/contact |
|---|---|---|---|
| Sigma Feeds Limited Company | P.O Box 18138 Nairobi | Isinya / Namanga Road, Kajaido | Shah Kirtesh Tel: 0733600895 |
| Uga Fish Feeds Kenya Limited | P.O Box 31833 - 00600 Nairobi | Industrial Area, off enterprise road | Dr. E. Onyango Tel: 020 – 2634081 |
| Economy Farm Products Kenya Ltd | P. O. Box 64983 - 00620 Nairobi | Nanyuki Rd. Industrial Area, Nairobi | John Gathongo Tel:+ 254 - 00202013366 |
| Maisha Bora Fish Feeds Limited | P.O. Box 60803 - 00200 Nairobi | Kikuyu, Nairobi | Gilbert Gathuo Tel: 020 – 2511824 |
| Thoyu Feed Limited | P.O. Box 4491- 20100 NAKURU | Sungura road Industrial Area | Priscilla Nduta Tel: +245728427898 |
| Kwality Fish Feeds Limited | P.O Box 71-00200- Nairobi | Off Ruiru Kiambu Road | Peter Cotti Tel: +254721274386 |
| **Cottage Feed Industries** | | | |
| Othaya Fish Feeders S.H.G | P.O Box 82 Othaya | Othaya | Moses Ndungu Tel: 0726849170 |
| Chumara Fish Feeds | P.O Box 353 Chuka | Chuka | John Marangu Tel 0735628971 |
| Bidii Fish Farmers S. H. G | P.O Box 215 Luanda | Luanda- Emuhaya | George Ambuli Tel 0723117706 |
| Osifeeds Ltd | P.O Box 134-00606 Nairobi | Kajiado | Susan Kisoso 0720751859 |
| Zibag Fish producers & Processors | P.O Box 1333, Nyahururu | Nyandarua | DFO Nyahururu Tel 0721622474 |
| Hesao Integrated Fish Farming Organization | P.O Box 3844 Kisumu | Nyalenda B | Richard Okongo Tel: 0722 620169 |

Based on the results in table 3 above, which was carried out before fish feed standards were set, only two feed suppliers (UGA FISH-Pallets and SIGMA FEEDS) met the optimal crude protein content requirement of at least 26%. Today, the Kenyan aquaculture sector has been boosted by the existence of fish feed standards for different stages of fish development. Indeed, this is valuable information to many fish farmers. Having vetted all the fish feed production farms in the country; the government must conduct regular checks to ascertain whether the feeds meet the set specifications. In addition, on-farm experiments should be done to establish the performance of the commercial feeds from the authenticated millers. The cost of these manufactured feed should be subsidized so that many farmers can afford.

**4. The on-farm feed management practices in Kenya**

The type and value of feed inputs that farmers select is dependent upon a number of factors including the market (local or export), the value of the fish, the financial resources available and the culture system [21, 22]. Generally, inputs for low-value species that are grown for local consumption are usually limited to fertilizers, farm-made feeds or locally produced small-scale commercial feeds comprising one or more ingredient sources while commercially manufactured pelleted feed inputs are used for high-value species that are cultured in intensive systems. The latter is not commonly practiced in Kenya due to limited intensive systems and cost implications. In Kenya, most grow-out fish are fed twice a day (morning and evening) with between 26 - 30% CP diets while fingerlings are fed at least 3 times a day at 3% body weight with 30 - 40% CP diet. The feeding is done at the same time and place daily through hand feeding method. Most poor farmers use wheat, rice and maize bran supplemented by some leaves and vegetables [23, 24]. However, the best feed management practice is to use formulated diets. Studies have compared local brans with compounded feeds and the results have demonstrated that compounded diets promote better fish growth [24]. The economic comparisons have also favored the utilization of formulated diets [25]. Thus, lower-cost compounded diet formulated from locally available ingredients for semi-intensive production must be developed to sustain the rising aquaculture development in Kenya.

Due to rising competition for land and water resources in Kenya, a move towards intensification should be prioritized. However, this system requires the adoption nutritionally complete feeds and may increase the demand for commercially produced feeds [26]. The farm-made feeds are generally more affordable than commercially manufactured feeds and still remain the primary feed source for many semi-intensive farmers in Kenya. Some production sectors have already seen significant improvements to the quality of farm-made feeds. For example, farmers in Vietnam that use farm-made feeds for striped catfish production have improved their feed formulations and manufacturing techniques [27]. Formulations now contain up to six ingredient sources, and the feeds are extruded to form semi-moist pellets with improved water stability [27]. Kenya can emulate the efforts of the successful countries. Whereas Kenya has embraced the use of locally available feed ingredients specifically agro-industrial wastes, joint research initiatives geared towards expanding the list of ingredients and improving on FCR, reducing toxins and anti-nutritional factors will improve quality and reduce the cost of commercial and farm made feeds.

## 5. Optimizing feed management strategies

There is no doubt that profitability of commercial farming operation is of paramount importance to all farmers. In this context, adopting appropriate feed management strategies is instrumental in ensuring that feed used is optimized with maximum returns. While maximum growth rates will be attained by feeding to satiation, over-or under-feeding results in feed inefficiencies [28]. Underfeeding lowers growth rates and promotes population size heterogeneity as hierarchies develop [29]. Optimization of feeding strategies requires farmers to calculate appropriate ration sizes and feeding rates, feeding frequencies, and feeding times that take into consideration the endogenous feeding rhythms of the farmed species [30]. Farmers using commercially manufactured feeds should be supplied with technical support to assist them in determining ration sizes and feeding schedules. In many respects, it is in the interest of the feed manufacturing company to ensure that their feeds are used appropriately as it promotes good production outcomes and develops long term commercial relationships. The farmers using farm-made feeds and purchase feed ingredients from suppliers are less likely to have access to the information that they need to determine how they should design their feeding regimes. In the absence of this information, farmers will find it difficult to determine appropriate feed rations, and in many respects, they are more likely to adopt inappropriate feeding strategies. In Kenya, majority of farmers do not feed their fish according to the prescribed rates, and fail to take into consideration ambient temperature, body mass and pond biomass when determining feed rations. Farmers neither maintain feed records nor adjust feed rates accordingly. Farmers do not know how to monitor their feed use, or use FCR to determine feed efficiencies. Even simple farm data such as stocking rates, mortality, feed use and water quality are lacking. In the absence of this data it is difficult for farmers to assess and monitor the efficacy of their production systems and to determine whether changes to their management strategies have demonstrable improvements in production efficiencies. There is a clear need to train farmers in feed management practices, promote the use of feed tables and ensure that farmers maintain adequate feed and production records. Indeed, some farmers tend to over-feed the fish in the mistaken belief that feeding more result to higher growth rates.

In few instances innovative farmers have reported developing their own feeding strategies to optimize feed use. For example, some farmers spread their farm-made feeds at fixed points in their ponds and feed at the same time daily. However, placing mash feeds in this manner result in much of it being dispersed in the water column and being wasted. More innovative methods such as 'bag feeding' in which the feed mixtures are placed in bags that are located throughout the pond should be practiced. This method promotes demand feeding and results in higher growth rates, improved feed ingestion rates, and higher retention rates [31].

Restrictive feeding techniques where the fish are left unfed for one day in every ten days reduces feed costs and stimulates compensatory growth is important [32]. While the potential for restrictive feeding regimes has been demonstrated experimentally for the African catfish (*Clarias gariepinus*), it has yet to be adopted as a farming strategy [33]. Break feeding schedules which involves splitting feed rations into two rations, delayed by 20 minutes can be practiced in Kenya. The practice allows both the dominant and smaller fish to be fed to satiation and promotes minimal size variations at harvest. Evidently, the role that the innovative farmers play in improving on-farm feed management practices is an important one, and mechanisms need to be developed to promote and communicate these innovations to other farmers.

## 6. Promotion of pond natural productivity for feed management

Promoting natural productivity provides food source for low trophic fish feeders. The use of inorganic and organic fertilizers in extensive and semi-intensive production systems is a well-established practice in many countries [34]. However, considerable differences exist in the type of fertilizers used and in their availability, cost, and application rates. In Kenya, farmers fertilize ponds at sub optimal levels resulting in lower levels of production [34]. In such cases, training farmers to use simple indicators to measure the levels of natural productivity in their ponds and providing information to enable them to manage plankton, benthos and periphyton production is necessary to improve their production efficiencies. The need to establish the qualitative and quantitative relationships between natural productivity and the impact that the use of supplemental and farm-made feeds have on nutrient cycling and retention in the culture systems may be pertinent to improving production efficiencies [35]. Better understanding of these dynamics is central to improving nutrient retention in the culture systems, improving feed formulation, reducing feed costs and improving the efficacy of feed management systems.

## 7. Challenges of fish feed management

### 7.1 Feed formulation

Nutritionally balanced feeds are prerequisite to cost-effective fish production. The provision of species-specific feeds that address the nutritional requirements of the different life stages of fish is still a challenge for both commercial and farm-made feed production sectors [36]. Most commercially manufactured feeds are based on laboratory formulations using high quality ingredients but few are conducted under farming conditions. The formulations lack scientific research and are sold to farmers who may be unaware of the nutritional requirements of their farmed species. Indeed, the use of inappropriate formulations is a common problem. Some Kenyan farmers use commercial grow-out formulations that contain higher level of

dietary protein than required while others feed fish with commercial grow-out feeds designed for other fishes. While a significant amount of research has been undertaken to establish the nutritional requirements of many of the species groups, much of this information has not been communicated to the farmers producing farm-made feeds or to small-scale feed manufacturers. Many farmers producing farm-made feeds are often unaware of the nutrient requirements of their farmed species. Notably, dietary protein and energy ratios and how this change over the production cycle is still lacking [37].

### 7.2 Feed processing technology

Much of the aquafeeds used in Africa are either produced on-farm or by small-scale semi-commercial feed manufacturers [38]. Improvements to the quality and preparation of on-farm feed leads to improved productivity and cost savings. The quality of the feed ingredients used and the formulations applied, the manufacturing processes and type of feed produced can significantly affect feed performance. While farmers generally recognize the need to use quality feed ingredients, they often unaware that feed processing technology has a significant effect on feed quality. In Kenya, many of the feed ingredients that are used in farm-made tilapia feeds are poorly milled and fail to conform to the feed process standards. This leads to most of the feed being lost in the water column, resulting in low ingestion rates and high economic feed conversion ratios (eFCR). Farmers should be encouraged to use simple extruders to compress their feed ingredients into dry pellets. Likewise, improving milling and the binding characteristics of the pellets reduces the amount of fines, improves pellet hardness and water stability, improves eFCR, and results in cost savings to the farmer [39]. Focusing on improving efficiencies in the farm-made and small-scale feed manufacturing sectors is likely to bring significant gains to on-farm feed efficiencies. Other constrains to these sectors include inadequate access to finance, improper technical innovations and lack of feed formulation and processing knowledge. The potential to develop public-private partnerships with farmer groups and associations to share resources and improve access to improved manufacturing capacity should be considered.

### 7.3 Transport, storage and handling

Most Kenyan farmers are generally unaware of the importance of applying appropriate feed transport, handling and storage techniques. Transporting feeds in open trucks, motorbikes and bicycles can result in long transit times and, on poor roads, this can result in the pellets being damaged. Poor feed storage practices include storage in the open, exposing them to moisture, pests and bad weather [40]. Inappropriate feed storage conditions leads to nutrient loss, feed spoilage, lower yield and poor economic returns. Prolonged exposure to unfavourable storage conditions negatively impacts feed quality [41]. Feeds should be stored in cool well ventilated areas that are not exposed to the extremes of heat and humidity and are protected from pests. Feeds should also be used on a first in: first out basis. Better management guidelines focusing on feed storage and handling issues need to be developed and communicated to the farmers [42].

## 8. Conclusion and recommendations

For optimum fish production in Kenya, the feed industry must be improved to provide quality and affordable feeds to fish farmers. Appropriate feed formulation techniques and processing technologies must be communicated to the farm made and commercial feed processors. The farmer clusters and associations should be encouraged as an effective platform for information dissemination and promoting farmer to farmer training [43]. In addition, the identification and training of key innovative farmers to train other farmers, and farmer field schools have proved successful and need to be promoted further. Training needs should focus on the need to improve feed formulations; formulate species- and life-stage specific diets; and improve the understanding of ingredient quality, nutrient composition and selection, manufacturing processes, storage, and on-farm feed management practices. Access to up-to-date market information for small-scale feed manufacturers and farmers producing farm-made feeds is an issue that needs to be addressed. Contemporary market information including sources, suppliers, quality and cost is a prerequisite to the development of cost-effective farm-made feeds. Furthermore, the use of appropriate local and seasonally available feed ingredients that can be incorporated into farm-made should be encouraged. Farmers and small-scale feed manufacturers need to be made aware of the availability of these ingredient sources, and how they can best be incorporated into their formulations. Currently, information networks are either inefficient or lacking, and there is a need to promote programs that use local media to supply farmers with up-to-date feed ingredient availability, quality, and price and supplier details. A review of the governance mechanisms and the role that legal, policy and regulatory instruments play in ensuring feed quality revealed that there were significant regional variations in the regulatory instruments that are used to control the sector.

## 9. Acknowledgement

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