Journal of Geographical Research & Report
Vol. 2, Iss. 1, Pg. 55-70| July 2026 | DOI: 10.64712/jgeorr.v2i1.869

A review of challenges affecting feed availability and use in Ghana's aquaculture sector

Victor Owusu[1], Dimbie Iddrisu[1], Sandra Amponsah[1] & Jemimah Etornam Kassah[2]

[1]Department of Geography Education, University of Education, Winneba, Ghana
[2]Department of Biology Education, University of Education, Winneba, Ghana

Email: vowusu@uew.edu.gh

Abstract

It is important to study feeding practices and factors accounting for the high cost of feed among aquaculture practitioners to come up with policy interventions to improve the output of fish farmers. This literature review aims to analyze and assess the factors that contribute to the high cost of feeding in the aquaculture industry in Ghana and suggest a possible alternative way of getting quality and nutritional feed. Specifically, we reviewed selected published articles and reports that focus on the local feeding practices among aquaculture practitioners in Ghana and critically examined the factors accounting for the high cost of feeding in fish farming. The selected articles were read and reviewed extensively to fully immerse ourselves in the findings to obtain a sense of the whole. We then highlighted key findings from the articles that seem to answer our study objectives. Our review suggests that the type of fish feed being used is determined by the cost of feed, its accessibility, and availability as the sector still heavily relies on these prime ingredients in specific formulations for a range of aquatic feeds for the fish. Additionally, feed formulation acts as an important coping strategy in the context of small-scale farmers with limited financial resources in areas where commercial feeds are not available or accessible. Experimental studies are highly recommended and will be crucial to identifying the best and most cost-effective combination of locally available raw materials and optimal combinations of own-formulated feeds and commercial feeds which will minimize the high cost of the feeding challenges.

Keywords: Ghana, Aquaculture, feed availability, food security, and sustainability.

To cite this article: Owusu et al. (2026). A review of challenges affecting feed availability and use in Ghana's aquaculture sector. *Journal of Geographical Research & Report*, 2 (1), 55-70. 10.64712/jgeorr.v2i1.869

1 Introduction

Globally, aquaculture is the world's fastest-growing food production sector for the past two decades (FAO, 2022). From a yearly production value of 21.8 million tonnes in the 1990s; worldwide annual aquaculture production increased to over a million tonnes in the year 2020 (FAO, 2020). Aquaculture is defined as the farming of aquatic organisms by controlling at least one stage of the life cycle. The life cycle controls are conceptually divided into larval, nursing, grow-out, and broodstock management stages (Yakupitiyage., 2013). Aquaculture adoption has various positive impacts at different levels from farm and household to community and national levels: by providing vital economic, and livelihood opportunities, and contributing to food and nutrition security (Filipski & Belton., 2018; Bogard et al., 2015). Across the Global South, the fisheries sub-sector of agriculture remains a major source of livelihood in many coastal communities. An estimated 38.98 million people are engaged in capture fisheries with another 20.53 million people employed in aquaculture (FAO, 2020). Fish provides more than 3 billion people with a 20% intake of animal proteins, reaching as high as 50% or more in countries such as Bangladesh, Cambodia, the Gambia, Ghana, Indonesia, Sierra Leone, Sri Lanka, and several small islands developing States in the world (FAO, 2020; Hasselberg et al., 2020; Espe., 2006). This notwithstanding, over 800 million people worldwide face hunger (FAO, 2019). Tacon & Metian (2013), estimated that more than two billion people in the world suffer from micronutrient deficiencies.

Fish is the most preferred and widely consumed animal protein in Ghana, with annual per capita consumption estimated at 26 kg compared with the global average of 20 kg (Asiedu et al., 2017). The Fisheries and Aquaculture Sector play a key role in the socioe-conomic development of Ghana by contributing significantly to Gross Domestic Product (GDP), jobs, wealth creation, and food and nutrition security. This sector provides direct and indirect job opportunities for an estimated 10% of the population along with the fisheries and aquaculture value chain (Fisheries Commission, 2022; Espe., 2007) Marine fisheries in sub-Saharan Africa have suffered from rapidly declining fish landings, resulting in decreased income, loss of livelihoods, and severe economic hardships (World Bank, 2016; Yang et al., 2019). This poses a great threat to local food and nutrition security. Aquaculture has been promoted as the viable option to provide fish to complement the reduced volume of landed catch from the sea (Yang et al., 2019; Quagrainie., 2015). Aquaculture production in Ghana recorded 89,375.48mt in 2021 as compared to 64,004 in 2020; representing a 40% increase (Fisheries Commission, 2022). This increase in production was reportedly due to vaccination exercises, new entrants, and an increase in the provision of extension services by the Fisheries Commission of Ghana as well as private and donor organizations (Said., 2019). The Eastern, Greater Accra, and Volta are the three dominant regions that have consistently contributed significantly to total aquaculture production (90%) in Ghana (Amenyogbe et al., 2018).

However, the aquaculture sector faces several challenges that hinder its growth and contribution toward providing fish (Asiedu et al., 2017; Shi., 2016). One major challenge is the high cost of feed production (Ragasa et al., 2022a). Asiedu et al., (2017) opined that limited availability and high cost of feed are the major bottlenecks to improving the production and profitability of aquaculture in Ghana. This means that there is a strong linkage between the costs of fish feed and fish production. The cost of feed is high in Ghana, making it difficult for small-scale farmers to enter the market. This results in a lack of investment in the sector, which hinders its growth and development.

The majority of sub-Saharan African countries including Ghana continue to report low aquaculture production despite great potential resources for fish farming development due to high cost of fish feed (Gabriel et al., 2007). A study conducted by Hasimuna et al., (2019) on the challenges faced by aquaculture production and fish feed manufacturing companies in Zambia found that there is a lack of quality fish seed and feed as well as readily available raw materials for feed production. Amenyogbe et al., (2018), conducted a related study which revealed that limited knowledge of modern aquaculture techniques, inadequate supplies of improved seed, and lack of continuing aquaculture policy direction are hindering the sector. The high cost of fish feed and feeding makes the small-scale fish farmers despondent, thereby hindering the production and supply of fish in the country. The high cost of commercial fish feed is the most significant challenge to the development of aquaculture in Ghana. The cost of fish feed accounts for 60-70% of the total production cost in Ghana (Agyenim., 2018).

It is therefore important to study feeding practices and factors accounting for the high cost of feed among aquaculture practitioners to come out with policy interventions to improve the output of fish farmers. Therefore, this review aims to analyze and assess the factors that contribute to the high cost of feeding in the aquaculture industry and suggest a possible alternative way of getting quality and nutritional feed. Specifically, we reviewed selected published papers that center on the feeding practices among aquaculture practitioners in Ghana and critically examine the factors accounting for the high cost of feeding in inland fish farming in Ghana. This review will help to establish the fish feeding practices among aquaculture practitioners and highlights the reasons that are accounting for the high cost of fish feed. Sustainable aquaculture development is critical for the achievement of global food and nutritional security. The significance of sustainable fisheries development and production is highlighted in the United Nations Sustainable Development Goals (SDGs), where goal two (Zero Hunger) is designed to address ending hunger, achieving food security and improving nutrition, and ending all forms of malnutrition.

This paper may be useful for potential entrepreneurs or start-ups who intend to go into such aquaculture to enable them to prepare adequately for feed acquisition. It may also provide insightful information to relevant stakeholders and policy practitioners who may have an interest in aquaculture growth to assist farmers so that Ghana can meet its fish production targets (Hasselberg et al., 2020)

2 Methodology

2.1 Literature search strategy

The selection of literature for this review was guided by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). Secondary data were collected from published documents including articles, reports, online newspaper articles, and internet sources. These documents were selected using keywords and terms associated with aquaculture, feed types, feed safety, nutritional and food security and feeding practices in aquaculture through internet searches. The documents were selected based on their contribution to the ongoing discourse on feeding practices among aquaculture practitioners and sustainability. Articles published after year 2000 and presenting data from Ghana were included to capture the new emerging knowledge production concerning the topic under consideration.

This review was limited to the feeding practices and challenges among small-scale inland aquaculture practitioners in Ghana. To avoid missing relevant literature, reference lists of

selected articles were perused for relevant materials on aquaculture in Ghana. Literature that meets the pre-defined and exclusion criteria and were coherent with the subject of the investigation were included in the review (Hasselberg et al., 2020; Stake., 1995). The initial search criteria identified a total of 954 materials. However, applying the screening and eligibility processes, 51 articles were identified for full-text retrieval, out of which 41 were identified as meeting the final inclusion criteria as shown in Figure 1. Table 1 provides an overview of the number of research articles reviewed and their corresponding themes.

Table 1. Number of reviewed articles with their corresponding themes

Themes	Number of articles
Feeding practices and challenges	23
Feed production	15
Feed cost	3

We read through the selected articles severally to fully immerse ourselves in the findings to obtain a sense of the whole. We then highlighted key findings from the articles that seem to answer our study objectives. These were then developed into three themes namely; feeding practices and challenges, feed production and factors accounting for high feed cost. We drew on reports from the Food and Agriculture Organization (FAO), World Bank and Ministry of Fisheries and Aquaculture Development (MOFAD), Ghana to provide statistics on fisheries and global aquaculture production since this data were not readily available in the reviewed articles.

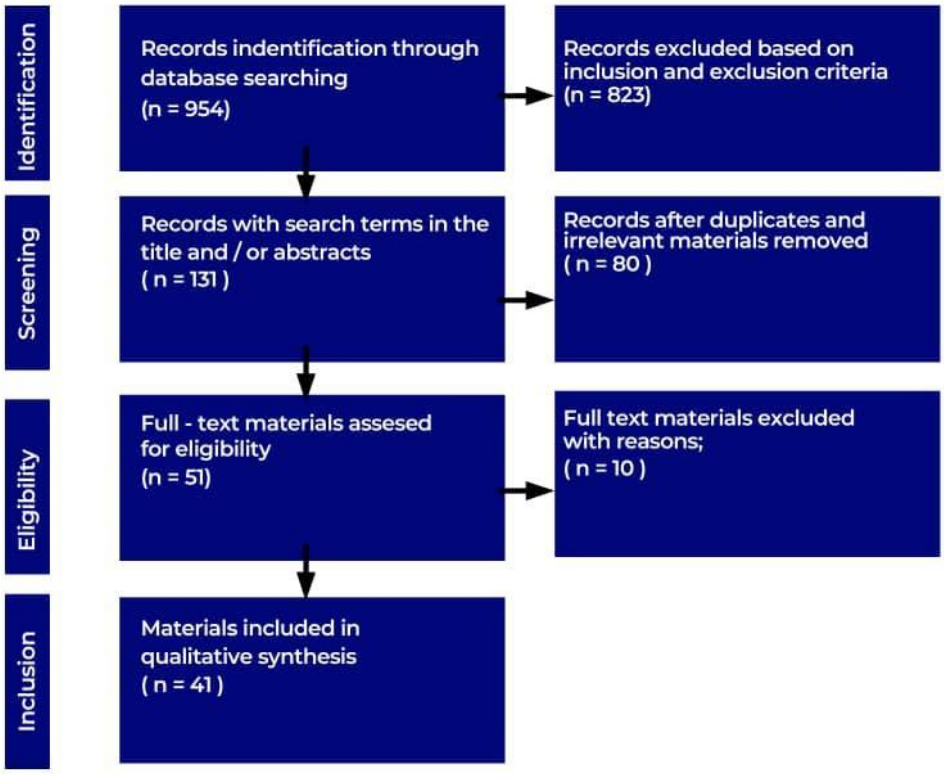

Figure 1. PRISMA flow diagram of the material selection process (adapted from Moher et al., 2009)

3 Brief Overview of Aquaculture in Ghana

The Ministry of Fisheries and Aquaculture Development (MOFAD) is mandated to ensure the availability and affordability of fish and other fishery products in Ghana. Through scientific research, MOFAD ensures the promotion of sustainable and thriving fisheries enterprises as well as providing extension and other support services to fishers and fish farmers. The fisheries resources of Ghana comprise; marine, inland, and aquaculture production. The marine sector is dominant, accounting for 61.3% of fish production, followed by the inland sector at 21.3% and aquaculture accounting for 17.4% (Fisheries Commission, 2024a).

The aquaculture sector in Ghana is regulated by several state institutions, to ensure that products are safe and environmentally sustainable. The Food and Drugs Authority (FDA) and the Ghana Standards Authority (GSA) are mandated by law to frequently monitor the feed quality. The Fisheries Commission is also responsible for ensuring the hatchery centers are certified. The FDA is to ensure that those who trade in fish and related products are of safe standards for public consumption.

Some of the key policy frameworks that regulate the sector includes; the fisheries regulation (L. I.1968) of 2010 which gave effect to Act, 2002 (ACT, 625) and amended Fisheries Regulation 2015 (L.I 2217). The Ghana National Aquaculture Development Plan (GNADP: 2012-2016) was developed under the support of Food and Agriculture Organization to guide investments in aquaculture and its related value chain activities. The plan had however, not been fully implemented due to funding issues till it expired in 2016. Besides, the plan had also been overtaken by current global trends in aquaculture since its adoption in 2012. Based on lessons learnt from the 2012-2016 plan, The Ghana National Aquaculture Development Plan (2024-2028) has been published and activities in the framework being operationalized. Among other things, the plan seeks to increase private sector led contributions to Ghana's aquaculture sector, and increase aquaculture production to 25% of total national fish production (Fisheries Commission, 2024b). In 2018, the government introduced the "Aquaculture for Food and Jobs" initiative. The objective of this policy framework was to increase domestic fish production to offset the importation of fish and fishery products, with a focus on Fish Hatchery Operations and Aquaculture Training and Extension. The mandate was to train youth groups to undertake and increase aquaculture production. Ghana's fisheries policies in recent years have emphasized on boosting local fish production to reduce imports of fish and fish-related products, as well as to make the fishing sector a viable one contributing to sustainable economic development and national growth.

Figure 2 shows the main aquaculture production areas in Ghana. Aquaculture production is predominant in the coastal regions of Ghana, such as the Volta and Greater Accra. Although the Eastern region is inland; it has the highest concentration of fish farms and production volumes due to its proximity to the river Volta, on which high-density aquaculture cages are situated (Fisheries Commission., 2022). Other inland regions with substantial production are the Ashanti, Upper West, Bono and Ahafo regions. There is potential for both freshwater, brackish water and marine aquaculture. In addition, these regions have good access to fish landing beaches and sites, markets, and harbors, making harvested fish accessible to the general public. These areas are also characterized by various aquatic resources and climatic conditions suitable for different fish species, making them ideal locations for aquaculture development. However, the availability of quality feed ingredients is limited, leading to a high dependence on imported feed products. Addressing these challenges will require a concerted effort from all stakeholders to develop and promote the industry. Inland fish farming is also

practised in the Ashanti, Bono and Ahafo regions, where ponds and reservoirs are used to cultivate fish species such as Nile tilapia (*Oreochromis niloticus*), African sharptooth catfish/ mudfish (*Clarias gariepinus*), and African arowana/bony tongue (Heterotis niloticus). Tilapia is the major species cultured in the country (63.65%), with African sharptooth catfishes (36.31%), bony tongue and cultured inland, in ponds, tanks and tarpaulin receptacles (Fisheries Commission, 2024a).

Figure 2 provides an overview of aquaculture production trends in Ghana from 2000-2023. Total aquaculture production from ponds, tanks, cages, dams/dugout and reservoirs was estimated at 89,375.48mt for 2021. Compared to 2020 production figures of 64,004.8mt, a 39.6% increase was achieved (Figure 2). Out of the total production of 89,375mt recorded in 2021, 68,714.53mt (77%) and 20,660.95mt (23%) represents the quantities for Nile tilapia and African catfish respectively (Fisheries Commission, 2022). In 2022, total aquaculture production was 132,652.40mt but reduced slightly to 116,107.83mt in 2023 due to flooding during the Akosombo Dam spillage of 2023 (Fisheries Commission, 2024a). In all of these; cage aquaculture forms the bulk of production of about 85% (Fisheries Commission, 2024a).

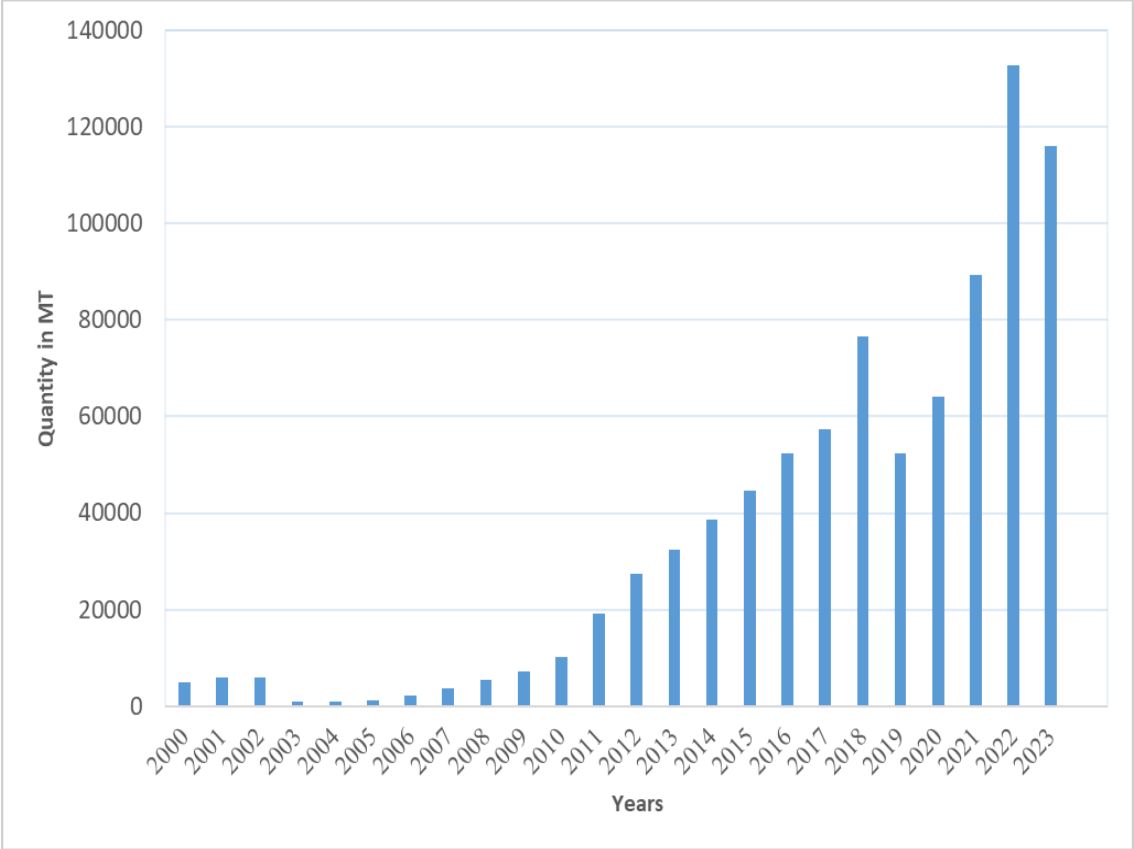

Figure 2. Aquaculture production (metric tons) Ghana (2000-2023).
Source: (World Bank, 2023; Fisheries Commission, 2024a).

Figure 3. Map of Ghana showing regions with highest contribution to aquaculture production. Source (Authors Own Construct, 2025).

4 Feeding Practices and Challenges Among Aquaculture Practitioners in Ghana

Aquaculture is an emerging sector in Ghana, and various feeding practices are employed by farmers to improve fish growth and production. This sector is essential for Ghana's economy and plays a critical role in achieving food security and poverty reduction. Aquaculture can help create livelihood opportunities due to its income generation from selling fish, provision of services such as feed, fingerlings, supplies, and logistics, and increasing income and food security of poor fish farming households (Kassam & Dorward, 2017).

Feeding and nutrition play an essential role in the sustained development of aquaculture production. Nutrition is the heart of aquaculture and feeding the fish with nutritionally enriched feeds may dramatically increase the overall production (Prabu et al., 2017). For instance, Kuhn (2017) delved into understanding fish nutrition, feed, and feeding and found that feeding fish is labor-intensive and very expensive. The findings also revealed that feeding

frequency is dependent on labour and feed availability, farm size, production system, and the fish species and sizes grown. Anani et al., (2017). also investigated the production and use of farm-made fish feed by small-scale pond fish farmers in Ghana. They found out that, the high price of fish meal in Ghana has created a situation that calls for comprehensive evaluation and improved use of other protein sources, especially domestic available plant by-products in fish feed formulations at the farm and commercial levels to increase fish production. The feeds produced and used widely in Ghana are categorized into conventional and non-conventional feedstuff or sources; the categorization is based on the availability and acceptability of the feedstuff involved.

4.1 Conventional feed sources

These are the feedstuff that is regularly used in the formulation of fish feed. These are commercial feeds which are formulated fish feeds that are readily available for purchase from feed mills. These feeds contain the necessary nutrients needed for fish growth and are convenient for farmers to use. They are commonly used by small-scale farmers due to their affordability and ease of use. Their usage is mostly standardized and widely acceptable. Many of these are cheap and readily available in large quantities. Examples include wheat bran, groundnut cake, and rice bran. Some are animal based (for example, fish meal, blood meal, shrimp meal), whereas others are plant-based (for example, maize, soya bean meal, cotton seed meal) (Gabriel et al., 2007).

4.2 Non-conventional feed sources

These are locally available feedstuff that is not standardized and can be grouped into three namely; kitchen wastes, animal sources; and plant sources of feed. Some aquaculture practitioners in Ghana use locally available feed ingredients to supplement the diet of their fish. These ingredients include plant-based materials such as cassava, maize, and soybean, as well as animal-based materials such as blood, bone meal, and fishmeal (Ahiah, 2019). Kitchen waste is used on an availability and convenience basis, without any standard. Examples are cassava and yam peels, kitchen remnants like bread, cooked rice, and cooked yam are also used in the culture of fish.

Animal and plant sources of feed, generally known as non-conventional feedstuff are derived from both animal and plant feed sources. Their levels of inclusion in fish feed vary and largely depend on their availability, nutrient level, processing technique, species of fish, and cultural farming pattern prevalent in the locality. The non-conventional feedstuff from animal sources is normally of high-quality comparable to some extent with the conventional types (Frimpong & Adwani, 2015). Examples include tadpole meal, maggots, earthworm meal, black soldierfly larvae and housefly larvae among others. Considerable variation may exist in the micronutrient content of fish depending on the species. Some farmers rely wholly on the natural productivity of ponds to achieve their production and others use agricultural by-products. Artificial feedstuffs are used by small-scale fish farmers in unbalanced proportions to feed tilapia in earthen ponds. Fish growth is slow in this system. Anani et al., (2017) argued that fish farmers who adopt non-convectional feed stuff formulation do not normally comply with appropriate and standardized feeds formulation protocol during farm-made fish production hence farm-made fish feeds produced by such farmers were found to be nutritionally imbalanced.

There are different ingredients for feed formulation and artificial feedstuffs. For instance, cottonseed-protein concentrate is a novel plant ingredient characterized by high protein

content and low free gossypol content and has been effectively used as a fish meal substitute in diets for hybrid grouper as compared with soybean meal and soy protein concentrate (Ahiah., 2019). However, many farmers in Ghana are not knowledgeable in feed management practices, including feeding frequency, quantity, and quality. Overfeeding, underfeeding, or feeding with inappropriate feeds can lead to poor growth rates, disease outbreaks, and high mortality. Ragasa et al (2022a) argued that many aquaculture farmers in Ghana lack adequate technical knowledge in feeding management and this limits the farmers' ability to provide appropriate feed, leading to poor growth rates and health problems in the fish. The challenge is how to find suitable and sustainable ways which ensure physical, social, and economic access to sufficient, safe, and nutritious feed at all times.

In Ghana, however, the feeding practices vary depending on the fish species, location, and farmer preferences (Ahiah., 2019). Here are some commonly used feeding practices in Ghana's aquaculture sector; some aquaculture practitioners in Ghana use locally available feed ingredients in addition to commercial feed to supplement the diet of their fish (Anani et al., 2017). These ingredients include plant-based materials such as cassava, maize, and soybean, as well as animal-based materials such as blood, bone meal, and fishmeal (Ahiah., 2019). Also, there is a feeding frequency and this varies depending on the species of fish and the production system. Some farmers feed their fish once a day, while others feed their's two or three times a day. Another feeding practice among aquaculture practitioners is the feeding rate. The feeding rate is usually expressed as a percentage of the fish's body weight. The amount of feed given to the fish is based on the size and growth rate of the fish and follows strict feeding rations.

The feeding method also varies depending on the production system. In cages and tanks; the feed is often dispensed through automatic feeders or hand-fed, while in ponds, feed is usually broadcast over the surface of the water. Aquaculture in Ghana faces quite a lot of feeding practices and feed challenges that have an impact on the growth, health, and productivity of fish. Similar to the capture fishery sector, where, some fish farmers depend on one type of species, while others target different species in different parts of the year in multi-species pond set-ups (Said & Trouillet, 2020).

5 Factors accounting for the high cost of fish feed in Ghana

Fish feed is one of the major ingredients in aquaculture production. Extruded feeds are more expensive due to the higher manufacturing costs (Kuhn., 2017). There are also areas where commercial feeds or local feed ingredients are not available or accessible to the farmers. In Ghana, feed accounts for 60–80% of tilapia production costs (Ragasa et al., 2022a). The high cost of feed and limited feed access are major issues faced by fish farmers. Many small-scale farmers across all regions continue to struggle to access, buy, and apply the optimal quantity of commercial feeds in their farms despite their contribution to local economic and food security (Asiedu et al., 2017). Pond farming, practiced by a vast majority of small-scale rural farmers, faces major challenges, including low productivity, low-quality seeds, low feed use, and poor aquaculture management practices (Ragasa et al., 2022a). Although some aquaculture practitioners in Ghana use locally available feed ingredients to supplement their fish's diet, the availability of these ingredients are limited. This makes it difficult for farmers to rely solely on local feed ingredients, compelling them to depend on expensive imported feed ingredients.

Aquaculture growth is restricted by several challenges such as high feed costs, limited feed access, and poor feed and management practices, especially among small-scale fish farmers (Ragasa et al. 2022b). Asiedu et al., (2017), found the absence of a reliable market, fish feed, and funds for farmers as the major constraints to fish farmers in Ghana.

Ragasa et al., (2022a) found that small-scale fish farmers complain that commercial feeds absorb at least 60% of their production budget. The authors attributed the apparent unaffordability of commercial feed to competing demands for maize, soya beans, and the sharp devaluations of the local currency. This makes the locally produced commercial feed almost as expensive as imported due to the depreciation of the Ghanaian currency driving prices upwards as fish feed manufacturing companies like Enam Papa and Raanan Fish Feed Company, operate in Ghana but feed remains prohibitively expensive for small-scale farmers (Gabriel et al., 2007). These threaten the livelihood of fish farming households, as well as the food and nutrition security of the general public. This unsustainable rising cost of aquaculture cannot aid aquaculture growth and further development.

The high cost of fish feed is a challenge or barrier to new entry into aquaculture farming. This affects food security; hence the nutrition security among the growing population in the country could be affected. It obstructs the sustainability and production of fish which fish farmers largely attributed to the high cost of fish feed and feeding (Arthur, 2018). The high cost of fish feed is because most of the feed ingredients used in the production of commercial fish feed in Ghana are imported, making it difficult for small-scale farmers to afford. Also, the high cost of transportation, import duties, and taxes increase the cost of feed ingredients, which is passed on to the farmers. Farmers are faced with high prices of quality feed, which affects their profit margins (Baidoo & Adu., 2018).

Another major reason for the high cost of fish feed in Ghana is the high cost of raw materials used in the production of the feed (Ragasa et al., 2022a). This is serving as a disincentive and discouraging to those who want to venture into the aquaculture or to those who are already engaged in the aquaculture as there is limited access to quality and affordable feed ingredients (Frimpong & Adwani, 2015).

Most of the raw materials used in fish feed production, such as fishmeal, soybean meal, and maize, are imported, which makes them expensive due to exchange rate fluctuations and high import tariffs (Efua-Konyim, 2017). Also, Ghana's economy is heavily dependent on imports, and fluctuations in exchange rates can lead to higher costs for imported feed ingredients. The sharp or continuous declines of the national currency continue to drive the prices of feed ingredient upwards. Ghanaian aquaculture is largely dependent on imported feed ingredients, which are subject to price fluctuations and availability (Abban., 2017). The high cost of fish feed in Ghana is due to the inadequate local production of raw materials. Practitioners' heavy reliance on imports makes the cost of fish feed production high (Arthur, 2018).

According to Asiedu et al., (2017), Ghana's local production of fish feed ingredients is not enough to meet the demand for feed production. This coupled with covid-19 pandemic and Russia Ukraine war quadrupled the prices of goods and services, with dire consequences for the fisheries sectors (Bennett et al., 2020).

Moreover, the government is unable to supply and subsidize fertilizers to farmers in recent years and the fish farmers are heavily dependent on some of these farms' produce such as

soya beans, and maize. As a result, many fish farmers fold up due to liquidity constraints, as they do not have funds to buy commercial feed, or cannot access them through credit. As a result, Ghanaian farmers who cannot afford to buy commercial fish feed often rely on locally produced fish feed. However, the quality of locally produced fish feed is often poor due to the lack of appropriate equipment and knowledge of feed formulation. As a result, the locally produced fish feed may not provide the required nutrients for fish growth, leading to slow growth rates and poor fish health (FAO, 2020). There have been interventions with aid from foreign organizations to provide training sessions on fish feed formulations, but these programs have not been able to be replicated nationwide. This led to poor coverage, with people still struggling to make their fish farms viable.

The high cost and demand for maize and soya meal make locally produced commercial feed almost as expensive as imported feedstuff (Asiedu et al., 2017). Hence, many farmers reduce the use of commercial feeds because of limited access to credit. Small-scale farmers in Ghana often lack access to credit, which limits their ability to purchase commercial fish feed and invest in appropriate equipment for the production of locally made fish feed (Baidoo and Adu., 2018). This hinders the growth of the aquaculture industry in the country.

In an attempt to formulate their feeds using cheaper and locally available raw materials to maintain similar levels of feeding intensity and formulating cost-effectiveness, the feed produced tends to be of poor quality as farmers may not be experienced in the calculation of ingredient ratios for a nutritionally balanced product (Ragasa et al., 2022a). This poses a huge challenge as the growth rate of fish tends to be compromised, or the feed is not accepted by the fish. In an attempt to formulate their feed, of which they have inadequate knowledge of fish nutrition, they use inappropriate feed formulations, which can lead to poor fish health and low productivity (Agyenim., 2018).

This limits the availability of alternative feed sources, which can reduce the dependence on imported feeds and increase the profitability of aquaculture farmers. This pushes some fish farmers to shift the use of different plant feed materials which are linked with anti-nutritional factors and associated decrease in the growth of fish and their feed digestibility and utilization (Amonoo & Gyasi., 2018). The majority of fish farms in Ghana are also small-scale, and this makes it difficult for them to enjoy economies of scale in the production and purchase of fish feed. Large-scale fish farms can buy feed in bulk, which reduces the cost per unit, but small-scale farmers cannot do so, and transportation costs for aquaculture feeds can be high, particularly for farmers located in remote areas where road infrastructure is poor (Amenyogbe et al. 2018).

Universal fishmeal production cannot satisfy the fish meal requirement of the aquaculture industry, and fish meal prices climbed with augmentation of the gap between the requirement and supply resulting in elevation of feed cost leading to scarcity of fish-based protein and lipid feedstuffs for use or processing fish feed (FAO, 2020). This demonstrates that the kind of feed farmers give to the fish in captivity is vital and the type of feed given to fish is determined by the cost and availability in the local market. Most fish farmers are struggling to increase fish production, and the high cost of feed is thwarting this effort in the face of ever-increasing prices linked to skyrocketing inflation (Aidoo, Boateng & Baidoo., 2019). Furthermore, the high cost of fish feed is partly responsible for the high cost of fish and their products in the country. There is, however, high demand for fish products which also leads to price hikes in the face of less supply. If this trend continues, millions of Ghanaians

who depend on fish and its products will suffer livelihoods and nutritional repercussions in the future as they will resort to the more expensive imported feed.

6 Implications of the high cost of feed on food availability and security

The high cost of feed and its associated challenges are threatening the fish supply and sustainability of fish stocks resulting in the declining incomes of already vulnerable small-scale fish farmers. The high cost of fish feed is partly responsible for the high cost of fish and their products as well as low fish production in aquaculture. However, the high cost of feeding remains a significant challenge that needs to be addressed to unlock the full potential of the industry. Therefore, a potential solution is for farmers to produce their feeds using cheaper and locally available ingredients to increase fish production in the country but which is balanced in protein, by the use of vegetable meals and oils (e.g., soy, corn, canola, palm, sunflower oils) in substitute of fishmeal and fish oil (Ragasa et al., 2022a). Significant amounts of fishmeal and fish oil have been successfully replaced with alternative ingredients derived mainly from commodity crops.

While there have been efforts by the Fisheries Commission of the Ministry of Fisheries and Aquaculture Development in conjunction with other state institutions and donor agencies such as the Water Research Institute to train farmers on feed formulations there is a lot more to be done (Ragasa et al., 2022a; Ahiah., 2019). There is a need to organize farmers into groups to facilitate access to equipment such as mills, extruders, dryers, and pelletizers to enable efficient presentation and packaging of formulated feed (Tetteh., 2019). After such training farmers are not able to maximise production due to the absence of such processing equipment.

Poultry by-product meals have also been widely used as a fish meal alternative in fish feed due to their high contents of digestible protein and taurine, good amino acid profile and phosphorus availability, and good palatability (Amonoo & Gyasi., 2018; Shi., 2016). Additionally, the slaughtered blood of animals from the abattoirs can be used as protein ingredients substitute for soya beans, fish meal, and other protein-like products which are very expensive in the country in the preparation of fish feed (Said., 2019; Elangoyan., 2000). This can reduce the high cost of fish feed and also improve aquaculture production to meet the country's demand and supply of fish consumption (Eikeset., 2018). A lot of pragmatic efforts are needed to deliver key concepts and practices to farmers as well as improve their learning and knowledge retention (Blasco et al., 2005; Wang et.al., 2021).

7 Conclusion

From the literature, it is evident that there are two fish feed source types namely; conventional and non-conventional feed stuffs that are used for feed formulation. In Ghana, aquaculture practitioners' practices vary in feeding depending on the fish species, location, and farmer preferences. One major challenge is the high cost of commercial fish feed, and small-scale farmers often cannot afford it. As a result, they resort to using low-cost, low-nutrient content feed sources such as rice bran and maize, which may not meet the nutritional requirements of the fish and may result in stunted growth and low survival rates. Furthermore, there is a lack of availability of raw materials for fish feed production in Ghana, most of the raw materials are imported, making it very expensive and also difficult for small-scale farmers to access them. This dependency increases the cost of production and reduces the competitiveness of Ghana's aquaculture industry. The high cost of feeding is compounded by the inadequate infrastructure and support services required for the production and

distribution of feed. This results in limited access to feed and high transportation costs, further driving up the cost of feeding in the industry. Another challenge is the lack of knowledge and skills in feed formulation. Small-scale farmers often lack the technical expertise and knowledge to formulate their feeds, which limits their ability to optimize feeding practices and achieve maximum productivity. The type of fish feed being used is determined by the cost of feed, its accessibility, and availability as the sector still heavily relies on these prime ingredients in specific formulations for a range of aquatic feeds for the fish. Despite this, feeding practices are not given the needed attention and the state lacks a focus on the role of fish and fish farming but such sub-sector is supporting numerous livelihoods and also contributing to fish as food, and its nutritional importance. This study also argued that fish farming is important for fish and for food security and nutrition security and hence it needs to be given greater priority to address the feeding challenges and practices and inform policy, at all the stages of the fish value chain. Policymakers should make sure that fish feed is made available and accessible in terms of distance and economical to the small-scale holder fish practitioners. This will aid sustainable harvests of fish for the country to realize the potential of these species to reduce micronutrient deficiencies and unemployment. Feed formulation can act as an important coping strategy in the context of small-scale farmers with limited financial resources in areas where commercial feeds are not available or accessible**.** Local feed formulation can serve as a pathway through which the feed formulation training can achieve impacts and increase own-feed formulation to increase productivity and profitability of the fish farming sector. Practical and interactive workshops should be organized for farmers, having experienced and seasoned fish farmers as speakers or resource persons during trainings. In terms of future research, experimental studies are highly recommended and will be crucial to identify the best and most cost-effective combination of locally available raw materials and optimal combinations of own-formulated feeds and commercial feeds which will minimize the high cost of the feeding challenges.

8 Ethics Approval and consent

The study does not involve human participants therefore no ethical approval was needed

9 Competing interest

No competing interest

10 Funding

No funding was received for this study.

References

Agyenim, B., & S. (2018). Fish feed and feeding practices in Ghana. *Aquaculture in the Anthropocene*, 163–185.

Abban, E. K., et al. (2017). Aquaculture in Ghana: status and opportunities. *Reviews in Aquaculture*, 9(3), 227-243.

Aidoo, J. B., Boateng, O., & Baidoo, S. K. (2019). Fish Feed Production in Ghana: Opportunities and Challenges. *International Journal of Agriculture and Biology*, 22(3), 659-667.

Arthur, P. F. (2018). Aquaculture in Ghana: status, prospects, and challenges*. African Journal of Aquatic Science*

Asiedu, B., Nunoo, F. K. E., & Iddrisu, S. (2017). Prospects and sustainability of aquaculture development in Ghana, West Africa. *Cogent Food & Agriculture*, *3*(1), 1349531.

Ahiah, L. A. (2019). *On-farm fish formulation, and feeding*. Training manual. Accra, Ghana: Fisheries Commission

Amenyogbe, E., Chen, G., Wang, Z., Lin, M., Lu, X., Atujona, D., & Abarike, E. D. (2018). A review of Ghanas aquaculture industry. *Journal of Aquaculture Research & Development*, *9*(08).

Amonoo, N. A., & Gyasi, E. A. (2018). Evaluation of Fish Feed Production and Consumption in Ghana. *Journal of Agricultural Science*, 10(6), 199.

Anani, F. A., Nunoo, F. K. E., Steiner-Asiedu, M., Agbo, N. W., & Nortey, T. N. N. (2017). Production and use of farm-made fish feeds by small-scale pond fish farmers in Ghana. *Journal of Energy and Natural Resource Management*, *4*(1).

Baidoo, S., &Adu, S. (2018). Feeding practices and challenges of catfish farmers in the Kumasi metropolis of Ghana. *Journal of Fisheries and Aquatic Science.*

Blasco M., Fondevila M., & Guada J.A. (2005). Inclusion of wheat gluten as a protein source in diets for weaned pigs. *Anim. Res*, 297-306.

Bogard, J.R., Hother, A.-L., Saha, M., Bose, S., Kabir, H., Marks, G.C., Thilsted, S.H. (2015). The inclusion of small indigenous fish improves nutritional quality during the first 1000 days, *Food Nutrition Bulletin 36*(3), 276-89.

Bennett, N. J., Finkbeiner, E. M., Ban, N. C., Belhabib, D., Jupiter, S. D., Kittinger, J. N., Mangubhai, S., Scholtens, J., Gill, D., & Christie, P. (2020). The COVID-19 Pandemic, Small-Scale Fisheries and Coastal Fishing Communities. *Coastal Management*, *48*(4), 336–347. https://doi.org/10.1080/08920753.2020.1766937

Efua-Konyim O.K. E. (2017). Feeding Ghana's aquacultural growth. Fs Media. *(https://thefishsite.com/articles/feeding-ghanas-aquacultural-growth*

Elangovan A., & Shim K. F., (2000). The influence of replacing fish meal partially in the diet with soybean meal on growth and body composition of juvenile tin foil barb (*Barbodes altus*). *Aquaculture,* 189(1-2), 133-144.

Eikeset, A.M., A.B. Mazzarella, B. Davíðsdóttir, D.H. Klinger, S.A. Levin, E. Rovenskaya, & Stenseth, N.C. (2018). What is blue growth? The semantics of "Sustainable Development" of marine environments. *Marine Policy* 87: 177–179.

Espe.,M., Lemme A., Petri A., & El-Mowafi A. (2006). Can Atlantic salmon (*Salmo salar*) grow on diets devoid of the fish meal? *Aquaculture*, (255) 1-4, 255-262.

Espe M., Lemme A., Petri A., & El-Mowafi A. (2007). Assessment of lysine requirement for maximal protein accretion in Atlantic salmon using plant protein diets. *Aquaculture*, 263(1-4), 168-178.

Filipski, M., & Belton, B. (2018). Give a Man a Fishpond: Modeling the Impacts of Aquaculture in the Rural Economy. *World Development*, *110*, 205–223. https://doi.org/10.1016/j.worlddev.2018.05.023

Fisheries Commission (2022). *2021 Annual Performance Report.* Ministry of Fisheries and Aquaculture Development. Accra: Ministry of Fisheries and Aquaculture Development

Fisheries Commission (2024a). *2023 Annual Performance Report*. Ministry of Fisheries and Aquaculture and Development. Accra: Ministry of Fisheries and Aquaculture Development

Fisheries Commission (2024b). *Ghana National Aquaculture Development Plan 2024-2028.* Accra: Ministry of Fisheries and Aquaculture Development

Food & Agriculture Organization (2022). *The State of World Fisheries and Aquaculture 2022*. FAO. https://doi.org/10.4060/cc0461en

Food & Agriculture Organization. (2020). Aquaculture in Ghana: Status and opportunities. *Food and Agriculture Organization of the United Nations*. https://www.fao.org/3/ca9229en/ca9229e

Food and Agriculture Organization (2019). The state of food security and Nutrition in the World *https:// www.unicef.org/media/55921/file/SOFI-2019-full-report.pdf Accessed 10.09.*

Frimpong, D. S. K., & Adwani, M. A. (2015). *The Challenges and Prospects of Fish Farming in Ghana: A Project Management Perspective*.

Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N., & Anyanwu, P. E. (2007). Locally produced fish feed: Potentials for aquaculture development in sub-Saharan Africa. *African Journal of Agricultural Research*, *2*(7), 287–295.

Hasimuna, O. J., Maulu, S., Monde, C., & Mweemba, M. (2019). Cage aquaculture production in Zambia: Assessment of opportunities and challenges on Lake Kariba, Siavonga district. *Egyptian Journal of Aquatic Research*, *45*(3), 281–285.

Hasselberg, A. E., Aakre, I., Scholtens, J., Overå, R., Kolding, J., Bank, M. S., Atter, A., & Kjellevold, M. (2020). Fish for food and nutrition security in Ghana: Challenges and opportunities. *Global Food Security*, *26*, 100380.

Kassam, L., & Dorward, A. (2017). A comparative assessment of the poverty impacts of pond and cage aquaculture in Ghana. *Aquaculture*, *470*, 110–122.

Kuhn, D. D. (2017). Understanding Fish Nutrition, Feeds, and Feeding, *.https://fisheries.tamu.edu/files/2019/01/FST-269.pdf*

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, T. P. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLOS Medicine*, *6*(7), 1–6. https://doi.org/10.1371/journal.pmed.1000097

Prabu, E., Felix, S., Felix, N., Ahilan, B., & Ruby, P. (2017). An overview on significance of fish nutrition in aquaculture industry. *International Journal of Fisheries and Aquatic Studies*, *5*(6), 349–355.

Quagrainie, K. K., Mensah, S. A., & Darko, E. (2015). Fish feed markets and interventions in Ghana. *Ghana Journal of Agricultural Science*, 51(1), 71-77.

Ragasa, C., Agyakwah, S., Asmah, R., Mensah, Emmanuel Tetteh-Doku, Amewu, S., Oyih, M. (2022a). Accelerating pond aquaculture development for food and jobs in Ghana. *Aquaculture* 547, 737476.

Ragasa, C., Osei-Mensah, Y. O., & Amewu, S. (2022b). Impact of fish feed formulation training on feed use and farmers' income: evidence from Ghana. *Aquaculture, 558*. 738378. https://doi.org/10.1016/j.aquaculture.2022.738378

Said A. & Trouillet B. (2020). Bringing 'Deep Knowledge' of Fisheries into Marine Spatial Planning, *Maritime Studies 19*(3-4).

Said, A. & Chuenpagdee, R. (2019). Aligning the sustainable development goals to the small-scale fisheries guidelines: a case for EU fisheries governance. *Marine Policy* 107: 103599.

Shi, Z., Li, X.Q., Chowdhury, M.K., Chen, J.N. & Leng, X.J. (2016). Effects of protease supplementation in low fish meal pelleted and extruded diets on growth, nutrient retention, and digestibility of gibel carp, *Carassius auratus gibelio*. *Aquaculture* 460, 37–44.

Stake, R. E. (1995). The art of case study research. Thousand Oaks*, CA: Sage.*

Santos, M, dos M.N.,Pintassilgo, P., Pita, C., Stergiou, K.I., Ünal, V., Veiga P., & Erzini, K. (2016). Small-scale coastal fisheries in European Seas are not what they were: Ecological, social, and economic changes. *Marine Policy* 98: 176–186.

Tacon, A. G. J., & Metian, M. (2013). Fish Matters: Importance of Aquatic Foods in Human Nutrition and Global Food Supply. *Reviews in Fisheries Science*, *21*, 22–38.

Tetteh, E. F., Adjei-Boateng, D., & Agyekum, W. A. (2019). Challenges faced by small-scale fish farmers in Ghana: A review. *Journal of Aquaculture Research & Development*, 10(1), 1-9.

Wang L., Cui Z., Ren X., Li P., & Wang Y. (2021). Growth performance, feed Cost and Environmental Impact of largemouth bass *Micropterus salmoides* fed low fish meal diets, Aquaculture Reports 20(7), 100757

World Bank (2023). Aquaculture production (metric tons), Ghana. https://data.worldbank.org/indicator/ER.FSH.AQUA.MT?end=2020&locations=GH&start=1960&view=chart

World Bank. (2016). Safety and Sustainability for Small-scale Fishers in West Africa, *[https://www.worldbank.org/en/news/feature/2016/05/16/safety-and-sustainability-for-small-scale-fishers-in-west-africa.*

Yang, J., Owusu, V., Andriesse, E., & Ablo, A. D. (2019). In-Situ Adaptation and Coastal Vulnerabilities in Ghana and Tanzania. *The Journal of Environment & Development*, *28*(3), 282–308. https://doi.org/10.1177/1070496519852992

Yakupitiyage, A. (2013). On-farm feeding and feed management strategies in tropical aquaculture. *FAO Fisheries and Aquaculture Technical Paper*, *583*, 361–376.