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Review Article

Current Fish Feed Status and Development of New Feeding Technologies for Aquaculture Growth and Development in Kenya: Rapid Review

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Abstract

Aquaculture has emerged as a promising sector for addressing the ever-increasing demand for fish protein in Kenya, where over 50% of fish consumption is reliant on imports. However, the sustainable growth and development of aquaculture in Kenya are significantly influenced by the availability and quality of fish feed, which constitutes over 50% of the total production costs. The current fish feed status in Kenya is characterized by several challenges, including limited availability of high-quality feed ingredients, high feed costs, and inconsistent feed quality and nutrient composition. These challenges pose significant constraints to the efficient production of healthy and marketable fish, limiting the full potential of aquaculture growth in Kenya. To address these challenges, efforts are being made towards the development of new feed formulations and feeding technologies that can improve the efficiency and sustainability of fish feed production in Kenya. This includes the utilization of locally available feed ingredients, such as agricultural by-products and aquatic macrophytes, to develop cost-effective and nutritionally balanced feed formulations. Moreover, research is underway to optimize feed processing techniques, such as extrusion, pelleting, and encapsulation, to improve feed quality, stability, and digestibility. Additionally, innovative feeding methods, such as automated feeding systems and precision feeding, are being explored to minimize feed wastage and maximize feed utilization, thereby enhancing fish growth and reducing production costs. The development of new feeding technologies for aquaculture growth and development in Kenya holds great potential to address the challenges associated with fish feed availability, quality, and cost. By optimizing feed formulations, processing techniques, and feeding methods, the aquaculture sector in Kenya can improve its productivity, profitability, and sustainability. However, further research, investment, and collaboration among stakeholders, including government, research institutions, feed manufacturers, and farmers, are essential for the successful implementation and adoption of these new feeding technologies to drive the growth and development of aquaculture in Kenya.

Keywords: Aquaculture growth; Fish feed status; New feeding technologies

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Introduction

The capture fisheries production has been dwindling over the years due to climate change, overfishing, introduction of invasive species to the self-sustaining stocks in the inland lakes and other anthropogenic factors [1]. For instance, Lake Victoria, which produces a bulk of inland fisheries in Kenya accounting for ~ over 80 % of the total national catch is currently suffocated by several challenges that lower the fish catches [2]. Consequently, L. Victoria annual fish production has declined from ~ 150,000 tons in 2013 to 102,000 tons in 2020 (Fisheries stat, 2021). This decline has resulted to a reduced per capita fish consumption of 4.5 kg per year, which is much lower than the global average per capita of 20 kg per year reported by FAO [3]. Comparatively, aquaculture has shown the great potential of bridging the fish demand - supply deficit among developing countries especially in the sub-Saharan Africa region [4]. However, in Kenya, the aquaculture sector is facing many critical challenges. The most common ones include lack of affordable high-quality fingerlings for culture and fish feed [5]. These challenges together with weak adoption of the existing aquaculture technologies such as biofloc, periphyton, and multi - level aquaculture technologies have slowed down the growth and development of aquaculture production in Kenya. These challenges have been compounded by inadequate training and capacity building on best production and management practices for fish farming [6]. While the fish mongers have taken the entrepreneurial advantage to import frozen tilapia from China, there have been several inconclusive discussions among various stakeholders as to whether the current importation of fish can sustainably bridge the existing demand - supply gap [7]. With the persistent growth in annual fish supply gap of about 350,000 tons p.a, the future surge of fish demand is expected to spur the growth of aquaculture subsector, creating hundreds of job and business opportunities within the expanded value chain, especially for the youth and women in rural areas who play an active role in aquaculture. Aquaculture plays a pivotal role in the increased supply of high-quality fish protein for the improved food and nutrition security. The recent increased national per capita fish consumption (from 1,000 MT/y in 2000 (equivalent to 1% of national fish production) to 12,000 MT/y, representing 7% of the national harvest, in 2010) can be owed to the many 'fish eating' initiatives by the national and county governments geared towards improvement of fish consumption. Fish have high quality proteins which confers the body with several health benefits, especially among the undernourished children and breastfeeding mothers. Although the growth in Kenyan aquaculture production is still marginal its future prospects of contributing significantly to the country's national fish production is high. To argument capture fisheries production in Kenya, there has been growing interest to culture fish in unexploited Small Water Bodies (SWBs), which include, rivers, dams, wetlands and introducing cages in lakes over the last decade. Due to the foregoing developments, supplemental feeding is required to boost aquaculture growth and development for future sustainability in fish production. This review paper seeks to discuss the current fish feeds development trends, distribution and value chain networks and reach to farmers.

Review Methodology

This study involved a comprehensive, detailed literature search and review of published articles, policy documents and expert opinions. To understand the details of the current status of fish feeds and the upcoming technologies in the sector, the review process focused more on the various nodes within the aqua feed sector within the country. The core sectors analyzed were the ingredient production and access, fish feed formulation and production, new technologies within the aquaculture sector- including their adoption and potential for upscaling.

The authors conducted a thorough literature review with three main objectives:

a. Compilation of relevant datasets and information from past and ongoing projects related to fish feed production, access and distribution in Kenya (availability and access to ingredients, distribution and access to fish feeds);

b. Review of published documents and reports to identify various aquaculture technologies and innovations within the country that are linked to fish feed production and utilization.

c. Identification of the various fish feed technologies (already in use and those still under validation in different projects) and their potential for adoption and upscaling within the aqua feed sector in Kenya.

d. Identification of potential benefits of these new technologies to the aqua feed sector and the possible spill over effects associated with their adoption.

Based on the stated review objectives and bearing in mind this was a rapid review, the bias that could arise during the process was eliminated by the steps below;

i. Review existing literature and data, selecting appropriate ones to include in the results;

ii. Assess the data presented and its relevance to objectives; and finally

iii. Identify knowledge gaps where additional research is required in the future and make recommendations.

Based on the methods described, the review was done under the subthemes outlined below.

Situation Analysis

Aquaculture growth and development in Kenya has been driven by marginal subsidies injected into the subsector during 2009 - 2012 Economic Stimulus Program (ESP) and several fish-eating initiatives. The inter-sectorial ESP was one of the institutional frameworks that recognized growth in aquaculture production as one of the viable options for revamping the country's food sector, to foster economic development, and alleviate or completely eradicate poverty. According to Munguti [5], some technological interventions have also been employed to boost aquaculture growth and development. Recent technologies include biofloc technology, genetic engineering, selection and breeding and hybridization. These aquaculture technologies seek to increase protein utilization for improved growth performance and reduce the cost of production by replacing fishmeal with more affordable and readily available protein ingredients. However, since the last decade, Kenya is yet to report significant contribution on aquaculture production on a global scale because of slow adoption of the available aquaculture technologies [8]. Various studies have posited that Kenya has a significant and great potential for aquaculture farming and production. According studies, aquaculture production of culture species such as tilapia, common carp, trout and catfish started in the early 1900s in rivers and static ponds. However, notable fish farming started in 1948 with the establishment of Sagana and Kiganjo fish farms. According to Munguti [5], the primary cultured fish species in Kenya today are Nile tilapia (75%) and African catfish (15%) but efforts to introduce other indigenous fish, such as *Labeo victorianus,* in aquaculture have not been widely adopted by farmers and this has been attributed to mortality rates and lack of sufficient and efficient fish feeds. In Kenya, there are significant efforts to boost aquaculture production, and this has been done through the establishment of several aquaculture facilities in various parts of the country to serve as research centers, training facilities, and sources of fingerlings and feed for fish farmers. They include the National Aquaculture Research Development & Training Center (NARDTC) in Sagana, Kisii fish farm training center, Kiganjo trout farm, Ndaragua trout farm, Chwele fish farm, Lake Basin Development Authority (LBDA) in Kisumu, Wakhungu fish farm in Busia, Sangoro research station, Kegati research station, and Kabonyo and Ngomeni fish farms. Over the past decades, aquaculture production in Kenya has been characterized by various challenges such as lack of fish feeds, competition, cheap fish feeds, population growth escalating to unsustainable levels and increasing food insecurity, challenges coming from shared natural water bodies like L. Victoria, reduction in water levels, and water pollution. These challenges have led to the dwindling of the aquaculture production in Kenya despite the fact that Kenya is endowed with several inland natural water resources such as Lakes Victoria, Turkana, Baringo, Naivasha, Chala, Kanyaboli, and Jipe, among others. Major rivers such Tana, Athi, Nyando, Nzoia, Gucha, Migori, Yala, and Mara have contributed significantly to aquaculture production in

Kenya. However, it is worth noting that, though most parts in Kenya have showcased suitability and sustainability for fish farming, "only about 0.014% of the 1.4 million ha of potential aquaculture sites are used for aquaculture and about 95% of fish farming is on a small scale. Some studies have pointed out that in Kenya, regions such as Coastal, Rift Valley, Western and Nyanza provinces have played a major contribution to aquaculture production in Kenya. The Fish Farming Enterprise Productivity Program under the ESP was aimed at injecting commercial thinking into fish farming to build up a vibrant aquaculture industry. The program aimed to increase production of farmed fish from 4,000 MT to over 20,000 MT in the medium term and to more than 100,000 MT in the long term. Therefore, with increased effort to boost fish production, there is also need to for better, improved, and formulated fish feeds.

various aquaculture techniques

Modern aquaculture technologies are categorized into three: extensive system; which incorporates low level of technology, low degree of control, low production level of efficiency; semi-intensive system where supplementary feed are used to maintain high stocking rates or; intensive systems which is characterized by a high degree of control, high initial costs, high-level technology, and high production efficiency. Supporting studies have shown that consumption of fish has the potential to alleviate diseases. Fish provides a crucial source of protein given it is much easier to digest and is also a complementary to most regions of Africa with high carbohydrate diet Fish contains all essential amino acids, minerals and micronutrients such as iron, zinc, omega-3 fatty acids and vitamins, often in highly bio available forms. Three major aquaculture technological developments have been at the centre point of aquaculture establishment in Kenya, these are: (i) fish breeding and genetics for particularly the Nile tilapia and the African catfish; (ii) advances in feed technology and formulation; and (iii) the continued growth in the volume and value chains of fresh water aquaculture. Most aquaculture farms in Kenya are relying aquaculture technologies such as the use of earthen, concrete and liner ponds depending on the soil water retention capability, with some yet adapting to other new forms of technologies such as wooden-raised lined ponds, circular and rectangular raceways, recirculating system, hydroponics and aquaponics, as well as; high density intensive production in cages.

Crude protein sources

The subject of feeding and fish feeds form the central discussion in the sustainability of various aquaculture systems. Cultured fish have varied nutritional requirements depending on their feeding habits. For instance, the highly omnivorous African catfish require high in protein content in their diets compared to exclusively herbivorous species such as the Nile Tilapia. This makes their feed more expensive than those of Nile tilapia. High cost of fish feed that accounts for up to 70% of the total production costs usually results from the inclusion of high-quality animal-based protein ingredients which are essential in promoting faster growth in cultured fish [9]. Their high-quality protein usually is responsible for highly palatability; digestibility and assimilation of fish feed into fish tissues to build up high quality and balanced Amino Acid (AA) profile. Besides being a relatively expensive ingredient, fishmeal, the common source of protein in fish feeds is geographically unavailable to most farmers and has many other competetive uses such as formulation of poultry and livestock feeds [10,11]. The main sources of fish meal in Kenya are the freshwater shrimps, *Caridina niloticus,* and the discards of silver cyprinid, *Rastrineobola argentea.* However, the seasonal availability of *C. niloticus* has served to increase the overall cost of production because of competition for the use of fishmeal from other production enterprises such livestock sector, where it is mainly used as feed ingredient for poultry and other livestock. Increased dependency on fish meal often leads to unsustainable exploitation of freshwater fisheries in Lake Victoria, while threatening the stability of food chains of the self-sustaining native and exotic stocks as well as diversity of lake Victoria's highly diverse multi species ecosystems [2]. Slow growth and development of aquaculture has been linked to availability of few reputable large-scale feed mills which continues to hamper aquaculture growth contributing to increased cost of production, in addition to decreased availability and reliability of the quality fish feed supply [9]. Some unscrupulous sellers have resorted to incorporating of low-level crude protein in fish feeds which they sell directly to unsuspecting farmers resulting to slow growth of the cultured species. Most semi-intensive pond culture systems employ pond fertilization together with supplemental feeding to increase nutrient supply for fish growth [5]. It is recommended to fertilize the ponds of Nile tilapia prior to stocking of fingerlings to promote production of live feeds (Which include larger zooplankton such as daphnia and phytoplankton). However, supplemental feeding is still required as the production tends to be insufficient to meet the nutritional requirements of early stages of growth.

Chemical analysis of different fish feed components

In addition to pond fertilization, previous studies have recommended a paradigm shift from overdependence of fishmeal towards the use of cheap and readily available alternative protein sources. Access to quality feeds is one of the challenges faced by most aquaculture farmers lack adequate resources to purchase the feeds. Most of these farmers lack adequate knowledge to formulate homemade feeds from locally available feedstuffs such as corn meal, wheat bran, and rice bran and cassava meal. These feedstuffs have low palatability and low digestibility due to their high crude fiber content, which reduces the efficiency of converting fish feed into biomass and consequently the net yield.

Although plant-based ingredients are readily affordable, they contain low crude protein levels and lack other essential micronutrients. Some feedstuffs such as Soya beans have antinutritional factors which require additional processing before they are incorporated into fish feeds. In addition, adoption and incorporation of new feed technologies, such as biofloc to maximize on-farm utilization of available protein sources and reduce discharge of effluents to surrounding water sources [12]. These have been projected to cause a knock-on effect to decreasing over-reliance on fish meal protein and reversing the dwindling trends in freshwater fisheries. While several studies have evaluated and compared the proximate composition of locally available proteins sources such as redworms Eisenia foetida, Black solder fly and bioflocs, finding an alternative protein source that can adequately substitute fishmeal in formulated fish feeds is still a high global interest. Some previous studies have reported that *E. foetida* is a viable alternative to fish meal because of its high composition of protein, essential amino acids, fats and minerals which are comparable to the composition of fishmeal [13,14]. For instance, [15] compared the proximate composition of dried red worms, *E. foetida* and fishmeal (Figure 1).

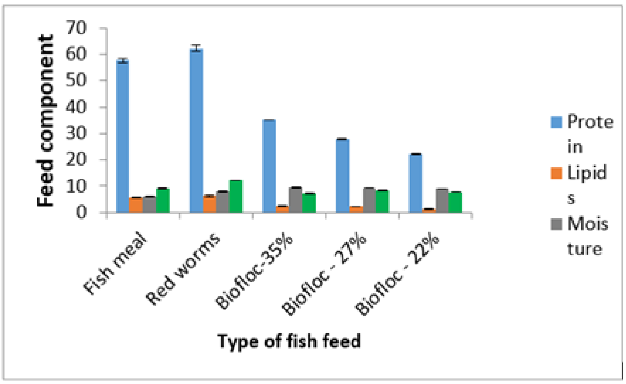

Figure 1: Comparative chemical analysis of different components of fish feeds used in aquaculture trials. Data obtained from [13,15].

Nevertheless, although its proximate composition indicates it is a viable alternative for replacement of fishmeal; little information has been documented on its use in feed formulation. UNGA FEEDS and Sigma Feeds are some of the major private commercial fish feed millers with extensive network of distributors in many parts of the country. These companies produce micro-extruded tilapia and catfish pellets that offer better pellet stability and reduced nutrient leaching into the culture water. The pellet sizes range from 0.1 mm to 5.0 mm, targeting the fish stage with specific gape size to economize consumption, while the specific protein level included in the feed target specific requirements to support optimum growth and development and reduce production cost (Table 1).

Species	Feed description	Crude protein %	Price Kg (in Kshs)
Catfish	0.3 mm weaning powder	62	850
Catfish	0.5 – 0.7 mm granulate starter	57	450
Catfish	2 mm - 3 mm floating pellets	40	200
Catfish	4.5 mm floating pellets	35	185
Tilapia	0.8 – 1.6 mm granulate powder/ pellet	40 - 45	325
Tilapia	2 mm - 3 mm floating pellets	25	160 - 170
Tilapia	4 mm high protein finisher pellets	30	135
Tilapia	4 mm low protein finisher pellets	25	120

Table 1: Specific protein level, feed size and cost of fish feed sold by Unga LTD Company (Data source: Unga LTD).

It is prudent to note that both fry and fingerling stages require crude protein levels of > 40% and > 30% respectively, for muscle tissue formation which may have an important impact on later growth and maturation. Therefore, the fish feeds should be formulated in such a way that they provide balanced nutrition, their protein content is sufficient to support growth and muscle development, so that the fish can attain the consumer demand driven sizes during the production cycle, and the required fatty acids and available amino acids in line with the requirements for the export market.

Use of insects in aquaculture and fish feeds

Aquaculture has become an increasingly important industry as global demand for seafood continues to rise. However, the availability and cost of traditional fish feed ingredients such as fish meal and fish oil are becoming more limited and expensive. This has led to the exploration of alternative protein sources, including insects. Insects have long been used as a natural food source for fish and are a promising option for aquaculture due to their high protein content, balanced amino acid profile, and high digestibility [16]. Black soldier fly larvae (*Hermetia illucens*) are one of the most commonly used insects in aquaculture. They can be raised on a variety of organic waste products such as food waste and manure, making them a sustainable and environmentally friendly option [17]. Black soldier fly larvae are high in protein, with a protein content of up to 60%, and they also have a balanced amino acid profile. In addition to protein, black soldier fly larvae are also high in fat, making them a good source of energy for fish [18].

Several studies have examined the use of black soldier fly larvae in fish diets. One study conducted in Nigeria evaluated the replacement of fish meal with black soldier fly larvae meal in the diet of catfish (*Clarias gariepinus*). The results showed that the use of black soldier fly larvae meal resulted in higher growth rates and improved feed conversion ratios compared to a diet containing fish meal [19]. Another study conducted in China found that replacing fish meal with black soldier fly larvae meal in the diet of rainbow trout (*Oncorhynchus mykiss*) resulted in similar growth rates and feed conversion ratios. In place of fishmeal in animal feed, the Black Soldier Fly (BSF) (*Hermetia illucens*) has been found as a suitable substitute [20]. Fish waste that isn't used for human food is converted into fishmeal, a high-protein feed ingredient. Due to its high protein content and favorable amino acid profile, fishmeal is frequently used in animal feeds, but due to the negative effects of fishing on the marine ecology, questions have been raised concerning the sustainability of fishmeal production [21]. Contrarily, the black soldier fly larvae can be raised on a variety of organic waste products, including vegetable scraps, food scraps, and manure, potentially reducing the environmental impact of the manufacture of animal feed [22].

The high protein content of black soldier fly larvae (Table 2), which is comparable to fishmeal, is one of the main benefits of utilizing them as animal feed. The larvae are nutritionally equivalent to fishmeal because they have an excellent balance of all the important amino acids. The larvae also contain a lot of fat, which makes them an excellent source of energy for animals. Utilizing black soldier fly larvae also has the benefit of producing high-quality protein from organic waste. They are therefore a desirable solution for supporting circular economy principles and waste reduction [23]. Animal feed manufacturers can lessen their dependency on fishmeal and other conventional proteins by using organic waste as a feedstock for black soldier fly larvae. The use of black soldier fly larvae in animal feed is subject to several restrictions, nevertheless. One potential problem is the variation in the nutritional value of the larvae, which can be impacted by elements like the feedstock utilized, the conditions of rearing, and the stage of the larvae. This means that careful observation and quality control are necessary to make sure that the larvae satisfy the dietary needs of the intended animal species [24]. Costs associated with mass-producing black soldier fly larvae are still another possible barrier. The expense of building up and running a commercial-scale plant may be too high for some animal feed providers, even though the larvae can be raised on organic waste materials. Additionally, there can be legal restrictions on utilizing black soldier fly larvae in animal feed, especially in areas where they are not typically eaten [25].

Constituents	Black soldier fly larvae	Housefly maggot meal	Mealworm	Locust meal	House cricket	Mormon cricket	Silkworm pupae meal	Silkworm pupae meal (defatted)	Fishmeal	Soymeal
					DM, %					
Crude protein	42.1 (56.9)*	50.4 (62.1)	52.8 (82.6)	57.3 (62.6)	63.3 (76.5)	59.8 (69.0)	60.7 (81.7)	75.6	70.6	51.8
Lipids	26.0	18.9	36.1	8.5	17.3	13.3	25.7	4.7	9.9	2.0
Calcium	7.56	0.47	0.27	0.13	1.01	0.20	0.38	0.40	4.34	0.39
Phosphorus	0.90	1.60	0.78	0.11	0.79	1.04	0.60	0.87	2.79	0.69
Ca:P ratio	8.4	0.29	0.35	1.18	1.28	0.19	0.63	0.46	1.56	0.57

*Values in parentheses are calculated values of the defatted meals.

Table 2: Main chemical constituents in insect meals vis-à-vis fishmeal and soymeal (adapted from [16]).

Mealworms (*Tenebrio molitor*) are another commonly used insect in aquaculture. Mealworms can be raised on a variety of substrates such as cereal by-products, making them a potential low-cost alternative to traditional fish feeds. Mealworms are high in protein, with a protein content of up to 50%, and they also have a good amino acid profile [26]. One study conducted in Germany evaluated the replacement of fish meal with mealworm meal in the diet of rainbow trout. The results showed that the use of mealworm meal resulted in similar growth rates and feed conversion ratios compared to a diet containing fish meal (Table 3) [16].

Amino acids	Black soldier fly larvae	Housefly maggot meal	Mealworm	Locust meal	House cricket	Mormon cricket	Silkworm pupae meal	Silkworm pupae meal (defatted)	Fishmeal	Soymeal	FAO Reference protein[1]
Essential											
Methionine	2.1	2.2	1.5	2.3	1.4	1.4	3.5	3.0	2.7	1.32	2.50[2]
Cystine	0.1	0.7	0.8	1.1	0.8	0.1	1.0	0.8	0.8	1.38	
Valine	8.2	4.0	6.0	4.0	5.1	6.0	5.5	4.9	4.9	4.50	3.50
Isoleucine	5.1	3.2	4.6	4.0	4.4	4.8	5.1	3.9	4.2	4.16	2.80
Leucine	7.9	5.4	8.6	5.8	9.8	8.0	7.5	5.8	7.2	7.58	6.60
Phenylalanine	5.2	4.6	4.0	3.4	3.0	2.5	5.2	4.4	3.9	5.16	6.30[3]
Tyrosine	6.9	4.7	7.4	3.3	5.2	5.2	5.9	5.5	3.1	3.35	
Histidine	3.0	2.4	3.4	3.0	2.3	3.0	2.6	2.6	2.4	3.06	1.90
Lysine	6.6	6.1	5.4	4.7	5.4	5.9	7.0	6.1	7.5	6.18	5.80
Threonine	3.7	3.5	4.0	3.5	3.6	4.2	5.1	4.8	4.1	3.78	3.40
Tryptophan	0.5	1.5	0.6	0.8	0.6	0.6	0.9	1.4	1.0	1.36	1.10
Non-essential											
Serine	3.1	3.6	7.0	5.0	4.6	4.9	5.0	4.5	3.9	5.18	-
Arginine	5.6	4.6	4.8	5.6	6.1	5.3	5.6	5.1	6.2	7.64	-
Glutamic acid	10.9	11.7	11.3	15.4	10.4	11.7	13.9	8.3	12.6	19.92	-
Aspartic acid	11.0	7.5	7.5	9.4	7.7	8.8	10.4	7.8	9.1	14.14	-
Proline	6.6	3.3	6.8	2.9	5.6	6.2	5.2	-	4.2	5.99	-
Glycine	5.7	4.2	4.9	4.8	5.2	5.9	4.8	3.7	6.4	4.52	-
Alanine	7.7	5.8	7.3	4.6	8.8	9.5	5.8	4.4	6.3	4.54	-

Table 3: Amino acid composition (g/16 g nitrogen) of insect meals versus FAO reference dietary protein requirement values, soybean meal and fish meal (adapted from [16]).

Crickets (*Acheta domesticus*) have also been explored as a potential protein source in aquaculture. Crickets are high in protein, with a protein content of up to 70%, and they also have a good amino acid profile. One study conducted in China evaluated the replacement of fish meal with cricket meal in the diet of Nile tilapia (*Oreochromis niloticus*). The results showed that the use of cricket meal resulted in similar growth rates and feed conversion ratios compared to a diet containing fish meal [27]. Silkworms (*Bombyx mori*) have also been explored as a potential protein source in aquaculture. Silkworms are high in protein, with a protein content of up to 60%, and they also have a good amino acid profile. One study conducted in Japan evaluated the replacement of fish meal with silkworm pupa meal in the diet of yellowtail (*Seriola quinqueradiata*). The results showed that the use of silkworm pupa meal resulted in similar growth rates and feed conversion ratios compared to a diet containing fish meal [28]. The possibilities for employing black soldier fly larvae as a replacement for fishmeal in animal feed are encouraging. The larvae provide a sustainable and environmentally friendly alternative to traditional protein sources, while also helping to reduce organic waste. However, several issues must be addressed, such as guaranteeing consistent nutritional quality and addressing production costs. With more research and development, black soldier fly larvae could play a major part in the future of animal feed production [29].

Conclusion and Recommendations

Conclusion

The current fish feed status in Kenya presents significant challenges to the sustainable growth and development of the aquaculture sector. Limited availability and quality of fish feed ingredients, high costs, and inconsistent feed quality are hindering the efficiency and profitability of fish farming in the country. However, the development of new feeding technologies holds immense promise in addressing these challenges and unlocking the full potential of aquaculture in Kenya. Efforts to optimize locally available feed ingredients, improve feed processing techniques, and explore innovative feeding methods can lead to the development of cost-effective, nutritionally balanced, and high-quality fish feed. This can enhance fish growth, productivity, and profitability, while minimizing environmental impacts. Collaborative efforts among stakeholders, including government, research institutions, feed manufacturers, and farmers, are crucial in driving the development, adoption, and implementation of these new feeding technologies. Additionally, policy support, capacity building, sustainable practices, and improved market access are essential to create an enabling environment for the growth of aquaculture in Kenya. By implementing these measures, Kenya can address the current fish feed status challenges and promote sustainable aquaculture growth and development, leading to increased fish production, improved food security, economic prosperity, and environmental sustainability. Overall, the development of new feeding technologies for aquaculture in Kenya offers promising solutions to overcome the existing limitations in fish feed availability, quality, and cost. With the right support, investment, and collaboration, the aquaculture sector in Kenya can thrive and contribute to the nation's socioeconomic development while ensuring environmental sustainability.

Recommendations

1. Research and Development: Continued research and development efforts are needed to identify and optimize locally available feed ingredients, develop cost-effective and nutritionally balanced feed formulations, and improve feed processing techniques to enhance feed quality and stability in Kenya's aquaculture sector.

2. Collaboration and Partnerships: Collaboration among government, research institutions, feed manufacturers, and farmers is crucial to drive the development and adoption of new feeding technologies. Public-private partnerships can help facilitate knowledge transfer, technology adoption, and investment in the aquaculture sector.

3. Capacity Building: Building the capacity of farmers, feed manufacturers, and other stakeholders through training programs and workshops on best practices in fish nutrition, feed management, and feeding technologies can improve the understanding and adoption of modern feeding techniques.

4. Policy Support: Government policies and regulations should incentivize the development and use of new feeding technologies, such as tax incentives, subsidies, and grants, to promote innovation, investment, and sustainable growth in the aquaculture sector.

5. Sustainable Practices: Promoting sustainable feed production practices, including responsible sourcing of feed ingredients, minimizing waste, and reducing environmental impacts, can enhance the sustainability of aquaculture growth and development in Kenya.

6. Market Access: Improved market access for aquaculture products can enhance the economic viability of fish farming and provide incentives for farmers to invest in modern feeding technologies. Market linkages, value addition, and market information systems can facilitate better market access for aquaculture products.

By implementing these recommendations, Kenya can overcome the challenges in the current fish feed status and harness the potential of new feeding technologies to drive aquaculture growth and development, contributing to food security, economic prosperity, and environmental sustainability.

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