A review of aquafeed business models and the feed value chain in Zambia and Malawi

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Executive summary

Over the past decade, the aquaculture sector in Zambia and Malawi has grown tremendously. The availability of commercial feed companies producing complete commercial feed diets in Zambia has been a key factor in the growth of the aquaculture industry. However, the use of commercial feeds among smallholders remains low. Low use of complete diet feeds among smallholder farmers is a key constraint to improving the performance of smallholder farmers in the sector.

The goal of this review is to recommend aquaculture feed distribution models that could promote the use of commercial feeds among smallholders as well as offer recommendations on investments in the feed value chain.

This review aims to achieve the following:

- Understand the constraints around the use of commercial feeds in Zambia and Malawi.
- Identify existing opportunities for feed in the aquaculture sector.
- Understand existing aquaculture feed distribution models in the region to identify lessons learned and how they apply to Zambia and Malawi.
- Offer recommendations for upgrading commercial feed supply models for Zambia and Malawi.

For both Zambia and Malawi, critical challenges in aquaculture include access to quality inputs, particularly seeds and feeds, which account for the most significant proportion of operational costs. Lack of technical knowledge in better management practices is another critical challenge among smallholders. Besides the perceived cost of purchasing commercial feeds, smallholder fish farmers incur high transportation costs, as most feed distributors are located far from rural farmers. In Malawi, local commercial production of floating feeds is nonexistent. Feed producers in Zambia and Malawi import most ingredients in fish feeds, which impacts the prices of commercial feeds.

Despite these challenges, opportunities are available to develop the fish feed value chain. They include developing alternative and cheaper fish feeds, private sector engagement to strengthen feed distribution networks, and microfinance and credit solutions. There are also opportunities for harnessing economies of scale within farmer groups and clusters.

Four research gaps need exploring to identify low-cost feed distribution networks:

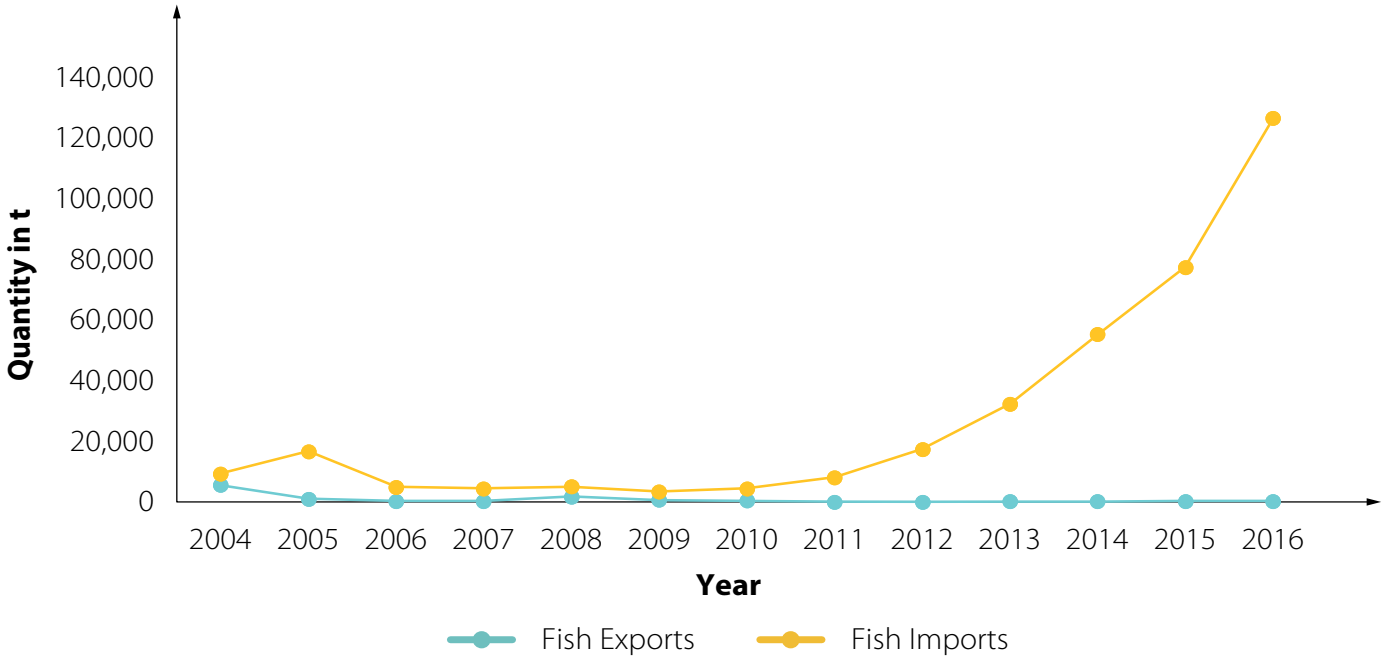
1. Understanding is needed regarding the critical mass of smallholders that is required to make it profitable for commercial feed companies to supply feed.
2. Fish farmers' profiles require segmentation to understand their willingness and ability to adopt commercial feeds.
3. Understanding is needed regarding the economic returns regarding the use of commercial feeds under different market scenarios.
4. Identification is required regarding options for microfinance and access to cash and in-kind credit for the purchase of commercial feeds.

Several feed models have been successful within Africa and Asia, and these can be piloted and tested in Zambia and Malawi. The first is a micro-franchise model using a network of local agro-dealers as agents (aquashops), who equally provide technical knowledge and training to smallholders. The second is a cooperative model using farmer groups and clusters to buy feed in bulk and to sell it to both members and non-members or, alternatively, to aggregate feed orders to achieve critical mass in feed distribution. The third model involves empowering cooperatives to be small-scale feed millers by supporting them with equipment and training in feed formulation. These models open up opportunities but also pose challenges depending on the prevailing circumstances.

Introduction

Aquaculture is the fastest growing food production sector in Zambia, increasing from 12,988 t in 2012 to 36,105 t in 2018 (DOF 2019; FAO 2020). In 2018, aquaculture production in Zambia represented almost one-third of total fish production (DOF 2019). Per capita fish consumption in Zambia stood at 10.4 kg in 2014 and is projected to increase to 13.3 kg by 2030 (Tran et al. 2018). Among countries in the Southern Africa Development Community (SADC), Zambia is currently the regional leader in aquaculture, accounting for 33% of total fish production in the region. In Malawi, aquaculture production increased from 4984 t in 2015 to 9230 t in 2019 (Government of Malawi 2020).

In both Zambia and Malawi, however, fish supply to the domestic market still falls short of domestic demand, and the two countries depend on fish imports to cover this shortfall. For instance, the estimated supply-demand gap is about 20,000 t a year in Malawi (Government of Malawi 2016), which is covered by imports from neighboring countries, mainly Zambia, and from as far away as China. In Zambia, fish imports increased 56.3% from 55,184 t in 2014 to 126,345 t in 2016 (Figure 1), and the domestic demand for fish is projected to increase to 138,900 t by 2030 (Ministry of National Development Planning 2017; Tran et al. 2019). Moreover, studies show that informal fish trading occurs in both countries (Mussa et al. 2017). An estimated 102,263.9 t of fish were traded between Zambia and its neighbors in 2016, with the Democratic Republic of Congo accounting for 95% of informal trade in the four border posts under study (Mussa et al. 2017). In Malawi, annual informal fish exports in 2016 were estimated at 24,115.68 t, with Mozambique accounting for the highest volumes (Mussa et al. 2017).



Source: Zambia Revenue Authority Cross-Border Fish Trade Records.

Figure 1. Formal fish exports and imports from 2004 to 2016.

Despite the need for increased domestic production, access to quality inputs like seed and feed remains a significant challenge in smallholder aquaculture (Brummett et al. 2008; Genschick et al. 2017; Mulumpwa 2018). Feed accounts for over 60% of operation costs of fish production (Jamu and Ayinla 2003; El-Sayed 2014). Several factors account for the high cost of fish feed. For example, almost all micro-ingredients in feeds, such as fishmeal, premixes and vitamins, are imported, which is keeping the price of commercial feeds relatively high, resulting in low demand among smallholders (Genschick et al. 2017; Kaminski et al. 2018).

Fish feed standards and certification have yet to be established in Zambia and Malawi to avoid low quality feeds flooding the market and disadvantaging farmers. Standards provide the regulator with a clear definition of the minimum parameters used as a benchmark for quality certification. In Egypt, for example, there are provisions and articles applied for regulation and quality control inspection of aquaculture feeds (El-Sayed 2014). Similarly, in Uganda the bureau of standards has published criteria and standards for feed compositions (Uganda Bureau of Standards 2018). In Kenya, the development of fish feed standards was a culmination of several negotiations between aquaculture stakeholders, including the Kenya Marine and Fisheries Research Institute, Kenya Bureau of Standards, Department of Fisheries (DOF), commercial feed companies and fish farmers (Munguti et al. 2014). With potential growth in the feed sector, there is a need to establish and document clear fish feed standards for different parameters. These could be used as a guideline for quality assessment of feed formulations and to ensure that fish feed is derived from environmentally sustainable sources.

Low fish weight from poor feeding practices by smallholders could deter private sector investment in market development. Equally, most smallholders are limited in accessing high-return markets, which can constrain efficient use of feeds (Kaminski et al. 2018). Poor access to credit to finance their enterprises and purchase inputs is also a deterrent to smallholders, which affects the efficient use of inputs (FAO 2017). Despite these challenges, the feed sector is considered the second-largest source of job creation in the aquaculture industry due to the backward links to farms growing soy and maize (Krishnan et al. 2017).

With this background of low use of commercial feeds, this review was conducted under the framework of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) project called Piloting Inclusive Business and Entrepreneurial Models for Smallholder Fish Farmers and Poor Value Chain Actors in Zambia and Malawi. The project aims to establish pro-poor, gender- and youth-inclusive businesses and entrepreneurial models that provide sustained access to smallholder fish farmers in Zambia and Malawi, with productivity and profitability enhancing fish seed, feed and knowledge. Since the project seeks to improve farmer access to feed, among other issues, the overall aim of this review is to recommend aquaculture feed distribution models that could promote the use of commercial feeds among smallholders as well as offer recommendations on investments in the feed value chain.

This review has four main objectives :

- To understand the constraints around the use of commercial feeds in Zambia and Malawi.
- To identify existing opportunities for feed in the aquaculture sector.
- To understand existing aquaculture feed distribution models in the region for identifying lessons learned and their applicability to Zambia and Malawi.
- To offer recommendations for upgrading commercial feed supply models for Zambia and Malawi.

This document is based on a review of diverse literature—including scientific journal articles, technical reports and project documents from WorldFish as well as other organizations—and data from a smallholder fish farmer census conducted in Northern and Luapula provinces of Zambia in 2019.

1. Review of the fish feed value chain in Zambia

1.1. Smallholder aquaculture

There are an estimated 20,000 small-scale farmers operating mainly earthen pond systems at the household or community level. Overall, the DOF (2019) estimates that there were 34,334 ponds operated by smallholders in 2018. Most of these farmers are in provinces with no major urban cities, particularly in Northern and Luapula (DOF 2019). Farmers in these provinces are the most disadvantaged, with limited access to commercial feed, as all feed producers are located over 850 km away. Transportation costs further increase the cost and availability of feed in these underserved regions.

The average age among farmers in Zambia is 46, and only 24% are under 35 years old. There are also noticeable disparities between men and women in the aquaculture labor force. In Northern and Luapula provinces, 86% of fish farmers who responded to a smallholder farmer fish census were men, and only 14% were women (Kakwasha et al. 2020). Direct employment along the aquaculture value chain is estimated at 20,000 jobs, though most are at the farm level and unskilled (VCA4D 2018). While large commercial fish farms contribute a large majority of aquaculture employees, jobs at these farms are male-dominated (VCA4D 2018).

1.2. Fish feed and feeding practices

In Zambia, feeding and fertilization regimes can be categorized according to three technologies: fertilization/manuring, use of unprocessed by-products from local crop and vegetable production, and commercial feed application (Genschick et al. 2017). Use of commercial feeds is still low among smallholder fish farmers, with only 19% of smallholders in Northern and Luapula provinces using commercial feed (Kakwasha et al. 2020). The majority of farmers use materials from their farms to feed their fish. Some smallholders who use commercial feed depend on free or subsidized distribution from development projects (Kaminski et al. 2018).

In terms of feeding practices, most smallholder farmers spread feed all over the surface of the water. Some farmers feed their fish at specific points in the pond to get them accustomed to feeding at these spots. Feeding practices for floating feeds entail farmers using floating (feeding) hose rings or pipes to contain the feed and stop it from floating away to the pond margins, where it is harder for the fish to consume and where birds can eat it. Some farmers use feeding trays when giving sinking feed to fish. The trays are placed in the water column to avoid feed sinking straight to the pond bottom.

1.3. Commercial feed production

As a result of the growth of its commercial fisheries and hatcheries, Zambia has the most established commercial fish feed manufacturers in the SADC. Its commercial feed millers are located mainly in the south of the country, in Lusaka and Southern provinces. In Southern Province, Siavonga District alone has two international commercial feed millers, driven by a large number of commercial fish farms located on Lake Kariba. Because of the high demand for feeds, feed mills have invested significantly in the development of aquafeeds over the past few years. These mills include Savanna Streams, Farm Feeds, Olympic Milling, Tiger Feeds, Novatek Animal Feeds, Skretting and Aller Aqua.

Kaminski et al. (2018) estimate that Zambia's feed companies produced about 30,000 t of fish feed in 2016. Novatek Animal Feeds, for example, produces about 600–800 t of feed per month with four different product lines (fry mash, juvenile crumble, starter pellets and grower pellets), none of which existed in the market in Zambia before 2015 (Kaminski et al. 2018). Eight feed mills have established a supply of domestically produced pelleted feed (sinking and floating) for commercial aquaculture. Two of them signed supply contracts with commercial fish producers: Skretting supplies Lake Harvest Ltd., and Aller Aqua has a contract with Yalelo (Kaminski et al. 2018).

1.4. Alternative feed solutions

Efforts to develop affordable and nutritious feed with alternative ingredients have been underway in Zambia. In partnership with the Natural Resources Development College and others, WorldFish conducted a study to investigate the effect of partially or totally replacing fishmeal with the single-cell protein DY-Pro in the diets of tilapia (*Oreochromis niloticus*) in order to develop affordable alternative feeds.

1.5. Fish feed value chain actors

In Zambia, the major producers of commercial aquafeed are Novatek, Aller Aqua and Skretting (Table 1). Novatek and Skretting also export directly to Malawi. Olympic milling and tiger feeds focus on specific feeds, though on a smaller scale. Besides commercial feed producers, there are also commercial fish farms who produce their own feeds, such as Kafue Fisheries and Miracle Fisheries. Other larger fish farms have formal partnerships with large commercial feed producers, such as Yalelo Fish Farm with Aller Aqua, and Kariba Harvest with Skretting. These partnerships ensure a continuous, and therefore reliable, supply of feed.

Most agro-dealer shops are, however, located in towns, which poses a challenge for smallholders to access. The majority of farmers in Northern and Luapula provinces (65%) travel over 20 km to buy commercial feeds (Kakwasha et al. 2020). There is a need to calculate and establish a critical mass of volume that the private sector, particularly small and medium enterprises, needs to profitably and sustainably reach rural smallholders within their localities.

There are development projects that have supported fish-feed distribution channels to reach smallholders, but these have faced sustainability challenges once the project elapsed. For instance, private sector landscape mapping (Uhlenbrock 2019) showed that the Better Changes project delivered fish feeds such as starter, grower and finisher from the Olympic fish feed company. Better Changes had 25–30 outlets in Mbala, Mpulungu, Mansa, Luena and Mporokoso, where farmers could buy feeds. There were about 150 fish farmers buying fish feed. Feed was delivered by motorbikes and trucks. The project depended on the success of the seller, and challenges of feed theft were reported. In Zambia, some farmers have small feed mills that are operated manually. They produce sinking pelleted feed for their own use, and sometimes sell it to neighbors.

The Norweigan Agency for Development Cooperation funds a project in Zambia called Aquaculture Technical, Vocational, and Entrepreneurship Training for Improved Private Sector and Smallholder Skills (AQ-TEVET). As part of the project, WorldFish and Musika worked with commercial feed companies to set up distribution points in the underserved provinces of Northern and Lupaula. Aller Aqua and Novatek have so far set up outlets in Kasama, Northern Province.

Name	Description
Novatek	Novatek offers six specific feed types, including fry, juvenile and adult grow-out feeds. It produces extruded, slow-sinking pellets predominantly from soy-based ingredients and imported fishmeal and bone meal (between 18% and 45% crude protein). It sells directly to individual commercial farms. The company has built relationships with over 100 independent agents and selling outlets, and exports to Malawi, Botswana, Zimbabwe and Mozambique.
Skretting	Located in Siavonga, Skretting specializes in tilapia feed for the Zambian market. The firm works with large fish farms and hatcheries countrywide, as well as smallholder farmers in Northern Province. Mpende Fisheries is one of the commercial hatcheries/fisheries that uses its feed.
Aller Aqua	Located in Siavonga, Aller Aqua produces feed for all stages of the fish production cycle, such as starter, grower and finisher. It produces feed with a relatively higher protein content, so the price is relatively higher.

Table 1. Commercial fish feed producers in Zambia.

1.6. Key challenges

- Poor road networks hinder transportation of commercial feeds in rural areas.
- Inflation affects fish feed prices because most ingredients are imported. For example, feed companies peg their prices against the US Dollar and adjust for inflation. However, this is not reflected in table-fish prices, which remain constant regardless of increased feed prices (Uhlenbrock 2019).
- Farmers do not have real-time information on the cost of inputs when they negotiate prices with buyers, which can affect their ability to invest proceeds from fish sales into buying feed.
- Knowledge is limited about the benefits of commercial fish feeds for smallholder farmers, and there is a lack of access to extension services.
- Farmers incur high transportation costs because they are located far from feed distribution networks.
- Orders of fish feed from smallholders are small, and demand is inconsistent.
- A proportion of smallholders believe commercial feeds are expensive.

Photo credit: Henry Kanyembo/WorldFish

From left Susan Kamfwa and her husband, Seggi Nsombo (hatchery operators in Nsombo Luwingu, Zambia) showing the feed for their broodstock.

2. Review of the fish feed value chain in Malawi

2.1. Smallholder aquaculture

The Government of Malawi estimates that in 2019 there were 15,465 smallholder fish farmers, an increase from 6000 in 2016 (CASA 2019; Government of Malawi 2020). Of these farmers, 61.5% were male and 38.5% female (CASA 2019). Most smallholders practice earthen pond-based fish production. In total, the DOF recorded 10,007 active fishponds in 2019, covering a combined area of 251.6 ha. If they were individually owned, then each smallholder farmer would, on average, have a pond area of approximately 250 m^2. This is not the case, however, as the majority of smallholder farmers in Malawi are organized into farmer groups and farmer associations.

The Innovative Fish Farmers Network Trust is an umbrella association for farmer groups and medium, small and micro enterprises in aquaculture. The majority of farmer groups in Malawi are usually formed in response to or because of NGOs and donor-funded projects that require one to be a member of a farmer organization as a condition for support. As such, some of these groups do not sustain aquaculture activities beyond the lifespan of the projects they were established under (CASA 2019).

2.2. Fish feed and feeding practices

The majority of smallholder farmers in Malawi either use organic manure to fertilize their ponds to create natural food organisms for the fish to eat (Mainza and Musuka 2015) or make homemade feeds, like maize bran (Mulumpwa 2018). The use of homemade feeds is non-viable, as it results in low yield and because most farmers abandon fish farming (Mulumpwa 2018). This is largely because most homemade feeds are incomplete diets that are unable to meet the nutritional requirements of fish. This results in poor yields at harvest. Use of commercial feeds is estimated at less than 10% (Imani Enterprises et al. 2016), and most users are commercial farms.

The feeding practices of some smallholders involve using homemade formulations fed to fish as a paste placed on feeding plates. In other cases, the ingredients are generally spread over the ponds in dust or powder form. The latter practice is often wasteful, so most of the nutrients are lost instead of being consumed by the fish. The majority of smallholders make homemade feeds from a mixture of ingredients that may include grains and vegetables. They dry the ingredients, mix them together and take the mixture to a public mill for grounding into flour. They then cook the flour into a porridge paste, let it cool and place the semi-solid paste on floating plates in the ponds for the fish to feed on.[1]

2.3. Commercial feed production

Maldeco, a commercial cage farming company in Malawi, was the sole producer of commercial fish feeds in Malawi, but it only produced sinking feeds. The company stopped feed production around 2019 and currently imports floating fish feeds from Zambia for internal use only. Sinking feeds have a low uptake, as most of the feed ends up accumulating at the base of the pond or is wasted in the water reservoir in the case of cage-based production. Under the Agricultural Technology Transfer (AgriTT) project, the Lilongwe University of Agriculture and Natural Resources (LUANAR) conducted an experiment demonstrating that floating feed imported from Zambia had a 30% performance edge on fish growth over the sinking feed from Maldeco.

The National Aquaculture Centre (NAC) installed a feed mill that can produce floating fish feed. It is now selling feed to a few farmers, but the capacity is too small to support the commercial production needs of smallholders. The NAC is still testing this equipment, which was bought under the phased-out AgriTT project (2012–2017). LUANAR also bought similar equipment with financial support from AgriTT, but this had yet to be installed because the construction of the housing facility was still underway (CASA 2019).

Among the considerations firms make in setting up industrial production is the demand for feeds. In South Africa, for example, a firm would only invest in a dedicated feed line and associated costs if the demand for a specific feed exceeds

5000 t annually (Hecht 2007). In Malawi, some commercial feed millers, such as Landell Mills, are evaluating the potential demand for fish feed because they are considering establishing industrial feed mills (CASA 2019). Currently, commercial feed is imported into Malawi from Zambia by distributors and agents.

At present, there is a lack of understanding among farmers in Malawi regarding the economic returns of using imported commercial feed. This was the impetus for the Gold Standard Plus for Commercial Pond Aquaculture project in Malawi by WorldFish. The Golden Aquaculture Pond Standard developed in 2010 aimed at developing best management fish farming practices to enable smallholders to engage profitably. However, the project considered on-farm feeds, because there was no capacity for feed production in Malawi at the time and no possibilities for feed imports. Currently, WorldFish and its partners are piloting the Gold Standard Plus for Commercial Pond Aquaculture project, using commercial feeds imported from Zambia, to understand the economic returns of using commercial feeds in Malawi. The project aims to calculate the profitability of smallholder aquaculture pioneer farms, as well as standard gross margins, considering different decision scenarios and feed costs.

2.4. Alternative feed solutions

Some strands of literature have discussed alternative fish feed solutions that use local ingredients to substitute for imported, expensive animal- and/or plant-source ingredients. In Malawi, for example, Mulumpwa (2018) explored the viability of insect meal as a protein source in fish feeds. Development initiatives like the CultiAF project (2014–2017) in Eastern and Southern Africa have aimed at developing insect feed for fish. Equally, the AgriTT research project in Malawi worked with LUANAR to test different feed formulations. Similarly, WorldFish is testing alternative fish feed sources, such as cassava chips, sweet potato peels, soy cake and agroforestry seed (moringa) under the Development of Smart Innovation through Research in Agriculture (DeSIRA) project.

2.5. Fish feed value chain actors

Although currently there are no commercial feed producers in Malawi, some commercial fish farms have taken downstream roles of producing their owns feeds to supplement commercial feeds and balance out their profitability (CASA 2019). Chambo Fisheries is vertically integrated and produces feeds for its own use, though it hopes to expand to commercial feed production, while Chonona Fisheries bought mills for internal feed production. The NAC installed a feed mill that can produce floating fish feed and is selling it to a few farmers.

Name	Description
Maldeco	Maldeco was the only producer of commercial feeds in Malawi, producing sinking feed until 2019. However, it has stopped production and is currently importing floating feed from Zambia. Sinking feeds have performance deficiencies in tilapia vis-à-vis floating fish feed currently imported from Zambia.
Chambo Fisheries	Chambo currently produces floating feeds for internal use only. It uses a biofloc system, which contains protein-rich macro aggregate of organic material and micro-organisms, including diatoms, bacteria and algae. Feed ingredients are bought from a range of sources. Private networks transport fishmeal from Namibia and South Africa.
Chonona Fish Farm	Chonona bought a medium-sized feed mill capable of producing floating fish feed. By 2019, however, installation of the equipment was awaiting completion of construction of the anchorage and housing facility.

Table 2. Fish feed producers in Malawi.

2.6. Key challenges

- There is a lack of locally produced floating feed, as floating feed is imported from Zambia.
- Minimum volumes of imports are a constraining factor for Zambian-based feed companies; a financially viable truckload is 5–10 t.
- Orders of fish feed from smallholders are small and the demand perceived as inconsistent, making it difficult for fish feed companies to invest in the sector.
- Import prices on feed are high because the Malawi government levies a 16% VAT on the landed value of feeds, which are mainly imported from Zambia.
- The current tax regime in Malawi reduces the competitiveness of local fish producers because of the high cost of feed imports, while table fish imports are duty-free (Imani enterprises et al. 2016; CASA 2019).
- Tilapia imports impact local smallholder farmers, which depresses the value of locally produced tilapia further and affects the viability of using high-cost imported feeds.
- Farmers have limited technical knowledge and expertise of running commercial fish farming ventures.
- Investors are unsure about the effective demand for floating feed in the country. For instance, Lenzie Mills expressed uncertainty about the volume of feed that can sustainably be sold to players in Malawi (CASA 2019).
- Logistical arrangements in reaching smallholder buyers of feed are yet another consideration that investors are contending with (Imani enterprises et al. 2016; CASA 2019).

Falesi Machipisa from Phalombe in Malawi feeding her brooders and fry using the floating feed.

3. Aquafeed distribution models

In this section, we present a review of cases of feed distribution models applied in the aquaculture sector. We offer a brief description of how the models have been applied in each specific case as well as the strength/outcome and challenges/weaknesses, as highlighted in the case studies (Table 3).

Model	Country	Brief description	Strength/outcome	Challenges/weaknesses
Franchise	South Africa (Karaan 1999 and 2002)	The article compares transaction costs in four models: independent small operators, contract growers, franchises and large-scale farmers.	Franchising brings economies of scale into marketing, processing, research and development, and input procurement, and improves competitiveness through access to extension services, price certainty and synchronized harvesting.	There are challenges in identifying targeted farmers for the franchise. Farmers have to pay a membership fee as well as royalties, which are recovered from sales.
Input micro-franchise (aquashops)	Kenya (Obwanga and Lewo 2017; Otieno et al. 2018).	These are driven by a non-profit organization. Farm Africa established aquashops to sell aquaculture inputs and equipment, and to provide training and technical support to farmers.	There were 56 shops set up over 5 years, benefitting over 7500 farmers by increasing their incomes 63%. Shops recruited 35 youths to work as aquashop agents to market inputs.	
Aggregation by cooperatives	Egypt (El-Sayed et al. 2014)	Cooperatives buy good quality feed in bulk for members through an annual tender process with savings on bulk orders. They also operate a credit system where farmers pay half of annual feed costs upfront and the rest on credit without a price increase.	Famers are able to buy high quality feeds at reasonable prices. Logistical and transportation costs are reduced.	This study found only two functional cooperatives, as most are non-functioning and play no role in providing fish feed services to farmers.
Aggregation by cooperatives	Uganda (Dalsgaard et al. 2012; Hyuha et al. 2017)	Registered in 2004, the Walimi Fisheries Cooperative Society (WAIFICOS) helps fish farmers acquire services and inputs necessary for their operations to thrive. This includes collective production, marketing and value addition of farmed fish products. The cooperative buys commercial feed from the Ugachick feed mill to sell to both members and non-members.	They produced a guide with the contact information of actors in the value chain. They organize annual symposiums with traders, policymakers and other stakeholders, and provide members with technical advisory services, affordable inputs and market links.	Cooperatives are often supported by governments and NGOs, particularly for purchasing capital intensive equipment and for training.

Model	Country	Brief description	Strength/outcome	Challenges/weaknesses
Aggregation by cooperatives	Vietnam (Ha et al. 2013)	Clusters sign contracts with feed millers and purchase feeds at negotiated prices. In return, they sell the feed to their members, who pay after harvest.	The model offers a 1.5% reduction in feed costs for individual farmers in the cluster.	
Public private partnership (PPP)	Kenya (Murekezi et al. 2018)	The program aimed to create decent employment opportunities for young people (men and women). It formed a partnership agreement with the county government on constructing a fish feed mill. It also partnered with private companies (seed and feed) to offer quality inputs and training to beneficiaries.	There were over 400 youth beneficiaries, both men and women. There were 25 groups with 570 ponds, with 13 hatcheries producing fry and fingerlings. There were also 13 groups involved in grow-out activities and marketing.	There was input diversion, poor quality feeds and a lack of guaranteed markets, and the PPP agreement was incomplete.
Contract farming	South Africa (Karaan 1999 and 2002)	It compared transaction costs in four models: independent small operators, contract growers, franchises, and large-scale farmers and large firms.	The buyer/firm provided rafts on a cost-recovery basis, as well as extension services, guaranteed markets, inputs on account and other frequent logistical assistance. Contract growers have high technical competence and efficiency.	Transaction costs are higher than franchises. Details on relationships in the contractual arrangement were not highlighted in the article.
Private feed manufactures	Egypt (El-Sayed et al. 2014)	A total of 85% of private sector fish feed producers sell their products directly to farmers, and only 15% to traders or retailers.		
Private feed manufactures	Zambia (Kaminski et al. 2018)	Feed manufacturers (Novatek, Aller Aqua, Skretting) mainly sell directly to commercial farms and selected distributors. They had set up factories in Zambia over the previous 5 years.	They sell high-quality feeds with high feed conversion rates.	They are located far from smallholder farms. They sell large volumes beyond the reach of most smallholders.
On-farm millers/small-scale millers	Bangladesh (Mamun-Ur-Rashid et al. 2013)	On-farm feed millers operate locally manufactured pelletizing machines.	They supply feeds to local rural farmers at lower prices.	A lack of knowledge and awareness of feed formulations led to poor feed quality. There were also inefficiencies in processing and drying feeds.

Model	Country	Brief description	Strength/outcome	Challenges/weaknesses
On-farm millers/small-scale millers	Kenya (Munguti et al. 2014)	Small-scale cottage feed millers operate locally made extruding and pelletizing machines.		The nutritional composition of some feeds is inadequate.
On-farm millers/small-scale millers	India (De Silva et al. 2007)	It is an important contributor of aquafeeds in extensive and semi-intensive pond farming.	It supplies feeds to local rural farmers at lower prices.	Statistics do not capture the volume of on-farm feeds well.
On-farm millers/small-scale millers	Nigeria (Hecht 2007)	About 70% of commercial feeds are produced by small-scale operators who have potential to produce extruded floating pellets, particularly grower pellets for tilapia and catfish.	Production of farm-made pelleted feeds is affordable.	There is a lack of a large enough storage facility that is also pest proof.
On-farm millers/small-scale millers	Kenya Ngugi et al. 2017)	In 2010–2013, the government (through the Fish Farming Enterprise Productivity Programme) provided 54 fish farm clusters with feeds, mixers and pelletizing machines to produce on-farm fish feeds for their own use and for sale to other farmers.		Many of these cooperatives are often supported by governments and NGOs particularly for buying capital intensive equipment and in training.
Fish feed retailers/ dealers	Egypt (El-Sayed et al. 2014)	Many small-scale fish farmers purchase feed from traders on credit (3%–6% higher) or pay 50% in cash and the rest on credit until the fish are harvested and sold.	They offer fish feed on credit.	Farmers might receive poor quality feeds.
Fish feed retailers/ dealers	Bangladesh (Mamun-Ur-Rashid et al. 2013)	They distribute 96%–98% of feed from feed mills to farmers, typically earning a return of 6%–7% on the purchase price.	They distribute about 5%–10% of total feed to remote areas, or to small farmers, through retailers. Most companies provide credit to feed dealers.	When dealers extend credit to customers, they add an extra 1%–3% to the retail price.

Table 3. Case studies of feed distribution models.

According to a study of the fish feed value chain in Egypt (El-Sayed et al. 2014), about 85% of private sector fish feed producers sell their products directly to farmers, while the rest sell to traders or retailers. Many small-scale fish farmers buy feed from mills or traders on credit at 3%–6% higher prices. The challenge in buying feeds from traders is that farmers might receive poor quality feeds. According to the same study (El-Sayed et al. 2014), about 70% of feeds produced by state-owned/public mills go to traders, and only 30% are sold directly to farmers. Cooperatives, which save money on bulk orders, buy feed in bulk for their members. They also operate a credit system in which farmers pay 50% upfront and the rest on credit. Unfortunately, few functional cooperatives exist.

In Kenya, the NGO Farm Africa set up a micro-franchise model of local aquashops that provide quality inputs as well as training and technical support to smallholder tilapia farmers (Obwanga and Lewo 2017). Aquashop owners invest in the businesses and receive technical support from Farm Africa, and they are part of an extensive network of other aquapreneurs.

Aquashop owners managed to recruit 35 youths, who have been working as aquashop agents to market the products and services while providing basic technical support, on a commission basis. Regarding another case in Kenya, the Food and Agriculture Organization established a PPP model to benefit young farmers, both men and women (Murekezi et al. 2018). A partnership was established with selected pioneer farms to provide training to support youths in aquaculture, along with another partnership agreement with the county government to build a fish feed mill. The main challenge, however, is the lack of a guaranteed market, and there are sustainability questions on youth engagement once the project ends (Murekezi et al. 2018).

The franchising model has also been used in South Africa to engage farmers in the production of mussels and oysters (Karaan 2002). Farmers pay a membership fee and pay royalties on sales of mussels and oysters. In return, they get access to inputs at affordable prices because of economies of scale in procurement, and farmers are also assured of a reliable market and extension services (Karaan 1999). The study found that franchise farmers have low transaction costs compared to contract growers and independent growers (Karaan 2002).

The cooperative model has been applied across different countries in Africa to generate a critical mass in input access and to aggregate output volumes to access high-value markets. In the wake of revitalizing aquaculture systems in Kenya, farmer-led, market-driven cooperatives were at the center of the government-funded Fish Farming Enterprise Productivity Programme under the Economic Stimulus Programme (Ngugi et al. 2017). To produce quality and affordable feeds, selected clusters were given feed mixers and pelletizing machines to make fish feeds, both for their own use and for sale to other farmers (Ngugi et al. 2017). In Uganda, fish farmer cooperatives formed an umbrella body of farmer clusters. One of the successful cooperatives is WAIFICOS. The cooperative buys commercial feed from Ugachick to sell to its members, with non-members paying higher prices (Hyuya et al. 2017). In Vietnam, horizontal coordination of farmers in clusters has given them access to the global shrimp value chain, as well as better prices for feeds and convenient payment schedules (Ha et al. 2013).

Progressive cooperatives have attracted private sector engagement to provide inputs and to market outputs equally. They have also benefitted from capital investments provided by the government and development partners. In the Kenyan case (Ngugi et al. 2017), the government provided feed mixers and pelletizing machines to the cooperatives. WAIFICOS received support from various donor-funded projects, for example, to purchase large tanks needed for storing commercial feeds and to buy production equipment (The Fish Site 2011; Dalsgaard et al. 2012).

Some case studies have highlighted the existence of small businesses operating on-farm pelletizing feed mills. In Bangladesh, feed mill machines are manufactured in local workshops at a cost of USD 1250–3125 and produce 50–300 kg of feed per hour (Mamun Ur-Rashid et al. 2013). In Kenya, locally made machines are operated by small cottage industries who sell fish feeds locally to farmers (Munguti et al. 2014). A key challenge is, however, the low quality of feed produced. It is primarily because of a lack of knowledge and awareness of feed formulations that provide sufficient nutritional value to fish at various growth stages (Mamun Ur-Rashid et al. 2103; Munguti et al. 2014). The other reason for low-quality feeds by small-scale producers is the inability to access feed ingredients year-round, especially out of season. Large companies are able to source ingredients in bulk while in season and stock them up out of season. Similarly, they are highly skilled to have alternative replacements for ingredients that are out of stock, and they can adjust the formulations based on available ingredients.

In India, the bulk of aquaculture production in extensive and semi-intensive pond farming depends on on-farm milled feed or "semi-commercial" aquafeeds (De Silva et al. 2007). The fact that there has been a considerable increase in aquaculture production, De Silva et al. (2007) concluded that these feeds might have contributed substantially to the growth of the sector. In Nigeria, small-scale feed millers or on-farm manufacturers produce over 60% of commercial feeds (Hecht, 2007). Among the challenges highlighted is that most of the operators do not have an adequately sized and pest-proof storage facility, which prevents them from purchasing raw materials in bulk when prices are low (Hecht 2007; Nyandat 2007).

Aquaculture is believed to be favorable for contract farming due to perishability, high technical expertise, food safety controls and high fixed costs in processing (Technoserve and IFAD 2011; GIZ 2013). However, case studies in sub-Saharan Africa are limited. Contract farming generally obligates farmers to supply volumes and qualities as specified and for buyers to make payments as agreed upon in the contract. Buyers typically provide embedded services, such as upfront delivery of inputs, as well as extension services, among others (GIZ 2013). One case is mussel and oyster contract farming in South Africa (Karaan 2002). Although the details of the relationships in the contractual arrangement are not explicitly defined in the article, the buyer provided rafts on a cost-recovery basis, extension services, guaranteed markets, inputs on account, and other frequent logistical assistance (Karaan 1999). The study found contract growers were more efficient and had high technical competence and lower transaction costs than small independent growers (Karaan 2002).

Regarding the applicability of these cases in Zambia and Malawi, input franchise models and cooperative models would be most applicable as feed distribution channels to rural smallholders. In Zambia, there are agro-dealers who may or may not be fish feed dealers. Establishing "aquashops," as in Kenya, by establishing a network link with feed producers will facilitate stocking of high-quality fish feed. Similarly, aquashop operators would be trained and could then offer training to farmers. The cooperative model is farmer-led and producer-driven. Farmers can be empowered to forge avenues to aggregate fish feed orders to meet the critical mass in distribution or buy feed in volumes and sell to other farmers. There is, however, a need to invest in these cooperatives through training and capital investment to boost their operations. There is an opportunity for cooperatives to engage in producing pelletized on-farm feeds to increase their profitability while still ensuring access to nutritious fish feeds. Again, there is a need to support the cooperatives with the required equipment and skills in feed formulation and processing.

Contract farming and franchising models are buyer-driven (Vorley et al. 2009) and require an interested private sector actor ready to take up the investment risks. Currently, there are no state/public millers in either Malawi or Zambia. PPPs, which are investments between the public and private sectors, are driven by donors and governments, particularly in capital investments or certification (Murekezi et al. 2018). The applicability of contract farming and buyer-driven franchising models among rural smallholders could be challenging because the commercial feed sector is still in its infancy. However, private sector investments could increase with its growth. PPPs could be integrated with other distribution models to facilitate their effectiveness.

Photo credit: Chosa Mweemba/WorldFish

WorldFish working with Great Lakes Product Limited Zambia.

Conclusion and recommendations

Low use of complete feeds among smallholder farmers is a key constraint to improving the performance of smallholder farmers in the aquaculture sector. Critical challenges in aquaculture for both Zambia and Malawi include access to quality inputs, particularly seeds and feeds, which account for the most significant proportion of operational costs in aquaculture. There is also a lack of technical knowledge in better management practices. Besides the perceived cost of buying commercial feeds, smallholder fish farmers have high transportation costs, as most feed distributors are located far from rural farmers. In Malawi, local commercial production of floating feeds is nonexistent. Feed producers in Zambia and Malawi import most ingredients in fish feeds, which impact the prices of commercial feeds. However, despite the challenges facing the aquaculture feed value chain in Zambia and Malawi, the sector does provide opportunities, particularly for the private sector and for smallholder engagement.

The following are some of the opportunities highlighted:

- Developing alternative fish feed solutions by using affordable local ingredients has been suggested as a substitute for imported ingredients, which are usually expensive.
- Private sector engagement could develop and strengthen feed distribution networks to make inputs more available in rural areas.
- In Malawi, there is an opportunity for private companies to produce feed in the country, as feed is currently imported from Zambia with an additional 16% import tax.
- Microfinance credit institutions and input suppliers can be integrated into the feed value chain to play a critical role in extending input credit to farmers.
- To increase profitability, farmers with more ponds would likely earn higher profits, as some costs, such as labor, could be fixed regardless of the number of ponds.
- Farmer groups and clusters could buy feeds together to access better prices and, due to the scale, reduce transportation costs.
- Producing on-farm pelletized feeds, either as individual aquapreneurs or clusters, could increase smallholder access to feeds that are locally available and at lower prices. However, there is a need to train aquapreneurs on appropriate feed formulations and processing to ensure high quality feeds.

Training farmers on feed management would reduce losses due to poor feeding practices and waste. Continuous training and improvement in better management practices could increase feed efficiency and profitability.

Based on the review and synthesis of the existing literature and project documents in Malawi and Zambia, there is still a significant gap on the economic assessment and performance of smallholder aquaculture.

The following research gaps need to be explored to develop the fish feed value chain:

- Calculate transportation costs for fish feed across the different distribution networks to establish viable and low-cost distribution channels.
- Assess the critical mass of minimum orders that could make it viable for the private sector to engage in feed distribution.
- Identify and segment farmer profiles and their willingness and ability to pay for commercial feeds.
- Assess options for microfinance and in accessing affordable cash and in-kind credit to buy commercial feeds.
- Assess commercial returns in the use of commercial feeds to capture different market scenarios.
- Explore and assess the capacity needs for potential on-farm feed millers.

Notes

[1] This is a common feeding practice that smallholder fish farmers in Malawi use based on personal communication from the WorldFish team in Malawi.

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We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decision-making on the critical issues of our times.

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