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Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA)

Ingredient and fish feed scoping report for Zambia

Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA): Ingredient and fish feed scoping report for Zambia

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About Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA)

WorldFish has partnered with the Norwegian Agency for Development Cooperation (Norad) on a 5-year project to develop low-cost and highly nutritious aquatic feeds based on novel ingredients. The project, known as Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa (FASA), will run from 2022 to 2027 with Norad funding the initiative through a NOK 80 million (approximately USD 8 million) grant. The project aims to enable 5000 smallholder aquatic food producers in Kenya, Nigeria and Zambia to test and use these feeds and ingredients, which will increase their income and improve their nation's food security as well as reduce waste and pollution. An estimated 30 and 40 percent of aquatic food producers engaged in the project will be women and youths, respectively.

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Introduction

Aquaculture production is one of the fastest growing sectors of the global food economy. Worldwide, it has increased by an average of more than 10% annually and accounts for about 50% of all fish consumed. However, production still remains far below demand, which may be connected to the high cost of fish feed.

Feed is one of the main inputs in aquaculture production, but infrastructure for fish feed is one of the least developed sectors of aquaculture, particularly in Africa and other developing countries of the world (Gabriel et al. 2007). To a large extent, sustainability in aquaculture relies on feed, which is necessary for the growth and survival of fish larvae (Jamabo et al. 2019). Ogueji et al. (2020) stated that good quality feeds in aquaculture is a key determinant for maximum growth in fish, feed use efficiency and flesh quality. Fish feed constitutes about 65%–70% of variable costs in fish culture (Soliman et al. 2018).

All fish need sources of feed to maintain their normal physiology and growth, which may be seen as an increase in the number of cells and invariably body length and weight. Fish feed can be grouped into three forms: natural live foods, conventional raw materials and non-conventional raw materials. Natural live food, such as plankton and other natural foods, occurs naturally in the environment where fish live (Jere et al. 2021). Non-conventional raw materials, such as blood meal, are usually rare in markets and not commonly used to produce fish feed commercially. Conventional raw materials are commonly known and widely accepted for use as fish feed (Gabriel et al. 2007). But irrespective of the classes of raw materials fish feed contains, supplying target organisms with a balanced diet is important to increase weight and high yields, particularly under intensive fish culture systems where all nutrients are supplied in complete feeds (Omitoyin 2007).

Feeds required to boost fish yields depend on their composition and the digestibility of the individual feed ingredients (Yossa et al. 2021). Adequate combinations of various feed components, through proper formulation, are critical for fish to enhance the digestibility and use of compound feeds. In Zambia, because of the country's reliance on imported feed ingredients, the soaring cost of formulated fish feeds is the main constraint holding back the expansion and development of the aquaculture sector (Mwema et al. 2022), and this has prompted efforts to look for suitable alternative feed ingredients. As such, there is a need to research conventional and non-conventional local raw materials and by-products to assess their potential as novel local ingredients in fish feeds. The aim is to develop low-cost sustainable feeds that have potential for high nutrient use in Zambia's growing aquaculture sector.

Objectives of the scoping study

The main objective of the study was to gather information on the sources, price, availability and seasonality of ingredients and fish feeds that are available in Zambia. Furthermore, the scoping provided insights on the fish feed value chain and its influences on the country's aquaculture industry.

The study also had three further specific objectives:

1. Present baseline information on the feed sector in Zambia.
2. Collate data on the sources, price, availability and seasonality of local feed ingredients and feeds in six provinces: Lusaka, Eastern, Southern, Northern, Luapula and North-Western.
3. Forecast future demands for ingredients and feeds to support the aquaculture industry in Zambia.

1. Methodology

1.1. Study site

The study was conducted in six provinces: Northern, Southern, Eastern, North-Western, Luapula and Lusaka (Figure 1). The selection of the provinces was based on a brief consultation with the Ministry of Agriculture, Ministry of Fisheries and Livestock, Indaba Agricultural Policy Research Institute, and WorldFish Zambia, as well as various feed millers and brewery companies. In addition, the selection criteria focused on areas that had high potential for aquaculture, strong agriculture practices in place, significant livestock and fishery production, and the presence of food and beverage processing companies. The criteria were established based on the fact that these areas would theoretically have the capacity to support sustainable fish feed production (CSO 2021).

1.2. Scoping design and sampling

This was a cross-sectional study that applied a purposive sampling technique. This non-probability sampling involved selecting units based on their purpose and specific characteristics that were needed for the targeted sample (Bhandari 2020). The selection of local ingredients and feeds was guided by their availability, taking into consideration seasonality, abundance over the past 5 years, quantity, and relative costs. Targeted nutrients included protein, carbohydrates, lipids, vitamins and minerals. These categories of nutrient sources were further grouped into animal-based and plant-based sources.

A ranking method was used based on specific categories to select districts and camps/wards where local ingredients and feeds are most located. In each of the six targeted provinces, the five top-performing districts were selected, from which the three top-performing camps/wards were then chosen. In total, the study targeted 30 districts and 90 camps/wards (Table 1). From these, black markets, feed outlet shops, local farmers, abattoirs, grain millers, food processing firms and brewers were visited.

1.3. Data collection

A semi-structured template was used to collect data through interviews with key informants, including feed millers, farmers, producers of raw materials (ingredients), sellers of raw materials, sellers of feeds, government officials, brewery companies and food processors (Annex 1). A total of 120 semi-structured templates were administered (30 districts + 90 camps/wards) (Table 1), and the scoping exercise lasted for 3 months (February–April 2023). The semi-structured template was designed to capture data on ingredients and fish feeds based on the seasonality of availability, quantity in metric tons or kilograms and the unit price in Kwacha per kilogram equivalent in a particular location. Additional information, such as demand, supply regimens and consumption by other competing users, was collected and used to determine the sustainability of the supply of local ingredients.

Before collecting the data, the template was pretested for 1 day at a nearby camp/ward in Lusaka. The aim was to ensure that the template captured the required information and that the data collector mastered the template.

	Province	Number of districts	Number of camps/wards
	Eastern	5	15
	North-Western	5	15
	Southern	5	15
	Luapula	5	15
	Northern	5	15
	Lusaka	5	15
Total	**6**	**30**	**90**

Table 1. Distribution of provinces, districts and camps/wards visited.

The selection criteria for the study provinces was based on several factors emanating from preliminary consultations with various stakeholders, such as the Ministry of Agriculture and the Department of Fisheries. The presence of feed millers and brewery companies was viewed as a huge contribution to ingredient availability in each catchment area. Also, consideration for selection was given to high potential areas for aquaculture and livestock activities.

It was also clear that the selected provinces were endowed with food and beverage processing companies, and the presence of these facilities guaranteed the sustainability of fish feed production. Overall, the selected provinces represent the most productive agroecological zones in Zambia. The geographical distribution of the provinces is shown in Figure 1.

1.4. Ingredients and fish feed samples

Six kilograms of novel local ingredients were collected for each of the five targeted nutrients (protein, carbohydrates, lipids, vitamins and minerals). In total, 50 ingredient samples (300 kg) were collected (6 kg per ingredient, 5 nutrient categories, 10 samples). Additionally, 30 kg of fish feed samples of assorted brands were collected (0.5 kg for each fish feed size for tilapia and for catfish, 3 commercial feed millers, plus 3 local feed millers, 10 samples per feed mill). Thus, a total of 330 kg of assorted samples of ingredients and complete feeds were collected from the scoping exercise. The collected samples were packed in Ziplock bags and then properly sealed and labeled. The labels on each sample bag included the date of collection, name of collector, location, area coordinates, type and quantity. The samples were then shipped to WorldFish Malaysia for proximate analysis and digestibility studies and the Swedish University for Agriculture Sciences for biochemical analysis and improvement. From this consignment, 11 plant-based and animal-based ingredients were finally selected and considered for the digestibility trials.

1.5. Data analyses

Descriptive statistics were used to analyze the data and summarize the dataset for the various categories of ingredients and feeds. The data was segregated from the food sources group, location, seasonality of availability with respect to quantity produced, estimated market prices and estimated amount consumed by competing users. The information was collated in spreadsheets using Microsoft Excel 2016 (summation, percentage and average functions). Relevant statistical analyses were then performed using IBM SPSS software version 26 (Core Team 2012).

Source: Google map 2011.

Figure 1. Provinces sampled for the scoping study.

2. Results

Across the six provinces, the survey sampled and interviewed a total of 365 respondents: 354 were general farmers while the remaining 11 were fish farmers. As shown in Table 2, the valid percentage in the output represents non-missing cases, while cumulative percentage stands for frequency distribution.

	Frequency	Percentage	Valid %	Cumulative %
General farmers	354	97	97	97
Fish farmers	11	3	3	100
Total	**365**	**100**	**100**	

Table 2. Respondents.

Province	Frequency	Percentage	Valid %	Cumulative %
Eastern	180	49.3	49.3	49.3
Luapula	32	8.8	8.8	58.1
Lusaka	27	7.4	7.4	65.5
Northern	80	21.9	21.9	87.4
North-Western	28	7.7	7.7	95.1
Southern	18	4.9	4.9	100
Total	**365**	**100**	**100**	

Table 3. Respondents per province.

2.1. Sources of ingredients

Three main categories of sources for ingredients were identified and segmented during the study: plant-based, animal-based and other, which included ingredients such as worms. Plant ingredients accounted for 71% and animal ingredients 22%, while other ingredients accounted for 7%, as shown in Figure 2.

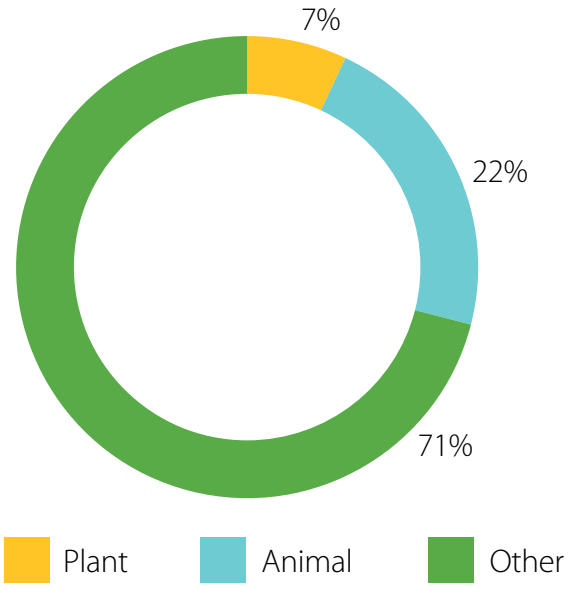

Figure 2. Percentage of ingredients, by source.

2.1.1. Plant-based ingredients

Out of all of the plant-based ingredients sampled during the study, only five were picked for consideration in the digestibility trials: chikanda, velvet bean meal, velvet meal seed, sunflower cake and tea waste. A complete list of the plant-based ingredients sampled is shown in Table 4.

Ingredient	Nutrient target	Source category	State
Maize	Carbohydrate	Plant	Unprocessed
Rice	Carbohydrate	Plant	Unprocessed
Sorghum	Carbohydrate	Plant	Unprocessed
Finger millet	Carbohydrate	Plant	Unprocessed
Cassava	Carbohydrate	Plant	Unprocessed
Chikanda	Unknown	Plant	Unprocessed
Soybeans	Protein	Plant	Unprocessed
Sunflower	Protein	Plant	Unprocessed
Cow peas	Protein	Plant	Unprocessed
Velvet beans	Protein	Plant	Unprocessed
Pumpkin leaves	Vitamins	Plant	Unprocessed
Palm tree seed oil	Lipids	Plant	Processed
Sunflower cake	Protein	Plant	Processed
Tea waste (red dust)	Protein/vitamins	Plant	Processed
Sunflower extra residue	Lipids	Plant	Processed
Maize brain	Carbohydrate	Plant	Processed
Rice brain	Carbohydrate	Plant	Processed
Cotton seed waste	Protein	Plant	Processed

Table 4. List of selected plant-based ingredients during the study.

2.1.2. Availability of plant ingredients, by province

Eastern had the most respondents (180) and the highest number of plant-based ingredients (15) followed by Northern (13) and Luapula (13), Lusaka (11), North-Western (9) and then Southern (5).

A principal component analysis (PCA) was done on the ingredients to illustrate the availability and sustainability of each one. A positive outlay on the grid in the output indicates the availability and sustainability of ingredients in the respective province, as shown in Figure 3.

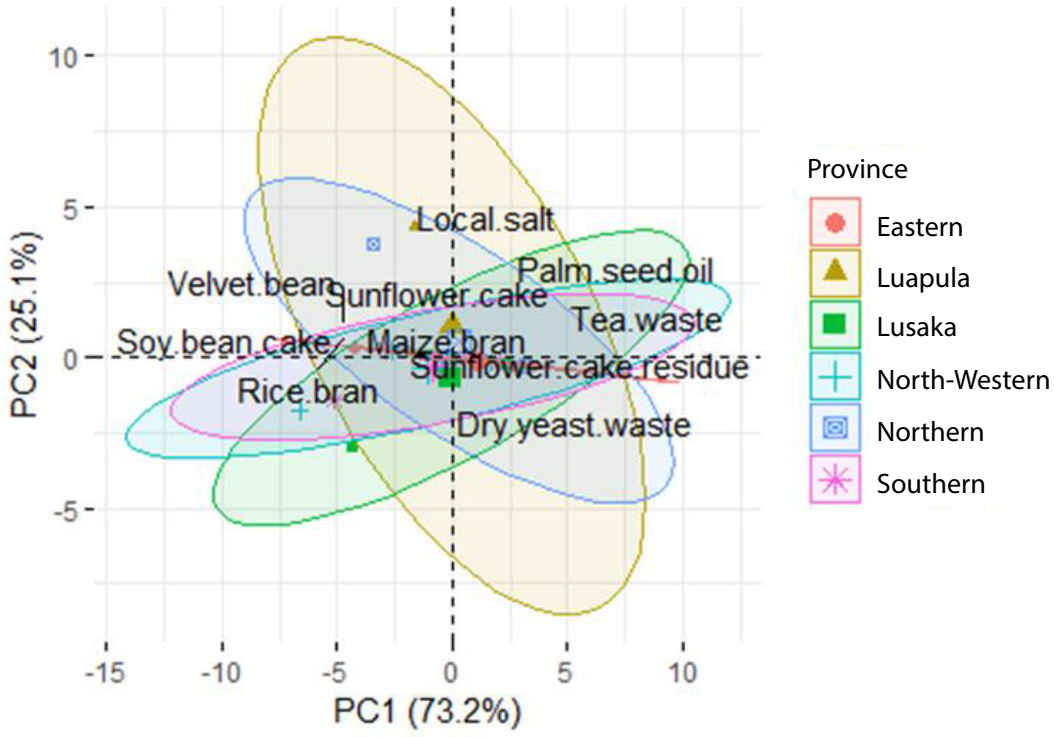

Figure 3. Availability of ingredients, by province.

2.2. Animal-based ingredients

Five animal-based ingredients, as shown in Table 5, were selected and shipped to Malaysia for assessment.

Ingredient	Nutrient target	Source category	State
Kakeya	Protein	Animal	Unprocessed
Chisense	Protein	Animal	Unprocessed
Crayfish	Protein	Animal	Unprocessed
Caterpillar 1	Protein	Animal	Unprocessed
Caterpillar 2	Protein	Animal	Unprocessed

Table 5. Animal-based ingredients selected during the study.

Eastern had the highest number of animal-based ingredients (10) followed by Southern (6), Northern (5), Lusaka (4) and then Luapula (3) and North-Western (3). Ultimately, only five ingredients were picked and shipped to Malaysia for laboratory assessment. A PCA was done on the ingredients for each of the six provinces. Positive outlay on the grid in output indicates available ingredients in the province, as shown in Figure 4.

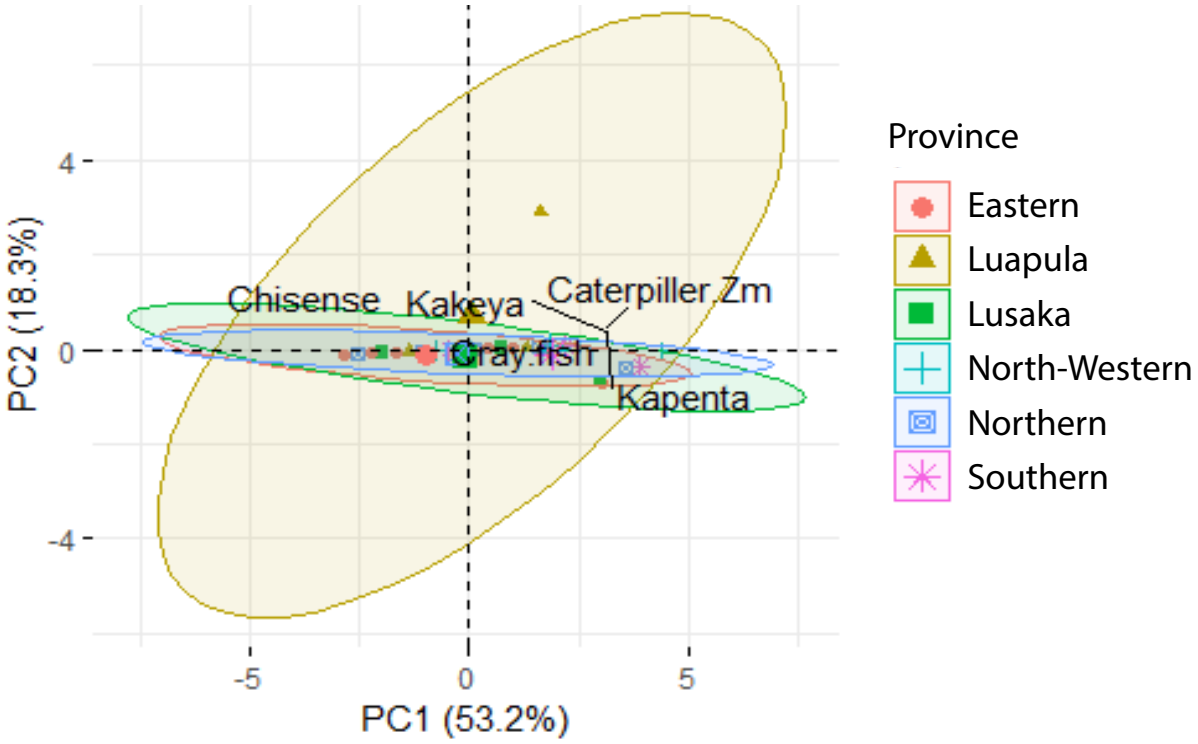

Figure 4. PCA of available animal ingredients, by province.

2.3. Ingredient pricing

Prices of the ingredients varied, with animal-based ingredients falling on the higher side, at ZMW 400–700, while plant-based ingredients recorded comparatively lower pricing, as low as ZMW 2.5 for a gallon of maize. As shown in Table 5, the minimum price was ZMW 2.5 for maize, and the maximum price was ZMW 700 for a live goat.

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Price	188	2.50	700.00	184.6862	12.7667	175.05

Table 6. Minimum and maximum average prices (ZMW) among the ingredients.

As shown in Figure 5, plant-based ingredients cost as low as ZMW 0, while animal-based ingredients cost ZMW 400 or more. The curve in the graph is skewed to the right, where pricing oscillates for animal-based ingredients. Most of the average price values for the plant-based ingredients fall on the left of the mean (ZMW 128.6).

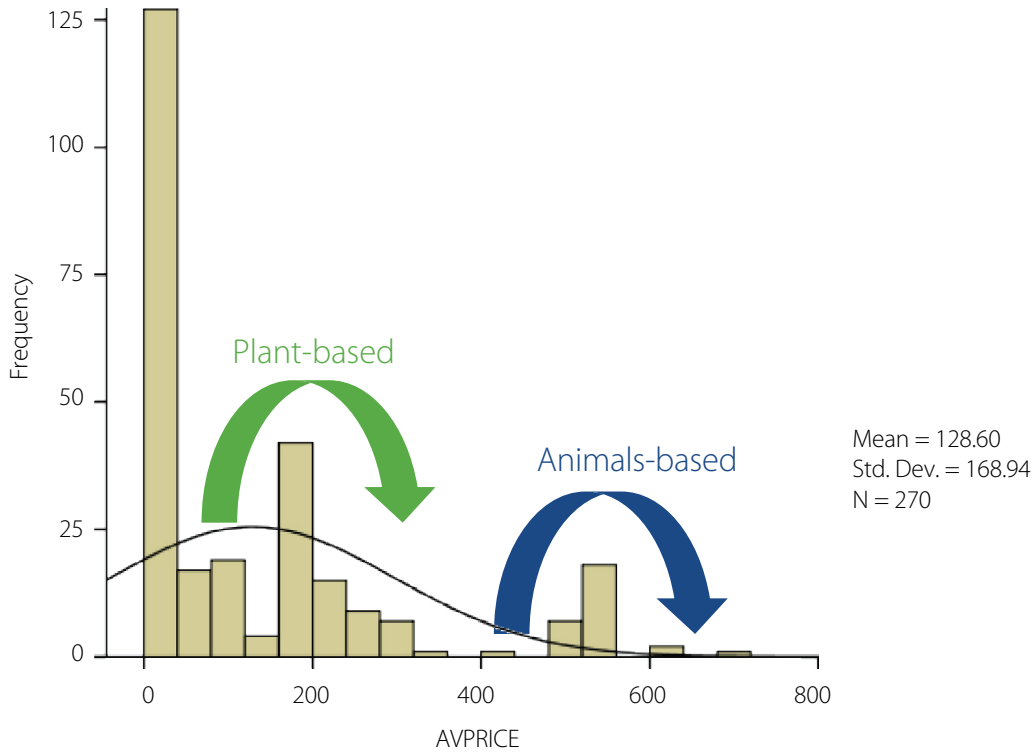

Figure 5. Average price (AVPRICE) among the ingredients.

2.4. Availability of ingredients, by season

Zambia has three seasons: the cold and dry season (May to mid-August), the hot and dry season (mid-August to mid-November) and the rainy season (mid-November to April). Except for doves, garlic and sheep, which are only available for a few months during the cold and dry season, the rest of the ingredients are available across all of the months of the other three seasons (Figure 6).

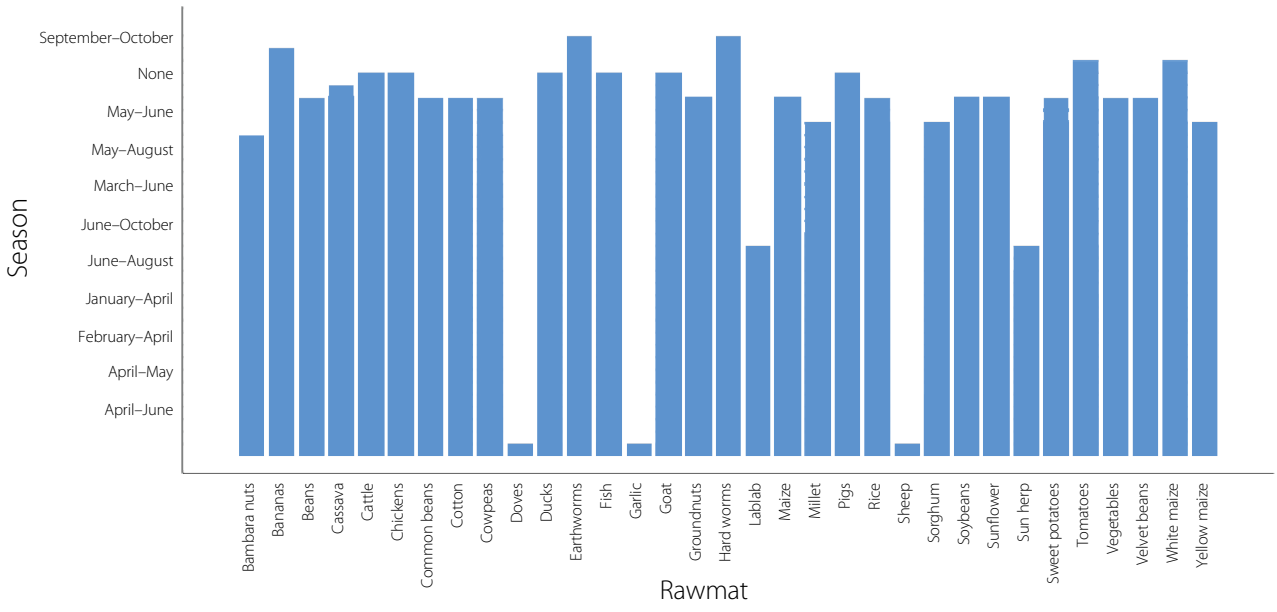

Figure 6. Availability of ingredients (RAWMAT), by season.

2.5. Availability of ingredients because of off-takers

The number of off-takers affect the availability of ingredients in the provinces. As shown in Figure 7, the majority of the ingredients are taken up through domestic consumption, followed by local market demand, then the Food Reserve Agency (FRA) and road traders, after which demands tails off to breweries.

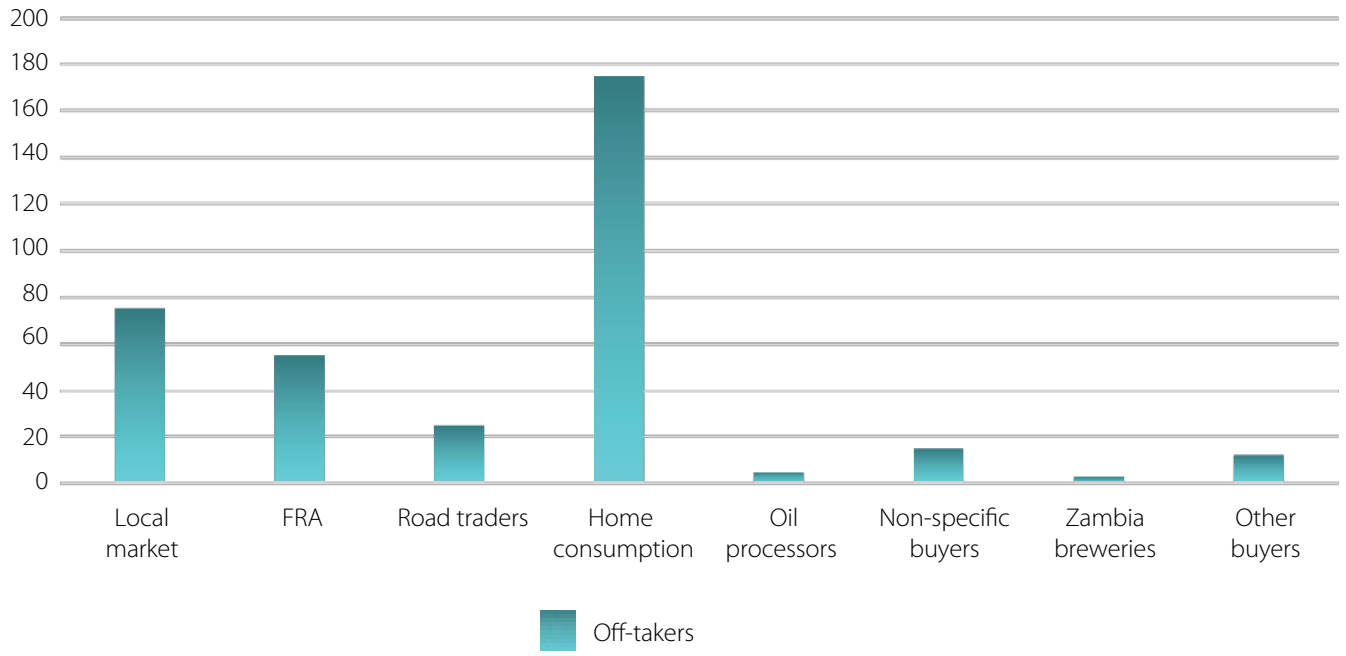

Figure 7. Number of off-takers of ingredients.

3. Discussion, conclusion and recommendations

The scoping study established that both plant- and animal-based ingredients exist in the six provinces surveyed. About 71% of the ingredients are plant-based and readily available in season at affordable pricing. Eleven plant-based and animal-based ingredients selected for onward digestibility trials should be adequate to generate information on inputs for feed formulations.

Although the six animal-based ingredients only accounted for 22% of the sources of ingredients, they had rich protein profiles, though they are not readily available and are on the higher side of pricing. Additionally, an average of 78.6% of animal ingredients produced by fishers, processors and forest gatherers were used for human consumption, significantly outpacing other uses like fish feeds. Therefore, these animal-based ingredients most likely will be unaffordable to most small- and medium-scale fish farmers in their quest to formulate cost-effective novel feeds.

Significant amounts of ingredients are taken up through home consumption and local markets, but this off-take will have little effect on the availability of the ingredients since the focus in feed formulations is on by-products rather than raw materials.

The abundance and availability of the selected ingredients across the six provinces in the study ensure the sustainability of the feed industry once the feeds are formulated and customized to the local farmers.

Sources of plant-based ingredients produced by agricultural farmers were more than double (56%) those of processors (23%), who produce by-products such as maize bran, rice bran, sunflower cake, soybean cake and brewery waste. This trend will be helpful in working with and helping smallholder farmers use intrafarm resources to formulate novel feeds.

Since Lusaka and Southern provinces are in close proximity to fish feed factories, the use and demand for commercial fish feeds was higher than the other provinces. This knowledge will be helpful for future assessments of the impact of the project intervention on cost-effective novel feed implementation.

From the scoping study, we make three recommendations:

1. Conduct a proximate analysis and digestibility studies on the selected ingredients to understand their nutritional composition and potential use as local fish feed ingredients.
2. Most ingredients are readily available soon after crop harvest in April, peaking in September/October, so timely access to these ingredients for feed formulations will be key to provide consistent feed production.
3. Encourage private sector participation in the production of ingredients to supplement aquaculture and flood the feed industry.

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Appendix

Respondents by province

Province					
		Frequency	**Percentage**	**Valid %**	**Cumulative %**
Valid	Eastern	180	49.3	49.3	49.3
	Luapula	32	8.8	8.8	58.1
	Lusaka	27	7.4	7.4	65.5
	Northern	80	21.9	21.9	87.4
	North-Western	28	7.7	7.7	95.1
	Southern	18	4.9	4.9	100.0
	Total	**365**	**100.0**	**100.0**	

Respondents by gender

Gender					
		Frequency	**Percentage**	**Valid %**	**Cumulative %**
Valid		25	6.8	6.8	6.8
	Female	159	43.6	43.6	50.4
	Male	181	49.6	49.6	100.0
	Total	**365**	**100.0**	**100.0**	

About WorldFish

WorldFish is a leading international research organization working to transform aquatic food systems to reduce hunger, malnutrition and poverty. It collaborates with international, regional and national partners to co-develop and deliver scientific innovations, evidence for policy, and knowledge to enable equitable and inclusive impact for millions who depend on fish for their livelihoods. As a member of CGIAR, WorldFish contributes to building a food- and nutrition-secure future and restoring natural resources. Headquartered in Penang, Malaysia, with country offices across Africa, Asia and the Pacific, WorldFish strives to create resilient and inclusive food systems for shared prosperity.

For more information, please visit www.worldfishcenter.org