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Extension manual on quality low-cost fish feed formulation and production

AFRICAN DEVELOPMENT BANK GROUP
GROUPE DE LA BANQUE AFRICAINE DE DÉVELOPPEMENT

WorldFish

TAAT
Technologies for African Agricultural Transformation

Extension manual on quality low-cost fish feed formulation and production

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Overview

Guide for users

The material in this guide has been put together to assist extension workers and other trainers in facilitating and delivering improved technologies to catfish breeders for profitable ventures. The content uses plain language for easy understanding.

In the modules, learning objectives, activities, materials and facilitation methods have all been highlighted, along with other key components, including instruments for pre- and post-course evaluations. Output evaluations, outcome evaluations and feedback mechanisms have been provided for periodic improvement of the manual. To achieve the learning objectives, activities must be properly scheduled and executed. The learning materials have been packaged for different hatchery and nursery staff to acquaint themselves with the knowledge and skills necessary to run a successful hatchery operation.

This manual is for instruction only. Trainers should adjust the modules as needed depending on the knowledge and experience of the trainees. The training methodologies and techniques for each module have been described in detail and carefully planned. Sticking to the methodologies will ensure that trainees actively participate and will help trainers achieve the expected outcomes. The modules have been arranged in order with a set time in which to discuss the information. If necessary, trainers, in light of their own experience, can change or modify the modules while maintaining the topic. However, starting and ending the session on time is important for both trainers and trainees. Assessing the success of the program is necessary for everyone involved, so trainees need to be evaluated during and after the modules to assess how much they have learned. Instruments for evaluation assist trainers in assessing how well the set targets have been met, while feedback from trainees enables assessment of the progress toward achieving the overall objectives.

Targeted audience

The manual is aimed at mainly catfish breeders—both women (30%) and men (70%) as well as youths (25%)—according to their level of involvement along the aquaculture value chain. Any catfish breeder within 15 to 60 years of age is considered a prospective learner.

FISH CRP

The CGIAR Research Program on Fish Agri-Food Systems (FISH) led by WorldFish is developing guidelines for better management practices (BMPs) at the global level and contextualized BMP resources at the country level to support sustainable low-cost fish feed production in WorldFish focal and scaling countries. This BMP manual, produced as part of this approach, aims to enhance the capacity of fish millers, grow-out fish farmers and extension service providers in Africa to support scaling of low-cost fish feed production.

Background

Technologies for African Agricultural Transformation (TAAT) is a framework developed by the African Development Bank as part of its efforts for agriculture development on the continent. It aims to enhance the use of proven agricultural technologies among stakeholders to foster the changes needed through farm-level productivity and value chain development. Aquaculture is one of the nine commodity compacts with proven technologies that have the potential to increase yields and benefits for upscaling in 12 countries in Africa: Benin, Burundi, Cameroon, Cote d'Ivoire, Democratic Republic of Congo, Ghana, Kenya, Malawi, Nigeria, Tanzania, Togo and Zambia. Led by WorldFish, the TAAT Aquaculture Compact has been training aquaculture subject matter specialists and youth agripreneurs as facilitators under capacity development and technology outreach.

There are three specific objectives of the Aquaculture Compact:

1. To create an enabling environment for aquaculture technology adoption by value chain actors.
2. To effectively deliver technologies to fish farmers and other actors along the aquaculture value chain.
3. To increase aquaculture production and productivity by identifying and disseminating quality tilapia and catfish seed, producing low-cost fish feed and through value addition.

In Africa, since fish feed makes up 60%–80% of production costs, it is inextricably linked to profit margins for fish farmers. Despite the high cost of feed, however, some commercial fish brands on the market are of poor quality. Using low quality feed can cause poor fish growth, pollute pond water and make fish prone to diseases and increased mortalities. Quality feed formulation is an integral part of a profitable fish farming business. However, since quality fish feeds are often imported, the weak local currency makes the cost of such products prohibitive for smallholders. Quality low-cost and well-formulated fish feed will, when used alongside other BMPs, improve the productivity of fish farming and increase farmers' income, contributing to greater profit and better human nutrition and food security. The purpose of this manual is to distribute methods that will expose training officers, extension workers, feed millers and fish farmers to BMPs in quality fish feed production and facilitation techniques.

Rationale

The TAAT Aquaculture compact has noted that fish farmers in Africa are confronted with many challenges in producing good quality feed. These include lack of access to quality feed ingredients, low skills of fish farmers and feed millers in formulation and preparation, nutrient requirements of fish, storage and packaging, feeding management, BMPs. This manual has been put together to assist extension workers and other trainers in facilitating and delivering improved technologies to formulating balance diet for aquaculture that promotes optimal fish growth and health.

Development objectives

i. To enhance the productivity of catfish.
ii. To increase farmers' income.
iii. To improve food (fish) security and nutrition.

Learning objectives

i. To enhance knowledge on how to identify local ingredients for fish feed production.
ii. To acquire experience of BMPs in formulating and producing feed for tilapia and African catfish.
iii. To build entrepreneurial skills in business plan development for sustainable low fish feed production.

Module instructions

Trainers should refer to the following instructions for how to begin and end modules 1 through 5.

How to start each module

Before beginning each module, trainers must prepare prompting questions for the participants. The purpose of the questions is to encourage participants to share their knowledge about the intended contents of the module. Next, trainers must then conduct a pre-evaluation by soliciting feedback from the participants. The purpose of the pre-evaluation is to assess the knowledge, skills and attitude of the participants before they start learning. After the pre-evaluation is complete, trainers can begin the module.

Each module begins with a set of questions about the content. This helps the trainers assess how much the participants know before the module begins.

How to end each module

Before ending each module, trainers must carry out a learning activity that leads to discussion, memory retention and action. Methods that trainers can use include lecturing with audio-visuals, brainstorming on issues raised, role playing on key issues, and group discussion and feedback. For learning materials, trainers can either write narrations or draw further illustrations about the content of the module and indicate or attach further reading material related to the content.

Each module also ends with a set of questions about the content. This helps trainers assess how much the participants learned during the module.

Fish feed at an IITA Youth Agripreneurs fishpond, Ibadan, Oyo State, Nigeria.

Module 1: Introduction

Pre-evaluation questions

1. Which of the following is not a feedstuff for fish?
   a) fishmeal
   b) rice
   c) palm kernel
   d) rice bran

2. Which of the following is an anti-nutritional factor?
   a) vinegar
   b) leucin
   c) gossypol
   d) palm oil

3. Why is food important for fish?

4. Why are carbohydrates important for fish feed?

5. Why is protein important for fish feed?

6. Why are fats important for fish feed?

7. Why are vitamins important for fish feed?

8. Why are minerals important for fish feed?

9. Why is water important for fish feed?

10. Why is processing feedstuffs important in fish nutrition?

1.1. Importance of good quality feeds

When fish eat a balanced diet, they grow fast and stay healthy. Fish food consists of both natural food and artificial (manufactured) feeds. In natural waters and well-fertilized ponds, microscopic plants (phytoplankton), microscopic animals (zooplankton), insects, crustaceans, copepods and molluscs are examples of natural foods. Natural food organisms in the water provide essential nutrients.

When natural foods are not available in sufficient quantity to provide adequate nutrients for fish growth and development, supplementary feeds can be used at regular intervals, such as daily or weekly. Supplementary feeds are manufactured or grown outside the fishpond. As the name suggests, these feeds supplement natural foods. They are not nutritionally complete and will not adequately support fish growth in the absence of natural foods. Some examples of supplementary fish feeds are commercially produced rations. They include rice bran, cassava leaves, kitchen refuse, oil seed cakes and other agricultural products and by-products. These are used in both extensive and semi-intensive culture systems.

In recirculating aquaculture and indoor culture systems, natural food is totally absent. Therefore fish farmers must feed their fish nutritionally with complete manufactured feeds that contain all essential nutrients. This is applicable only in high technology-based culture systems.

Complete (or balanced) artificial feeds are well-compounded mixtures of feedstuffs that can be mashed or used in pelleted form. Mash feeds are good for fry, while pellets are best for fingerlings, juveniles and adults, depending on pellet size.

Although using artificial feeds can be costly, especially commercially compounded rations, they do offer several advantages for fish culture:

- They enable high stocking density (stocking maximization), especially in polyculture systems.
- They promote faster fish growth, since food is always available.
- High fish yield is guaranteed relative to the stocking density.
- Uneaten artificial feed in the pond water is biodegradable, so it acts as fertilizer to promote plankton growth.
- During feeding, fish farmers can study the behavior (activity) of their fish and monitor their health.

Good quality feeds are important for nutrient-dense diets. A nutrient-dense diet is determined by the amount or proportion of a particular nutrient in relation to the total amount of nutrients in the diet. Commonly, a nutrient-dense diet is rich in protein and energy, and the amount of the specific nutrient is represented in proportion to the total energy content of the diet. A simple,

nutrient-dense diet can be rich in vitamins and minerals and have a low amount of fat and relatively few calories. (For example, many fruits and vegetables are considered vitamin and mineral nutrient-dense foods.) In general, fish feeds are nutrient-dense and low in calories. They are high in protein but low in sodium and total fats, and they contain vitamins, minerals and polyunsaturated acids and omega-3 fatty acids.

Good quality feed is key to fish production because it improves the yield or the quality of fish products, which in turn increases income. It is not possible for fish farmers to make a profit without using balanced feed for the fish. This is because feed has a direct impact on growth rate, productivity and animal health. A lack of good quality food can predispose fish to diseases, including nutritional diseases caused by a deficiency in certain nutrients.

1.2. Feedstuffs in fish culture

Feedstuffs are materials/ingredients grown or developed for feeding fish or for manufacturing fish feeds. Artificial feeds are produced by carefully selecting and blending ingredients to provide highly nutritious diets that induce high growth, maintain fish health and increase the quality of fish and associated end products, such as fish oil and fish eggs.

Feeds and feedstuffs contain the energy and nutrients that are essential for the growth, reproduction and health of aquatic animals. Dietary nutrients are essential for constructing living tissues. They are also a source of stored energy for fish digestion, growth, reproduction and other life processes.

Feedstuffs are either dry or wet (Plates 1 and 2). Dry feedstuffs are easy to store, transport and distribute to farmers or end users. Examples include palm kernel cake, soybean meal, fishmeal and cereals. On the other hand, wet feedstuffs require special treatment before they can be fed to fish. Examples include brewery waste and molasses.

In fish culture, feedstuffs are classified into energy feedstuffs and protein supplements. Energy feedstuffs are essentially of plant origin and contain less than 20% crude protein. Examples include cassava, wheat offal, rice bran, maize, and guinea corn. Protein supplements are made from either plant or animal materials and contain 20% crude protein or more. Examples of animal protein include fishmeal, bone meal, blood meal and poultry meal. Soybean meal, groundnut cake and cottonseed cake are some examples of plant protein materials. Protein of animal origin is of higher quality than that of plant origin.

The dietary protein requirements for catfish and tilapia at various stages of growth are shown in Table 1.

1.3. Feed ingredients and formulation

Individual feed ingredients may be fed to fish to supplement the natural food in a pond. However, it is better to fertilize the pond than to use a single ingredient. Combining ingredients makes better quality supplemental feed. A general rule is that fish grow well on feed containing 20%–30% crude protein, of which 2%–10% of the protein is from animal sources. When natural food is abundant and fish are stocked at low densities, then a 20%–25% protein content is sufficient. A crude protein content of at least 30% is more suitable for commercial operations where fish are stocked at higher densities and water exchanges are frequent.

When choosing feed ingredients, certain conditions must be met to produce good and quality feed:

- *Cost*: It is well known that feed represents about 70% of the total production cost in fish farming. It is therefore important to consider the cost of materials or ingredients used in fish feed production and to work on reducing cost without compromising quality.
- *Age of fish*: The stage of life for fish determines their nutritional requirements. Younger fish need feed with high quality protein, which is easily digestible. In some species, such as catfish, fingerlings require a crude protein above 45% while adults need about 30%.
- *Species*: Some fish species are carnivores, while others are herbivores. This feeding behavior determines, to a large extent, what they will accept as feed or food.
- *Nutritional composition*: This is the proportion of nutrients in the feed ingredients, including crude protein, carbohydrates, crude fat, vitamins, minerals and gross energy.
- *Nutrient digestibility or availability*: This refers to the extent to which fish can digest and absorb nutrients in the feed ingredients. Some ingredients contain certain nutrients that fish

cannot use. When the nutrient composition of these ingredients is determined at a laboratory, the nutrients might appear present, but in reality they are only available in a form that the fish might not necessarily be able to digest. An example is phosphorus contained in phytate. It forms complexes with either metals or proteins, so it is not available for fish.

- *Palatability*: This is the preference fish have for a particular feed or their ability to readily start eating and keep eating a specific feed.
- *Anti-nutritional factors*: These are biological compounds in feed ingredients that cause disease in fish and thus reduce nutrient use and fish growth. Anti-nutritional factors include gossypol, tannin, saponin, cyanogenic glycosides, lectins, protease inhibitors and toxic amino acids.
- *Danger-free*: Some feed ingredients can contain harmful substances, like plastic, pieces of metal, nylon and even heavy metals.
- *Stability*: This is the ability of feed ingredients to remain unchanged in quality when stored.
- *Inclusion rate*: This is the amount of feed ingredients incorporated into a feed formula. Most nutritionists and feed manufacturers have their own unique proportions of feed ingredients in a formula to produce fish feed.

1.4. Nutrient requirements for fish

In general, farming aquatic organisms is divided into intensive, semi-intensive and extensive. The difference depends on the degree of human intervention in their management, which gradually increases from extensive to intensive farming. This intervention can be quantified with the amount and quality of feeds provided, the elimination of catabolites (substances produced by the process of catabolism) and the supply of oxygen in the farmed water. In recent decades, the nutritional requirements of farmed fish species, formulation of animal feed and management of animal feed have been the subject of much research.

Standard nutritional requirements for fish are based on the lowest amount of nutrients necessary for good growth and health. These requirements vary with species and age.

To achieve optimal growth and production, fish must be fed a diet that meets all their nutritional requirements. These are divided into six classes, carbohydrates, protein, fats, minerals, vitamins and water.

1. *Carbohydrates*: These serve as a source of energy in fish feed, but they are also used as binders. Carnivorous fish require fewer carbohydrates than omnivorous fish.

2. *Protein*: This provides limited energy, but it is important for synthesizing and building body tissues, growth maintenance, reproduction, enzymes and hormones, egg production, etc.

S/No	Common name	Fish	% crude protein requirement
1.	Tilapia	*Oreochromis niloticus*	
		Fry	35
		Fingerlings	30
		Juveniles and adults	25
2.	African catfish	*Clarias gariepinus*	
		Fry	50
		Fingerlings	40
		Juveniles and adults	35
3.	Red mud catfish	*Heterobranchus bidorsalis*	
		Fry	50
		Fingerlings	40
		Adults	35

Note: More details on the nutrient contains of feedstuffs and the requirements of tilapia, catfish and many other species are available free of charge at www.iaffd.com/home.html?v=3.13.

Table 1. Dietary protein requirements for catfish and tilapia.

3. *Fats*: These provide fish with a large amount of energy, and they contain essential fatty acids needed for physiological processes.

4. *Minerals*: These are inorganic chemicals required for normal health and growth, and for controlling physiological processes.

5. *Vitamins*: These are organic chemicals needed in small amounts for normal health and growth, and for controlling body enzymatic processes.

6. *Water*: This is the universal solvent needed for all bodily functions.

The following are factors that affect the nutritional requirements of fish:

- *Genetics*: Variation in species might also mean variation in nutritional requirements. The potential growth rate and the efficiency of absorbing and using nutrients in fish feed will determine which nutrients are included.
- *Life stage or age*: Nutritional requirements are related to the stage of maturity of fish and its weight.
- *Reproductive state*: Female broodfish producing eggs and male broodfish producing milt will need different nutrients compared to fry. Nutrients that meet the current anabolic needs of the fish are important.
- *Temperature of the environment*: Nutritional requirements can also depend on the ambient temperature of the water derived from the climate where the farm is located. When digested, some feed can produce heat, which could be desirable for fish raised in cold regions.

1.5. Nutrient composition of feedstuffs

There are six nutrients in fish nutrition: water, carbohydrates, lipids, proteins, minerals and vitamins. Fish derive energy from lipids, proteins and carbohydrates. The chemical energy or heat density available for fish to use is 9 kcal in 1 g of fat, 4 kcal in 1 g of protein and 4 kcal in 1 g of carbohydrates. The term "nutrient-density" refers to the amount and type of a particular nutrient, or combination of them, contained in a feed, usually a pellet of specific size or volume. For example, a high-performance grow-out pellet could contain a high concentration of protein to supply the amino acids necessary to build muscle and support fast growth. The concept of nutrient-density encompasses the overall composition of the diet in relation to nutrients as well as caloric or energy density. The caloric or energy density of a feed is the number of calories (in relation to the total amount of nutrients) in a feed pellet of specific size or volume.

To increase the nutrient and energy density of a feed, something has to be taken out to provide room for the selected nutrient. What is decreased in the diet is usually carbohydrates, particularly in fish feeds. Most species of fish derive energy from proteins and fats more efficiently than from carbohydrates, similar to some terrestrial carnivorous species, such as cats. The moisture content of a feed pellet also will influence its nutrient and energy densities. More water adds weight but no nutrients or calories, so dry, nutrient-dense feeds will have higher energy and nutrient densities.

A wide range of local feedstuffs, such as agricultural by-products, animal meals and on-farm products, are available in African countries for farmers to use in fish culture. The conversion ratio in Table 2 shows the dry weight of feed needed to produce 1 unit wet weight of fish. A low conversion ratio means that fish will convert the feed into flesh more efficiently. High ratios indicate less efficient conversion. For example, if a diet were made of a single ingredient, it would take about 4–6 kg of ground maize and 10–20 kg of cassava peel to produce 1 kg of fish flesh.

1.6. Processing feedstuffs

Most feedstuffs have anti-nutritional factors, which are harmful to fish. These are substances that alter the nutritional value of the feedstuffs and at the same time affect the health of fish. They can be inherent to foodstuffs or the contaminants on the feedstuffs. They prevent easy digestion of nutrients in the feed. One of the ways to destroy anti-nutritional factors is to heat-treat feedstuffs. Heat destroys such factors as tripsin inhibitors in raw soybean or groundnut as well as gossypol in cottonseed.

Processing feed stuffs can also include one or a combination of grinding, proportioning, mixing, chaffing, soaking, heat treatment, alkaline treatment, urea treatment, tannic acid treatment, pelleting, etc. In their natural environment, fish have developed a wide variety of feeding specializations (behavioral, morphological and

physiological) to acquire essential nutrients and use varied food sources. Based on their primary diets, fish are classified as carnivorous (consuming largely animal material), herbivorous (consuming primarily plants and algae) or omnivorous (having a diet based on both plant and animal materials). However, regardless of their feeding classification, in captivity fish can be taught to readily accept various prepared foods that contain the necessary nutrients.

Increased understanding of the nutritional requirements for various fish species and technological advances in feed manufacturing have allowed the development and use of manufactured or artificial diets (formulated feeds) to supplement or replace natural feeds in the aquaculture industry. An abundant supply of feedstuffs is available, and fish farmers are now able to prepare their own fish feeds from locally available ingredients.

The following are the main sources of nutrients for fish feed:

- *Proteins and amino acids*: There are plant and animal sources of protein. The plant sources are soybean meal, legumes and wheat gluten, and many plant-based concentrates (such as corn protein concentrate and sunflower concentrate) are excellent sources of protein.
- Animal protein sources include fishmeal, magmeal from black soldier fly larvae fish hydroxylate and skim milk powder. Additionally, the building blocks of proteins (free amino acids), such as crystalline lysine and methionine, are commercially available to supplement the diet.
- *Lipids*: Oils from marine fish, along with vegetable oils from canola, sunflower and linseed, are common sources of lipids in fish feeds.
- *Carbohydrates*: Cooked carbohydrates, from corn flour, wheat or other cereals, are relatively inexpensive sources of energy that can spare protein (which is more expensive) from being used as an energy source.
- *Vitamins and minerals*: The variety and number of vitamins and minerals are so complex that they are usually prepared synthetically and are available commercially as a balanced and pre-measured mixture known as a vitamin or mineral premix. This premix is added to the diet in generous amounts (1%–2%) to ensure that adequate levels of vitamins and minerals are supplied to meet dietary requirements.
- *Pigments*: A variety of natural and synthetic pigments or carotenoids is available to enhance coloration in the flesh and the skin of freshwater and marine ornamental fish. The pigments most frequently used supply the colors red and yellow. The synthetically produced pigment astaxanthin is the most commonly used additive (100–400 mg/kg). Cyanobacteria, blue-green algae, dried shrimp meal, shrimp and palm oils, red peppers and yeast are excellent natural sources of pigments.
- *Binding agents*: Another important ingredient in fish diets is a binding agent to provide stability to the pellet and reduce leaching of nutrients into the water. Carbohydrates (starch, cellulose and pectin) and various other polysaccharides, such as extracts or derivatives from animals (gelatin) and plants (gum arabic and locust bean), are popular binding agents.
- *Preservatives*: Preservatives, such as antimicrobials and antioxidants, are often added to extend the shelf life of fish diets and reduce the rancidity of the fats. Vitamin E is an effective, though expensive, antioxidant that can be used in laboratory prepared formulations. Sodium and potassium salts of propionic, benzoic or sorbic acids are commonly available antimicrobials added at less than 0.1% in the manufacture of fish feeds. Ethoxyquin (EMQ) is also used as a feed preservative in certain countries to prevent mold.
- *Stimulant and attractants*: Other common additives incorporated into fish feeds are chemo-attractants and flavorings, such as fish hydroxylates and condensed fish solubles (typically added at 0.5%–2% of the diet). The amino acids glycine and alanine, as well as the chemical betaine, are also known to stimulate strong feeding behavior in fish. Basically, attractants enhance feed palatability and stimulant enhanced feed intake.
- *Other feedstuffs:* Fiber and ash (minerals) are a group of mixed materials found in most feedstuffs. In experimental diets, fiber is used as a filler and ash as a source of calcium and phosphorus. In practical diets, both should be no higher than 8%–12% of the formulation. A high fiber and ash content reduces the digestibility of other ingredients in the diet, resulting in poor growth of the fish.

Feedstuffs	% Protein	% Fat	% Fiber	% Carbohydrate	% Dry matter	% Mineral	Conversion ratio
Maize (white)	9.3	5.0	2.4	70.9	88.0	1.8	5
Maize (yellow)	10.8	3.6	3.5	71.2	88	1.9	5
Guinea corn	11.2	2.5	2.3	74.1	88	1.8	5
Palm kernel cake	19.1	7.6	43.2	17.9	-	5.5	8
Cottonseed cake	40.1	8.3	31.9	12.4	91	5.1	5
Rice bran/husk	9.9	4.4	40.2	8.7	91	21.8	5
Groundnut cake (industrial)	48.0	13.2	8.1	18.9	93	6.3	5
Groundnut cake (local)	40.6	23.4	6.0	19.0	93	6.2	5
Raw soybean	40.7	22.0	6.3	16.6	90	6.4	4
Soybean meal (toasted slightly)	46.2	24.8	4.7	17.2	90	7.9	4
Soybean meal (toasted severely)	48.1	23.9	4.1	20.7	90	7.9	4
Fishmeal (tilapia)	57.7	1.8	5.2	-	92	33.6	2
Clupeid (large)	73.1	80.0	1.1	-	92	20.2	2
Clupeid (small)	68.5	8.0	0.4	-	92	17.8	2
Cow blood meal	86.0	0.7	2.1	6.5	92	5.0	2
Millet	9.0	5.0	0.7	83.2	90	2.3	5
Flour mill waste	12.5	14.5	7.5	58.0	-	-	-
Brewers waste	22.8	17.8	18.8	46.4	93	-	10
Cassava (peeled)	2.6	0.5	0.4	94.1	88	2.4	18
Cassava (peels only)	5.3	1.2	21.0	66.6	88	6.0	18
Cassava (unpeeled)	2.7	0.5	3.1	91.0	88	2.7	18
Cassava leaves	14.7	8.4	15.6	45.2	88	16.1	18
Mucuna	28.5	0.7	9.5	57.2	91	4.0	4
Water leaf	21.1	1.5	10.3	87.4	-	4.6	-

Source: NAERLS 2002.

Table 2. Nutrient composition of local feedstuffs and expected conversion ratio of feed to fish flesh.

Feed formulation combines selected ground feed ingredients in varying proportions to comply with the predetermined nutrient requirements of a fish species. When feedstuffs for the desired nutrient composition have been selected, they can be prepared through a process of milling, mixing and pelleting. Milling can be carried out with a hammer mill machine (Plate 1).

Mixing ingredients, including premixes, can be premixed by hand to form a mash before pelletizing. A mechanical mixer can be used for large-scale feed production (Plate 2). If cereals in the formula are not adequate to bind the particles of the feed mixture, cassava starch can be added as a binder.

After pelleting, the pellets should be dried in an oven (not the direct sun, which can deteriorate some nutrients, such as fatty acids) and then packed in water impermeable bags, such as nylon Ziploc bags. This is to prevent mold from forming and pests from attacking.

The following are some considerations in producing pellets:

- Use good quality feed ingredients.
- Make sure the particle size of ground ingredients is uniform. Fine grinding is preferable. Leaf meals should be sun or oven dried before grinding.
- Mix weighed ingredients thoroughly in desired proportions.
- Determine what pellet type to produce—whether floating or sinking types for surface feeders or bottom feeding fish, respectively. For floating pellets, add or spray oil.
- The particle size of pellets for most adult fish is at least 4.5 mm in diameter.
- Store dry rations, such as rice bran, ground maize and leaf meals, in a cool, dry place for several weeks. Take portions as needed to feed fish.
- Prepare moist rations daily by adding about 450 ml of water per kg of ingredients to form a dough-like mixture. Store this ration in plastic bags or containers, and divide it for morning and afternoon feeding.

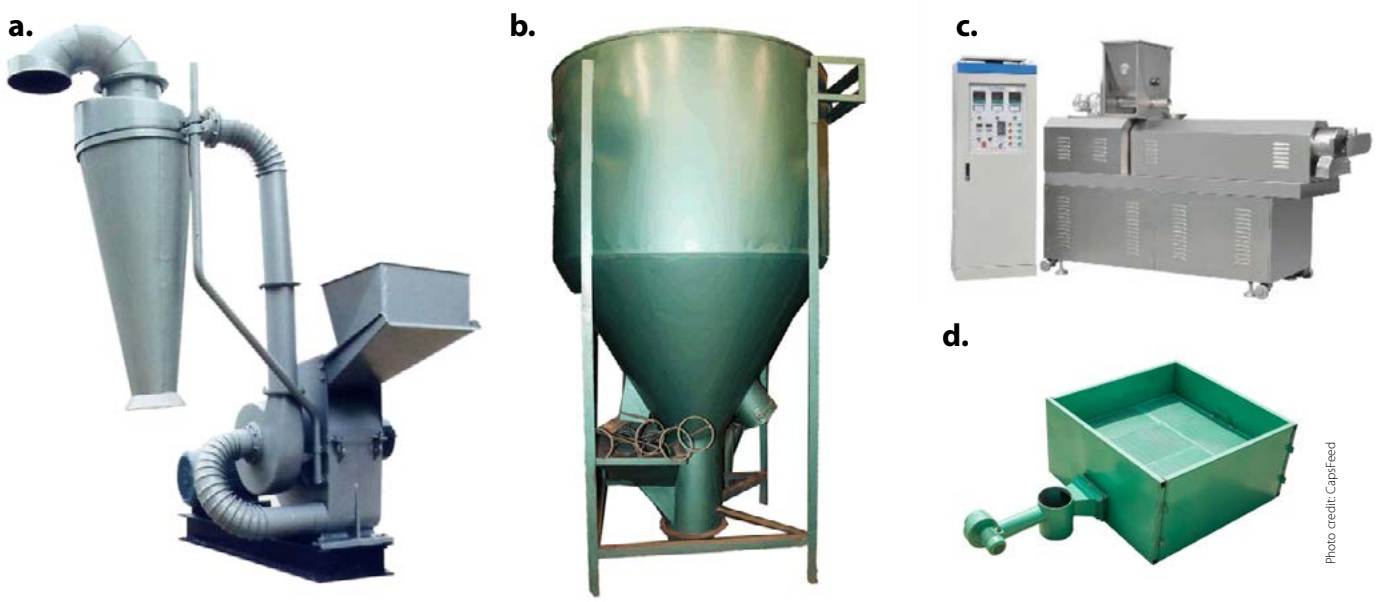

Plate 1. A CapsFeed floating fish feed line: a. Hammermill, b. Vertical mixer, c. Extruder and d. Feed dryer.

1.7. Non-conventional fish feed resources

Non-conventional feed resources (NCFRs) are feeds that are not usually common in markets and are not the traditional ingredients used for commercial fish feed production. NCFRs are credited for being non-competitive in terms of human consumption and also cheap to purchase. They come in the form of by-products or waste products from agriculture, farm-made feeds and processing industries, and they serve as a form of waste management for enhancing proper sanitation.

NCFRs include all types of feedstuffs, from both animal and plant origin as well as waste products:

- animal sources, such as silkworms, maggots, termites, earthworms, snails, tadpoles, poultry by-products and feather meal
- plant sources, such as jack bean, cottonseed meal, soybean meal, cajanus, duckweed, maize bran, rice bran, palm kernel cake, groundnut cake and brewers waste
- animal wastes from animal sources and processing of food for human consumption, such as animal dung, offal, visceral, feathers, fish silage, bone and blood.

They are usually cheaper than conventional feeds and can be recycled to improve their value if there are economically justifiable and technological means (such as fermentation) for converting them into useable products.

It must be noted that when using non-conventional feed, fish can be predisposed to toxic substances and even infections, so it is important to ensure proper treatments before feeding it to fish.

1.8. Worker safety

In a feed manufacturing factory, worker safety is important. Workshops must be well ventilated during feed production to ensure both the continuity of quality feed production and the

Photo credit: Capsfeed

Photo credit: David Olaniyan/Goodseed Integrated Farm

Plate 2. Fish feed pelletizer.

Photo credits: Ajibola Olaniyi/WorldFish

Plate 3. Fish feed pellets of 2 mm, 3 mm, 4 mm sizes.

safety of the staff and customers. Procedures must be put in place to prevent accidents, contamination of workers from toxic substances or pathogens and consequently the spread of disease in times of outbreaks from feed manufacturers to fish farms or vice versa.

It is necessary for feed manufacturers to implement the following measures to protect workers:

- Wear protective equipment where needed.
- Avoid touching eyes, mouth and ears.
- If applicable, maintain social distancing of at least 1 m among workers and between workers and customers.
- Disinfect production tools and machines regularly or before and after use, where applicable.
- Training workers before handling of equipment is very important.

Post-evaluation questions

1. Which of the following is a feedstuff for fish?
   a) cassava
   b) rice
   c) groundnut cake

2. Which of the following is not an anti-nutritional factor?
   a) cyanogenic glycosides
   b) tannin
   c) chitin

3. Which of the following is not a conventional feed?
   a) tadpoles
   b) extruded feed
   c) rice bran

4. What is the purpose of including carbohydrates in fish feed?
   a) binding
   b) repairing worn out tissues
   c) enhancing bodily processes

5. What is the purpose of including protein in fish feed?
   a) binding
   b) repairing worn out tissues
   c) enhancing bodily processes

6. What is the purpose of including fat included in fish feed?
   a) source of energy
   b) repairing worn out tissues
   c) bodily functions

7. What is the purpose of including vitamins in fish feed?
   a) source of energy
   b) repairing worn out tissues
   c) bodily functions

8. What is the purpose of including minerals in fish feed?
   a) source of energy
   b) repairing worn out tissues
   c) bodily functions

9. Why is water so important in fish feed or for fish? Give one reason.

10. Why is processing feedstuffs important before feeding them to fish?

Module 2: Formulating and producing African catfish seed

Pre-evaluation questions

1. Which of the following is considered a floating feed?
   a) crushed feed
   b) pelletized feed
   c) powdered feed
   d) extruded feed

2. Adult fish need more protein than fry. True or false?

3. Which of the following is not a mineral found in a fish diet?
   a) selenium
   b) calcium
   c) gold
   d) chlorine

4. Which of the following is a vitamin found in a fish diet?
   a) manganese
   b) thiamine
   c) sodium
   d) vitamin F

5. If catfish is considered omnivorous, what is tilapia considered?

6. Can a piscivorous fish eat duckweed?

7. Which fish species is more expensive to rear in terms of feeding cost: catfish or tilapia?

8. Fat stores more energy than carbohydrate. True or false?

9. What are micro-elements?

10. What is considered a micro-element? Give one example.

2.1. Nutritional requirements of catfish

Catfish feed on a wide range of food. They are omnivorous but are predominantly piscivorous. In the context of farming, this means they require high dietary protein for good performance, so they must be given feeds that are high in crude protein (35%–50%). Catfish feed requires certain nutrients that will help farmers optimize growth and increase the profit of their catfish farming business.

Below are the four classes of nutrients, in order of importance, that are essential for any feed formulation:

- *Protein*: This nutrient is required for building body tissue and replacing damaged tissue. It also includes physiological molecules such as hormones and enzymes. It can come from either plant or animal origin.
- *Carbohydrate*: This nutrient provides the energy that catfish need. Cereal grains and cassavas are the major sources of this nutrient.
- *Vitamins and minerals*: These control the growth, health and body processes of fish. Organic and inorganic chemicals are found in both vitamin and minerals.
- *Fat*: Fat contains vital fatty acids and also represents the energy source of choice for fish.

It is important to know the nutritional contents of available feed ingredients so as to understand and select the appropriate ingredients that will meet the nutritional needs of your catfish (Tables 3, 4 and 5). More details on the nutrients contained in feedstuffs and the requirements of tilapia, catfish and many other species are available free of charge at www.iaffd.com/home.html?v=3.13.

Tables 6 and 7 each contain a nutritional table of the feed ingredients required to make a basic catfish feed (Plate 4). They are for illustrative purposes only.

2.2. Catfish feed formulation and production

Feed formulation is an integral part of a catfish farming business, especially in tropical Africa. This is due to the fact that imported fish feeds are always expensive because of the logistical costs of importation and the weak local currency. This makes the cost of such products increase significantly.

The environment in Africa allows individual farmers to formulate feed for their fish to reduce the cost of feed production and to enjoy flexibility in their choice of feed ingredients for feed formulation.

Animal protein	Energy level (mg/kg)	Crude protein (%)	Fats (%)	Calcium/ phosphorus (%)	Methionine (%)	Lysine (%)
Meat meal	11.2	50–51	10	8	0.7	2.6
Blood meal	15.2	88–90	1	0.4	0.6	7.1
Feather meal	13.7	80–85	7	0.4	0.6	2.3
Poultry meal	13.1	60–64	13	2.0	1	3.1
Fishmeal	5	55–75	3	1.0	1.5	2

Table 3. Nutrient composition for common protein sources of animal origin.

Plant protein	Protein (%)	Energy (cal/kg)	Calcium (%)	Lysine (%)	Methionine (%)
Soybean meal	44–48	2557	0.20	3.2	1.4
Cottonseed meal	40–41	2350	0.66	4.2	1.4
Sunflower meal	46–47	2205	0.30	3.5	2.3
Groundnut cake	45.6–61.8	3860	1.7	3.2	1.0

Table 4. Nutrient composition for common protein sources of plant origin.

Ingredients	Protein (%)	Energy (cal/kg)	Calcium (%)	Lysine (%)
Wheat	13	3153	0.05	0.5
Sorghum	9.0	3263	0.02	0.3
Maize	8–11	3200	0.5	0.27
Cassava	2.5	1601	1.6	0.07

Table 5. Nutrient composition of energy-based ingredients.

Ingredients	Quantity (kg)
Maize/wheat/cassava flour (any of the three)	25
Soya/sunflower/cottonseed (soya preferred)	30
Groundnut cake/beniseed (either of the two)	20
Fishmeal (72%)	25
Vitamin/mineral premix	0.5
Lysine	0.1
Methionine	0.1
Vitamin C	0.1
Salt	0.2
DCP	1
Total	**102**

Table 6. Sample formula of a basic catfish feed.

Ingredients	Quantity (kg)
Maize	20
Poultry meal	15
Fishmeal (72%)	10
Blood meal	5
Soya	30
Groundnut cake	20
Vitamin/mineral premix	0.5
Lysine	0.1
Methionine	0.1
Vitamin C	0.1
Salt	0.2
DCP	1
Total	**102**

Table 7. Sample formula of a basic catfish feed.

Plate 4. Catfish response to feeding in an earthen pond (top) and feeding catfish in an earthen pond (bottom).

However, the majority of catfish farmers have little or no knowledge on this aspect of their business. Therefore, some fish farmers depend on the judgment/recommendations of their feed millers without questioning the recommendations that result in poor fish growth.

The least-cost approach is used to economize the cost of feed production. A least-cost computer program is usually used to formulate feeds in feed companies. Farmers formulating feed using this program must have information on the cost of feed ingredients, the nutrient concentrations in feedstuffs, the nutrient requirements and the nutrient availability from feedstuffs. It is also important to know the nutritional and non-nutritional restrictions set by the regulatory authority in the country.

One significant challenge of least-cost feed formulation is the combination of the nutrient levels to bring maximum profit relative to levels that result in best weight gain. Here are some examples of restrictions placed on nutrients and feed ingredients for least-cost formulation of catfish feeds.

2.3. Considerations for producing pellets and extruded catfish feed

The main difference between pelleted and extruded fish feed is that pellet feed has sinking properties while extruded feed is buoyant.

Ideally, choosing the feed ingredients and formula should be guided by the following:

- *Nutritional requirements of fishstock*: To formulate a quality feed, fish farmers need to have adequate knowledge of ingredients and the nutritional value of various ingredients, along with the nutritional requirements of the fish at various stages. From combined ingredients, it is possible to calculate the crude protein, energy and fat in the feed either manually or by inputting it into a dedicated computer program.
- *The presence or absence of anti-nutritional or toxic factors*: Some ingredients should not be used because of certain anti-nutritional elements in them. For instance, soybean grain must be well processed to remove anti-nutritional elements. Some ingredients, like groundnut cake, can also support the growth of aflatoxin, though this might not be a major concern in catfish farming, unlike in poultry.
- *Availability of preferred ingredients*: Certain ingredients are preferred over others. This can be connected to the cost and availability of such ingredients. When such ingredients are unavailable, fish farmers are saddled with the responsibility of choosing from a wide range of similar ingredients. For instance, when a flour type is unavailable, farmers are faced with the challenge of choosing from energy grains or processed tuber crops to complement the energy requirements of their fish.

- *Palatability of available ingredients*: An experienced catfish farmer understands that catfish have taste preferences. Fish farmers will make sure to choose from a variety of ingredients that will suit the taste of their fish. For instance, groundnut cake tastes better and smells better than its substitute benniseed, and soybean meal is preferred above cottonseed cake.
- *Costs and benefits of available ingredients*: Costs and benefits are important factors to consider in feed formulations. The cost of fishmeal (72% crude protein) could surpass its benefits as the best alternative if local fishmeal is available, especially in a situation where most imported fishmeal in the market is adulterated. Though there are many ways to meet the protein requirements for fish, animal protein, especially from fish, must not be totally removed from the feed, especially for African catfish production. The quality and quantity must be well sustained regardless of the choice of ingredients.
- *Available processing technology or methods*: This is a crucial factor to consider when formulating feed. Some ingredients should not be used at all because of the crude processing methods involved, which could lead to a loss of essential nutrients. Maize should not be used at all if the feed miller does not possess the technology to powder it because fish cannot fully digest maize particles that are not well milled.

2.4. Biosecurity in catfish feed production

Fish feed manufacturers are expected to maintain good hygiene. Care must also be taken to produce proper feed with a balanced diet. This will improve growth and general fish health without exposing them to nutritional deficiency-based sickness or infection from the presence of pathogens.

Manufacturers should adopt the following protocol for producing and storing feed:

- Obtain good quality feedstuffs or ingredients from reliable sources. Poor quality feed can also cause disease.
- Store feed in a cool, dry place after production to retain vitamin C, which is easily oxidized, and to avoid contamination from fungi, which can cause disease.
- Keep feed ingredients and manufactured feed away from rats and other animals, and store them in a cool, dry, secure place to retain their nutritional contents.
- Prevent entry to sensitive areas, such as places where there could be contact with feed during production.
- Ensure vehicles carrying feed ingredients or visitors are washed down with a broad-spectrum disinfectant. Otherwise, the vehicles should be parked away from facilities.
- Wash hands at the factory's entrance, before and after activities.
- Install a footbath at the entrance of the facility.

2.5. Disinfecting or cleaning equipment and machinery

When equipment is used and left unattended for long periods of time, it can become a breeding grounds for pathogens or harbor toxins if not properly cleaned before next use.

Good sanitation and disinfection procedures are as follows:

- Apply appropriate disinfectants (Table 8) at the proper concentrations and duration.
- Disinfect all production equipment and machines, including transportation vehicles. Do this regularly as long as production is ongoing, and allow everything to dry thoroughly, especially in parts of the production chain where the dryness of feed is required, such as the packaging room.
- Depending on the type of disinfectant, it might be necessary to wash items thoroughly after disinfection to remove any toxic residues.
- Use anti-microbial agents used for disinfecting non-living objects or surfaces to destroy or inactivate pathogens.

Post-evaluation questions

1. What is the crude protein content required for catfish feed?
   a) 35%–50%
   b) 60%–70%
   c) 75%–80%
   d) none of the above

2. Adequate knowledge of ingredients and nutritional value of various ingredients will help a farmer to formulate a quality feed. True or false?

3. Soybean grain must be well processed to remove which of the following?
   a) excess nutrients
   b) aflatoxins
   c) anti-nutritional factors
   d) none of the above

4. Groundnut cake tastes and smells better taste than its substitute benniseed. True or false?

5. Soybean meal is preferred over cottonseed cake. True or false?

6. It is not necessary to wash items thoroughly after disinfection. True or false?

7. Groundnut cake can support the growth of which of the following?
   a) aflatoxin
   b) viruses
   c) spores
   d) all the above

Disinfectant	Concentration	Duration	Comments
Benzalkonium chloride	250–500 ppm	10–30 minutes	Plastics, floors, footbaths, walls, equipment and furnishings
Didecyl dimethyl ammonium chloride	400 ppm	5 minutes	Plastic, floors
Phenols	2%–5% active ingredients	10–30 minutes	General disinfection
Chlorine	200–500 ppm	10–60 minutes	All surfaces except plastic; when cleaning tanks, disinfect for 24 hours, then neutralize, rinse and dry
Ethyl alcohol	70%–80% ppm	10–30 minutes	Hands, tools, work surfaces
Isopropyl alcohol	60%–80% ppm	10–30 minutes	Hands, tools, work surfaces
Iodine	100–250 ppm	20–30 minutes	Antiseptic on tissues; follow product label instructions if using for egg surface disinfection
Hydrogen peroxide	3%–30% (weight percentage)	5–30 minutes	General disinfection
	3%–30%	5–15 minutes	Follow label instructions to treat fish or disinfect eggs
Virkon® Aquatic 21.4% potassium peroxymonosulfate and 1.5% sodium chloride	0.5%–1% or 50–100 g per 10 L of water	10–15 minutes	General disinfection; commonly used for footbaths
Chlorhexidine (most solutions contain 2% active chlorhexidine)	Add 1 ml to 100 L of water for disinfection	5–10 minutes	General disinfection; commonly used for footbaths

Note: Adapted from Bowker JD, Trushenski JT, Gaikowski MP and Straus DL, eds. 2014. Guide to using drugs, biologics, and other chemicals in aquaculture. American Fisheries Society Fish Culture Section. Yanong RPE and Erlacher-Reid C. 2012. Biosecurity in aquaculture, Part 1: An overview. SRAC Publication No. 4707.

Table 8. Common disinfectants, with dosages and applications.

Module 3: Formulating and producing tilapia feed

Pre-evaluation questions

1. Which of the following statements is correct?
   a) Nile tilapia are omnivores.
   b) Nile tilapia are carnivores.
   c) Nile tilapia are limnivores.
   d) none of the above

2. Adult tilapia fry need more protein than adult tilapia. True or false?

3. Which of the following is not a nutrient in a fish diet?
   a) carbon
   b) calcium
   c) protein
   d) manganese

4. Which of the following is considered a vitamin in a fish diet?
   a) manganese
   b) thiamine
   c) sodium
   d) vitamin F

5. If catfish are omnivorous, what are tilapia?

6. Can a herbivorous fish eat duckweed?

7. Why is tilapia cheaper than catfish to raise in terms of feed?

8. What are macrominerals?

9. What are microminerals?

10. Are disinfectants important in a feed manufacturing factory?

3.1. Nutritional requirements for tilapia

Nile tilapia (*Oreochromis niloticus)* is a widely cultured species because it grows and reproduces in a wide range of environmental conditions and tolerates stress from handling. It is omnivorous, with a herbivorous tendency, so it can feed on a wide range of both natural and artificial foods. Nile tilapia has considerable potential for aquaculture in many tropical and subtropical regions in the world. Several attributes make it popular to farm in ponds: easy breeding, fast growth, tolerance of adverse environmental conditions, good taste, good market price, high tolerance of low water quality, efficient food conversion, resistance to disease and good consumer acceptance.

The major nutrient requirements of cultured tilapia show that early juvenile fish (0.02–10 g) require a diet higher in protein, lipids, vitamins and minerals and lower in carbohydrates. Sub-adult fish (10–25 g) require more energy from lipids and carbohydrates for metabolism and a lower proportion of protein for growth. Adult fish (>25 g) require even less dietary protein for growth and can use even higher levels of carbohydrates as a source of energy.

3.1.1. Protein

Protein requirements for optimal growth depend on the quality and source of dietary protein, fish size or age and the energy content of the diet. The energy content can vary from as high as 45%–50% for larvae, 35%–40% for fry and fingerlings (0.02–10 g), 30%–35% for juveniles (10–25 g) down to 28%–30% for grow-out/ finishing (>25 g) (Table 9). The best protein digestibility occurs at 25°C–30°C, and the optimal dietary protein to energy ratio is between 110 and 120 mg/kcal of digestible energy for fry and fingerlings, respectively. Tilapia broodfish require about 30%–35% protein for optimal reproduction and spawning efficiency. Good larval growth and survival will require 40%–45%. The crude protein content of the diet is an indicator of the amino acid composition, because Nile tilapia actually requires amino acids, not proteins. Their requirements are the same 10 essential amino acids as for other finfish.

3.1.2. Lipids

The minimum requirement of dietary lipids in tilapia diets is 5%, but improved growth and protein use efficiency has been reported for diets with 10% lipids. Both n-3 and n-6 polyunsaturated fatty acids are essential for maximal growth of hybrid tilapia (*O. niloticus x O. aureus*).

3.1.3. Carbohydrates

Carbohydrates are included in tilapia feeds to provide a cheap source of energy and to improve pellet binding properties. Tilapia can efficiently use as much as 35%–40% digestible carbohydrates. Carbohydrate use among tilapia is affected by a number of factors, including source, other dietary ingredients, fish species and size, and feeding frequency. Tilapia use complex carbohydrates, such as starches, better than disaccharides and monosaccharides. Dietary use of carbohydrate appears to be higher in bigger fish.

3.1.4. Vitamins

In semi-intensive farming systems, vitamin supplementation is not essential for tilapia. However, in intensive culture systems, where limited natural foods are available, vitamins are generally necessary for optimal growth and health of tilapia. Other dietary factors are known to affect several vitamin requirements of tilapia. These must be taken into consideration in diet formulations. For example, the vitamin E (fat soluble vitamin) requirement is influenced by the dietary lipid level. Nile tilapia requires 50–100 mg/kg when fed diets with 5% lipids and 500 mg/kg for diets with 10%–15% lipids.

3.1.5. Minerals

There is little information on the mineral requirements for tilapia. Like other aquatic animals, tilapia are able to absorb minerals from the culture water, which makes it difficult to determine the amounts. Despite its ability to absorb minerals from the culture water and the presence of minerals in feed ingredients, tilapia should be given feed containing supplemental mineral premixes. This ensures that sufficient levels of dietary minerals are available to protect against deficiencies caused by reduced bioavailability, such as when plant phosphorus sources are used in tilapia feeds. Like vitamins, the amount of minerals added to the diet also depends on the source of the element.

More details on the nutrient requirements of tilapia, catfish and many other species are available free of charge at www.iaffd.com/home.html?v=3.13.

3.2. Use of soybean for more economical fish feed production

Soybean is a protein source readily available in many local markets. It is a relatively cheap feedstuff compared with good quality fishmeal, for instance. Low protein feeds might increase the chance of disease, so tilapia farmers are encouraged to use a nutritionally balanced soybean meal-based feed with about 32% protein to raise tilapia. This is because it maximizes economic return. It can increase the production rate and survival rate, lower the FCR, lead to larger return on investment (ROI), and reduce environmental impact through decreased frequency of water exchange and lower nutrient load in the effluent water (Table 10). Tilapia weighing an average of 50 g that are given feed with a 32% crude protein level can reach 510 g in size with an FCR of 1.19:1 in about 110 days. The formulation in Table 11 is for tilapia with an initial average weight above 50 g.

Life stage	Weight (g)	Requirement (%)
First feeding larvae	-	45–50
Fry	0.02–1	40
Fingerlings	1–10	35–40
Juveniles	10–25	30–35
Adults	25–200 >200	30–32 28–30
Broodstock	-	30–35

Table 9. Protein requirements of tilapia across stages in freshwater.

Parameter	36% Protein	32% Protein	28% Protein	24% Protein
Feed cost/kg (RMB)	5.85	5.054	4.55	4.15
Feed cost/kg of fish gain (RMB)	7.30	7.07	7.05	7.22
Net income/cage (RMB)	956	972	363.6	252
ROI (%)	17.5	20.2	7.0	4.6

Source: adapted from Enhua et al. 2010.
Note: RMB 10 (Renminbi) = USD 1.14

Table 10. Comparison of four feeds with different protein levels fed to Nile tilapia.

Ingredients	Four protein levels			
	24%	28%	32%	36%
Soybean meal 46%	25.5	33	43	44.2
Wheat middlings 16%	28	35	35	31.3
Low fat soybean hulls	30	11.9	11.9	
Fishmeal, anchovies 64/9	1	2	2.5	5
Wheat, feed flour 13.2%	6		8	10
Corn gluten meal 61%	3	3	4	6
Blood meal spr. 90/0.5	2	2	2	5
Fish oil, anchovies	0.75	0.6	1	1
Soy oil	-	-	1.8	4.5
Soy lecithin	0.5	1.5	1.5	1.
Ca phosphate mono	2.21	1.94	1.92	1.83
Vit PMX F-2	0.5	0.5	0.5	0.5
Min PMX F-1	0.25	0.25	0.25	0.25
Choline chloride 50%	0.1	0.1	0.03	0.03
DL methionine 99%	0.12	0.14	0.13	0.12
Stay C 35%	0.3	0.3	0.3	0.3
Antioxidant	0.02	0.02	0.02	0.02
Mold inhibitor	0.01	0.01	0.01	0.01
Mycotoxin binder	0.01	0.01	0.01	0.01
Total	**100**	**100**	**100**	**100**

Source: Manomaitis and Cremer 2003.

Table 11. Examples of feed formulations with four protein levels for Nile tilapia.

3.3. Considerations for producing pellets and extruded tilapia feed

Tilapia feed formulation and production is like that of catfish. Table 5 shows the inclusion rate and formulation using the nutritional requirements of tilapia. The considerations for producing pellets and extruded tilapia feed are similar to those for catfish in Module 2.

3.4. Biosecurity in tilapia fish feed production

Biosecurity is a set of practices to minimize the introduction, establishment and spread of pathogens. It is a sensible approach to adopt biosecurity practices because it is easier to prevent diseases than to cure them.

3.5. Good feed

The following protocol should be adopted for procuring and storing feed:

- Obtain good quality feed from reliable sources. Poor quality feed can cause nutritional diseases.
- Use feed before the expiry date to retain the nutritional contents and to avoid old feed becoming contaminated with pathogens.
- Keep feed away from rats and other animals, and store it in a cool, dry, secure place.
- Do not use fresh feed, such as trash fish and bivalves, which could contain pathogens. Use fresh feed only if it can be treated (cooked) to remove pathogens.
- Commercial pellet feeds are generally safe and present a low risk of disease transmission when stored properly.

3.6. Raw materials

It is necessary to use a system for checking the quality of raw materials before accepting them for producing fish feed. These include (a) conducting a microbiological assessment to identify and quantify any pathogens, (b) checking the nutritional contents to identify and quantify antinutritional factors, and (c) checking for foreign materials, such as metals, rubber or plastics materials, which can endanger the health and life of fish.

Plate 5. Locally made fish feed being sun dried.

3.7. Treatment and disposal of wastewater and solid waste

Wastewater and solid waste must be treated strictly in accordance with local and national regulations. Proper treatment and discharge reduce the risk of contaminating feed within the factory and other things in the vicinity. Discharging wastewater and general waste must be done properly to avoid environmental issues.

The following are procedures used to treat wastewater to an acceptable level before discharging to avoid spreading any diseases:

- Ensure that effluent from the factory first goes into sedimentation tanks.
- In treatment tanks, chlorinate and dechlorinate wastewater from sedimentation tanks before discharge.
- Dispose of solid waste properly according to local regulations and laws.
- Burn or bury solid waste materials to prevent the spread of pathogens.

3.8. People management

It is important to minimize the risk of staff and visitors transferring pathogens to the feed factory. Someone who has visited another site or farm could potentially carry pathogens that can contaminate the hatchery. Similarly, frequent movement among staff between different sections within the factory can also transmit pathogens.

To avoid contamination from people, factories should implement the following procedures:

- Restrict the movement of people and staff.
- Use the hand-wash and footbath at the entrance of the factory and in each section of the factory.
- Install a signboard on sanitation and disinfection procedures at entrance of the factory.
- Prevent unauthorized people from accessing the factory.
- Maintain a visitors logbook.
- Factory personnel should escort visitors into the facility.
- Replace the disinfectant regularly according to the instructions on the label.

Post-evaluation questions

1. Tilapia do not need polyunsaturated fatty acids in their feed. True or false?

2. Tilapia use starch well. True or false?

3. Tilapia use complex carbohydrates, such as starches, better than disaccharides and monosaccharides. True or false?

4. Which of the following is not necessary when checking the quality of raw materials before accepting them for producing fish feed?
   a) conducting a microbiological assessment to identify and quantify any pathogens
   b) verifying the nutritional contents to identify and quantify antinutritional factors
   c) checking the sugar concentration
   d) looking for foreign materials, such as metals, rubber or plastics materials

5. Which of the following statements is incorrect regarding biosecurity?
   a) It minimizes the risk of project failure.
   b) It leads to eventual loss.
   c) It reduces the chance of disease outbreak.
   d) It lowers the chance of economic losses from fish loss.

6. Which of the following is not a potential facilitator of disease outbreak?
   a) hygiene
   b) machines and equipment
   c) visitors
   d) all of the above

7. Which of the following is not a better management practice of waste disposal in a feed manufacturing factory?
   a) proper treatment and discharge
   b) water discharged close to the intake point or water source
   c) proper disposal of solid waste according to local regulations and laws
   d) solid waste materials buried or burned to prevent the spread of pathogens

Module 4: Feeding the fish

Pre-evaluation questions

1. What factors or things reduce feed quality in storage?

2. What are limnivores?

3. What makes feed go moldy?

4. Is overfeeding good for fish health?

5. Which of the following is considered a feeding habit?
   a) parasitivores
   b) carnivores
   c) fishing
   d) plasticity

6. Which of the following is not considered a feeding habit?
   a) limnivores
   b) piscivorous
   c) parasitiviorous
   d) omnivorous

7. Is the broadcasting feeding method effective?

8. Why is feed management important?

9. What is the advantage of using dry pellet feed?

10. What are some disadvantages of trash fish?

4.1. Fish feeding habits

Feeds are used to increase fish yields and are especially beneficial when

- maximum fertilization is not practiced;
- a pond does not respond well to fertilization
- fish are stocked at high density in a pond
- fish are confined in a cage, pen or other culture facility
- fish are held in tanks.

Fish usually feed to satisfy their energy requirements. The quantity of feed fish consume depends on various factors, such as appetite, feed quantity and palatability. All these factors being equal, a well-fed fish will grow well while a poorly fed fish will have slower growth and be prone to diseases. Farmers must supply fish under culture with a nutritious diet daily at the recommended rates.

Generally, fish species have different feeding habits. Carnivores, such as catfish, feed mainly on flesh foods, like fingerlings, crustaceans and worms in the water environment. Omnivores, such as tilapia, feed on both plant and animal foods. Herbivores, such as grass carp, feed mostly on plant materials. Most fish under culture are able to eat plant and animal food materials as well as supplementary feeds.

In a polyculture system, fish species can feed at different levels of the food chain in the pond. Tilapia is an example of a surface feeder and catfish an example of a midwater feeder, while African bony tongue an example of a typical bottom feeder. Some fish species are limnivores, also known as mud eaters, which feed mainly on algae and microorganisms in the pond bottom. These kinds of fish are constantly eating and can be fed both pellets and algae-based foods. A fish culturist should take these feeding habits into consideration when planning pond stocking and feeding practices.

4.2. Feed quantity

The quantity of feed is important in aquaculture, as overfeeding has a lot of disadvantages. In the wild, fish hunt for food, but in the culture system farmers control the feeding frequency, feed composition and feed quantity to meet a desired production target. Overfeeding leads to economic loss. Since feeding represents about 70% of the variable cost for a fish farm, it is not economically wise to allow feed wastage from overfeeding. Overfeeding predisposes the culture system to pollution and water quality problems. It can also predispose the fish to infection due to accumulated waste from uneaten feed and increased waste produced by fish that eat more than they need.

The amount of feed necessary in a pond, also called the feeding level or feeding rate, is usually the proportion of the biomass of fish in the pond. This

amount is usually given in a percentage of biomass. For instance, larvae are fed 8%–10% of their weight per day, fry are fed 5%–7%, juveniles 3%–5% and grow-out fish 2%–3%. It is important for farmers to estimate the volume of fish contained in their pond on a regular basis, either biweekly or monthly. This can be done through periodic sampling of anywhere from two to 50 fish to adjust the feeding level. As an illustration, if a pond contains 200 kg of fish at the grow-out phase and the farmer feeds them 3% of their weight per day, that amounts to 6 kg (200 kg*3%) of feed in the pond per day. However, daily feed should be distributed across several meals, ideally three per day, though two is also acceptable.

4.3. Methods of feeding fish

There are four main methods used to feed fish: broadcasting, point feeding, automatic feeding and demand feeding.

- Broadcasting spreads the feed throughout the pond.
- Point feeding has designated feeding points and must be done regularly.
- Automatic feeding is a programming system that feeds the fish at specified time and quantity.
- Demand feeding is usually a mechanical system that uses a stick applied to a slightly bowed plate sitting under a feed hopper. The stick goes straight into the water, and the feed is dispensed from the hopper when touched by the fish.

4.4. Feed storage

Feed must be stored in a cool and dry place away from pests, like rodents. The moisture content must be low enough to be stored without spoilage from mold. Feed should not be stored for over 3 months.

4.5. Feed grade feeding management

Fish feed management involves choosing the right feed, using correct feeding methods, calculating the feed cost and ensuring feed effectiveness. It is important because it reduces overall costs, ensures fish grow healthy and improves the water or culture environment by managing the water quality.

There are three types of feed grades: vegetarian, trash and pellet.

- Vegetarian feeds are made from plant sources. Examples are rice bran, soybean meal and groundnut cake.
- Trash feed are usually made of small fish, fishing by-catch or waste from fish processing plants.
- Pellet feed gets its name because it is shaped like a ball or tablet. There are dry pellet feed and moist pellet feed, which has a moisture content of about 35%. Dry pellet feed can either be pelletized or extruded.

It must be noted that trash feed, which has about a 70% moisture content, is made of irregular ingredients and is more likely to pollute the water. Moist pellets must be stored frozen, otherwise spoilage sets in. If there is no storage facility for moist pellets, they must be used immediately in production. Dry pellet feeds are more stable and should be stored in a cool dry place. They can last about 3 months.

Post-evaluation questions

1. What are limnivores?

2. When the moisture content of feed is too high, mold can grow on the feed. True or false?

3. What are the impacts of overfeeding on fish, fish health and water?

4. Which of the following are fish eaters?
   a) piscivores
   b) carnivores
   c) fishers
   d) plasticity

5. Which of the following is the feeding habit of fish that feed on mud?
   a) limnivores
   b) piscivorous
   c) parasitiviores
   d) omnivores

6. Is the broadcasting method of feeding effective?

7. Why is feed management important?

8. What are the advantages of using extruded feed?

9. What are some disadvantages of trash feed?

10. What factors or things reduce feed quality in storage?

Module 5: Business plan development

Pre-evaluation questions

1. What is capital?
2. What is a loan?
3. What is a grant?
4. Why is it important to have a business plan?
5. What is a brand?
6. What are market demographics?
7. What is competition?
8. What is market segmentation?
9. What is profit?
10. What is a business profile?

5.1. Purpose of a business plan

A business plan is a step-by-step blueprint of how a business owner will operate their business. It provides direction for every decision. A business plan has two main purposes. First, it is used to run a business with a clear and consistent vision. Second, it is required to gain access to funding, such as loans and grants for businesses.

A business plan is used to manage a business by stating the goals, how they will be achieved and when. The plan also summarizes what the business is about, why it exists and where it will go. It serves as a point of reference for partners, investors, employees and management to assess progress with reference to its objectives.

5.2. Business profile

A business profile is a list of basic details about a company. It highlights the strength of the company to prospective clients and customers. It is a form of a résumé that communicates a company's values, objectives, services, products and current status. A simple business profile format includes the name of the business, the address of the head office, phone number, website, company status and the contact information of the person in charge (name, phone number and email address).

5.3. Organization and products

Business organization details include the date of registration and the start of business, main areas of business activity, main product lines, services and the principal customer in industries and across geographical boundaries. Another important part is business capacity, which covers labor, finance and technical ability. These details include the business organization and number of employees, the financial circumstances of the business (optional) and the company's capacity for projects in terms of staff qualifications and certification. It also covers references to success stories in a similar project.

5.4. Description of management team

The management team is the group of individuals that organize the business strategy and ensure the business objectives are met. They operate at a high level of an organization and are responsible for day-to-day managing of other teams or individuals. A description of a management team helps third parties recognize what sets the business apart from others.

5.5. Market analysis

A market analysis is a qualitative and quantitative assessment of a market's attractiveness and its dynamics. These include market size (volume and value), buying patterns or preferences of customers, degree of competition, economic environment (including demand and supply forces) and various customer segments. A market analysis helps gain insight and understanding of potential customers and competitors. It is useful in identifying a niche for a business or in developing a marketing strategy. The process of a market analysis involves several factors: demographics and segmentation, target market, a market need assessment, and competition.

5.5.1. Demographics and segmentation

Demographics and segmentation is the division of the market according to age, race, gender, family size, religion, ethnicity, education and income. All of these give direct information on market size. They point to the target market and market need. The first step in the process of a market analysis is measuring the market size. Market size refers to the maximum total quantity of sales or number of customers a business has or the total potential number of customers or quantity of sales in a given year. There are two approaches for measuring market size: volume and value. Volume deals with the number of customers while value is the estimated monetary worth of the proposed business. The number of customers available to buy fish in an area can be compared with the value they attach to fish in that area.

Consider this example: Two areas have potential customers in the form of small farms that are willing and able to buy fish feed. The first area has 50 farms, which are able to pay USD 20.38 per bag. The second area has five farms, which are able to pay USD 27.17 per bag. It might be better to establish a business in the first area where there is a larger volume, even though it has lower value and higher competition. The market appears stable and accessible.

5.5.2. Target market

A target market is the group of potential customers a company wants to sell its products or services to. No small business can effectively target every potential customer, so it is wise for small businesses to target a niche market that enables them to compete with large established ones.

5.5.3. Market need assessment

A market need assessment deals with why customers buy the product. Some customers might buy tilapia fingerlings because they grow fast, while others might buy them because of taste, price, health or resistance to disease.

5.5.4. Competition

Identify the strengths and weaknesses of competitors so that your company can use them to better position itself in the market. Competition between companies selling similar products and services is a daily occurrence in business. A quick way to do a market analysis is to compare your competitors with your business using a simple table containing important drivers of demand (Table 12). This will give a reasonable view of businesses you are competing with and will enable you to determine their weaknesses, which your company can use to better position itself in the market.

The aim of comparing competitors' fish feed products and services with your company is to be able to discover their key weaknesses and take advantage of them to gain customers' attention. In Table 12, for example, the second competitor does not offer delivery services to customers, while the third offers delivery at USD 2.72 = (NGN 1000). Your company can leverage that by offering free delivery to customers. This gives it an edge over two of its three competitors.

Company	Competitor 1 (1.5–2 mm feed for fingerlings)	Competitor 2 (Live food for hatchlings)	Competitor 3 (4–6 mm feed for grow-out)	My company (4–6 mm feed for grow-out)
Revenues	USD 27,173.91	USD 1358.70	USD 2736.41	USD 2173.91 (first year target)
Employees	5	2	7	4
Size	1 feed mill and 3 sales outlets	1 feed mill and 1 sales outlet	1 feed mill and 1 sales outlet	1 feed mill and 1 sales outlet
Price	Low	High	Low	Low
Quality	Average	Low	Low	Superior
Delivery	Free	No	USD 2.72	Free

Table 12. Hypothetical analysis of competitors (USD 1 = NGN 368).

Only the second competitor produces live food, while the others are into pelletized fish feed production. This could mean that there are more customers who buy compounded feed, or it could be that there is a barrier to the entrance of new fish feed companies into the market. This is an example of why it is important to do a market analysis by comparing and studying competitors.

In fish feed, there are a lot of different alternative options in the market that fish farmers can choose from. The products are often similar, as most companies have feed sizes for the different stages of fish: 1.5 mm, 2 mm, 3 mm, 4 mm, 6 mm and 9 mm. A company producing fish feed has to have a competitive advantage if it is to succeed.

Several factors give a feed manufacturer a competitive advantage:

- A unique geographic location: A fish feed manufacturer located in the midst of fish farms or close to an area dominated by fish farms is more likely to make sales than one that is far away.
- Access to novel technology: A fish feed manufacturer will have an advantage over its competitors if it is able to develop a unique way of producing feed that makes feeding easier for fish farmers. The problems fish farmers face with feeding include the rate of water pollution from feed as well as feed efficiency.
- Access to natural resources restricted from competitors, especially foreign feed manufacturers: Some feed ingredients that might not be available to foreign fish feed manufacturers could be available locally. If harnessed, these could be a competitive advantage for the locally manufactured feed.
- The ability for a manufacturer to produce fish feed at the lowest cost: Being able to sell feed to farmers at a relatively low cost can give it a competitive edge. Fish feed accounts for over 70% of total operating costs, so a reduction in price means a reduction in the production cost for fish farmers. This could potentially increase profit as much as 30%. Most fish farmers will buy feed from a manufacturer that has a cheaper product and uncompromised fish feed quality.

Barriers to entry are obstacles or hindrances that make it difficult for a new company to enter an existing market. An analysis of barriers will answer two main questions:

1. What prevents new entrants from coming in and taking a good percentage of your customers?
2. What makes you think you will be able to break the barriers and successfully enter the market?

There are many barriers to entry. The following are barriers that fish seed production businesses, specifically, could face:

- Cost of investment: Investment in fish seed production is capital intensive.
- Location: The inability to secure a suitable location for fish seed production and other geographical factors will determine a successful enterprise.
- Brand loyalty: This covers consumer attachment to existing fish seed producers or their products.
- Brand cost: The marketing cost is high for a business to reach a certain level of recognition.
- Economies of scale: Existing fish seed producers benefit from a lower average cost due to the scale (size) of production. Inputs can be acquired in bulk, resulting in a lower appreciable cost of production.
- Being "the first mover": Some companies earn a strong position because they are the first to enter and dominate a market.
- Regulations: These are rules and guidelines made by governing bodies to control production activities or processes. A fish seed producer is expected to comply with these regulations, which can affect production activities. Regulations vary from one country to another.

5.6. Financial analysis

A financial analysis is the evaluation of the viability, stability and profitability to merit investment in the business or project. It is used to build a long-term plan to draw business activities. There are several methods of financial analysis. This module focuses on cost-benefits analysis (CBA), profit margin, and return on investment (ROI), as shown in Table 11.

5.6.1. Cost-benefits analysis

A CBA is a process by which organizations can analyze decisions, systems or projects, or determine a value for intangibles. The model is built by identifying the benefits of an action as well as the associated costs and then subtracting the costs from benefits. This is often used in capital

budgeting to analyze the overall value of money for undertaking a new project. The CBA produces a ratio called the benefit-cost ratio (BCR), which is an indicator of the relationship between the relative costs and benefits of a proposed project. It can be expressed in either monetary or qualitative terms.

The CBA process covers a detailed or exhaustive list of all the costs and benefits associated with the project. It includes both direct and indirect costs. Direct costs cover labor involved on the farm, equipment and machinery, seed cost, feed cost and all forms of farm inputs. Indirect costs concern electricity, overhead costs from management, rent and utilities.

If a project has a BCR greater than 1.0, this means that benefits outweigh costs. It implies that the business is feasible and worth investing in. For example, a BCR of 1.20 means that for every dollar spent in costs there is a financial gain of an additional USD 0.20.

Net present value (NPV) is the difference in the sums of discounted benefits and discounted costs. A positive NPV means the project is feasible while a negative one means it is not worth investing in and should not be considered.

The following are two rules guiding the use of an NPV or CBR:

1. If separate, unrelated projects are being assessed and the budget for funding the projects *is not limited*, use an NPV or BCR.
2. If separate, unrelated projects are being assessed and the budget for funding the projects *is limited*, the projects should be ranked with a BCR, not an NPV.

For businesses that have small to mid-level capital expenditures and a short to intermediate time to completion, an in-depth CBA could be dependable for a making sensible decisions. For large businesses with a long-term time horizon, a CBA helps calculate the current value of money through discounting. The BCR is computed as a ratio of the discounted benefit stream divided by the discounted stream of costs. Inflation is accounted for by deflating prices using price indices.

5.6.2. Profit margin

Profit margin is the amount by which revenue from sales exceeds costs in a business. There are four levels of profit margins: gross profit, operating profit, pre-tax profit and net profit.

Profit Margin = Net Profit/Revenue

A company takes in sales revenue, which covers the direct costs of the products or services. The gross profit margin is what is left over after the cost of the product or service is subtracted from sales revenue. Next, advertising, which is an indirect cost, is also subtracted, leaving the operating profit margin. Interest on debt and any unusual charges or inflows unrelated to the company's main business are then subtracted, which leaves the pre-tax profit margin. The net margin, also known as net income, is what is left over after taxes are paid. This is considered the company's bottom line.

The profit margin covers the following:

- It measures the degree to which a company or a business activity makes money, by dividing income by revenue.
- It is expressed as a percentage and indicates how much profit has been generated for each dollar of sales.
- The most significant and commonly used margin is net profit margin, which is a company's bottom line after all expenses, including taxes and other costs, have been subtracted from revenue.
- Profit margin is used by creditors, investors and businesses as an indicator of a company's financial health, management skill and growth potential.

5.6.3. Return on investment

This is a financial metric of profitability used extensively to measure the profit or gain an investment can realize. The ROI is a simple ratio of the gain from an investment relative to its cost. It is useful in evaluating the potential return from a stand-alone investment. It can also be used to compare returns from several investments.

The ROI can be positive or negative. A positive ROI means that net returns are good because total returns exceed total costs. A negative ROI means that the investment produces a loss because total

costs exceed total returns. Calculating an accurate ROI requires including total returns and total costs. It is better to express ROI as a percentage because it is easier to understand and make deductions from.

The following are the steps involved in calculating ROI:

- Calculate all costs and all income.
- Add all the costs to generate the total cost of production.
- Add all income to generate the total income.
- To calculate net income, subtract the total cost of production from the total income.
- To calculate the ROI, divide the net income by the total cost of production and multiply it by 100.
- To prevent omissions, it is important to know which factors to consider when calculating the cost.

In Table 13, the ROI is 23.1% and the CBR is 1.23, which is greater than 1. This suggests that the NPV of the business cash flows outweigh the NPV of the costs, so the business can be considered.

Ingredients	Inclusion rate (%)	Quantity of ingredient (kg)	Price (USD) per kg	Price (USD) of ingredients
Maize	35	350	0.27	93.21
Soymeal	25	250	0.35	88.32
GNC	20	200	0.33	65.22
Fishmeal (72%)	5	50	2.99	149.46
Wheat bran	8	80	0.15	11.96
Poultry meal	6	60	1.11	66.85
Premix	0.5	5	2.99	14.95
Vitamin C	0.2	2	4.89	9.78
Lysine	0.1	1	2.45	2.45
Methionine	0.1	1	3.94	3.94
Blood meal	0.5	5	0.65	3.40
Salt	0.05	0.5	0.11	0.05
Milling/Extruding		1000	0.11	108.70
Total cost of production				**618.26**
Income	**0.76 per kg**			**760.87**
Net profit	**Income-total cost of production**			**142.61**
ROI (%)	**(Net profit/Total cost of production) x 100**			**23.06610408**
CBR	**Income/Total cost of production**			**23.06610408**

Table 13. Financial analysis for producing 1 t of catfish feed using local feed ingredients in Nigeria (USD 1 = NGN 368).

5.7. Sourcing capital/grants

A capital-intensive project or business like tilapia seed production is usually difficult to start. This is a significant barrier to entry, so potential business owners must consider this challenge. If business owners do not have the funds to start or improve an existing business, the other available option is to look for a grant or get a loan.

There are many ways to secure the funds required to complete a project:

- Personal fundraising: The first investor in a business should be the business owner. This can be in the form of cash, in-kind, or collateral on assets. This signifies to potential investors that you have a long-term commitment for the project you are embarking on.
- Partnerships: This is an agreement between two or more parties to advance their mutual interest (sharing management and profits). The partners can be individuals, non-governmental organizations, businesses and community-based organizations. Check if there are other organizations, either not-for-profit or commercial, that could partner with you in sharing the capital costs of the project. Depending on the agreement and arrangement, they could join in management (sharing or dividing responsibilities) or be passive. It is advantageous when the partners are trained and equipped in different fields, because it increases the chance of success.
- Government or public funding: This depends on the country and agricultural policies. Government grants and subsidies could be available for low-interest loans expected to boost agricultural production. Check the lists of available government grants or loans either online or at government offices in charge of such funding.

Post-evaluation questions

1. What is the difference between a loan and a grant?

2. Is competition an advantage to a fish feed business?

3. What are the advantages of branding?

4. What are barriers to entry?

5. What are the safest forms of sourcing funds?

6. What are the challenges of sourcing personal funds?

7. What is the advantage of partnership funding?

8. What is the disadvantage of partnership funding?

9. Which of the following is not considered a direct cost?
   a) feedstuffs
   b) equipment and machinery
   c) feed
   d) rent

10. Which of the following is not considered an indirect cost?
    a) feedstuffs
    b) overhead from management
    c) electricity
    d) rent

Conclusion

Good quality nutrition in fish farming is essential to economical production of balanced commercial diets that promote optimal fish growth and health. Identification of quality feed ingredients in formulating a fish diet is important to achieve good feed conversion ratio (FCR) for increased production and putting in place the right feeding management.

Key terms

Term	Meaning
Algae	Photosynthetic organisms that possess photosynthetic pigments, such as chlorophyll. However, they lack true roots, stems and leaves that are characteristic of vascular plants.
Catabolites	Substances produced by the process of catabolism, a chemical reaction in an organism that breaks down complex molecules into smaller, simpler ones. For example, food is broken down into nutrients, such proteins, lipids and carbohydrates.
Cyanogenic glycosides	Natural plant toxins present in several plants, most of which are consumed by humans. Cyanide is formed following the hydrolysis of cyanogenic glycosides that occur when edible plant material is crushed either during consumption or during processing of the food crop. It is an antinutritional factor.
Ethoxyquin (EMQ)	A quinoline-based antioxidant used as a food preservative in certain countries and originally to control scald on pears after harvest (under commercial names such as "Stop-Scald"). It is used as a preservative in some pet foods to slow the development of rancidity in fats. Each country has a regulatory limit on the use of this product.
Feedstuffs	Ingredients grown or developed to make feeds for livestock and fisheries.
Feed conversion ratio (FCR)	Amount of dry feed required to grow 1 kg of fish. For example, if 2 kg of feed are required to grow 1 kg of fish, the FCR would be 2. This means that when a feed has a low FCR, it takes less feed to produce 1 kg of fish than it would if the FCR was higher. The lower the FCR, the better the feed performance and vice versa.
Fertilization	The fusion of haploid gametes, eggs and sperm to form the diploid zygote. During the spawning season, the male fish seek out the nests of fish eggs that the females have laid. When they find one, they swim over the nest and fertilize the eggs with their semen. This allows conception to take place, and immediately the eggs start to become fish.
Fingerlings	Fish eggs that hatch into larvae and grow up to the size of a finger. Usually they are no more than 8 weeks old.
Fry	Freshly hatched fish no more than 4 weeks old.
Gossypol	A natural phenol derived from the cotton plant (genus Gossypium). Gossypol is a phenolic aldehyde that permeates cells and acts as an inhibitor for several dehydrogenase enzymes. It has a yellow pigment and is an antinutritional factor.
Juveniles	Hatched fish no more than 12 weeks old. Typically, that are between 25 and 50 mm long.
Lectins	Carbohydrate-binding proteins that are highly specific for sugar groups of other molecules. Lectins play a role in recognition at the cellular and molecular levels and play numerous roles in biological recognition of phenomena involving cells, carbohydrates and proteins. They are an antinutritional factor.
Protease inhibitors	Synthetic drugs that inhibit the action of protease, an enzyme that cleaves two precursor proteins into smaller fragments, which are needed for viral growth, infectivity and replication. They are an antinutritional factor.
Saponins	Phytochemicals that can be found in most vegetables, beans and herbs. They are an antinutritional factor.
Tannins/ tannoids	A class of astringent, polyphenolic biomolecules that bind to and precipitate proteins and various other organic compounds, including amino acids and alkaloids. They are an antinutritional factor.
Zooplankton	Microscopic animal organisms moving freely in oceans, seas and bodies of freshwater.

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WorldFish

About WorldFish

WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

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.

WorldFish is part of One CGIAR, the world's largest agricultural innovation network.

For more information, please visit www.worldfishcenter.org