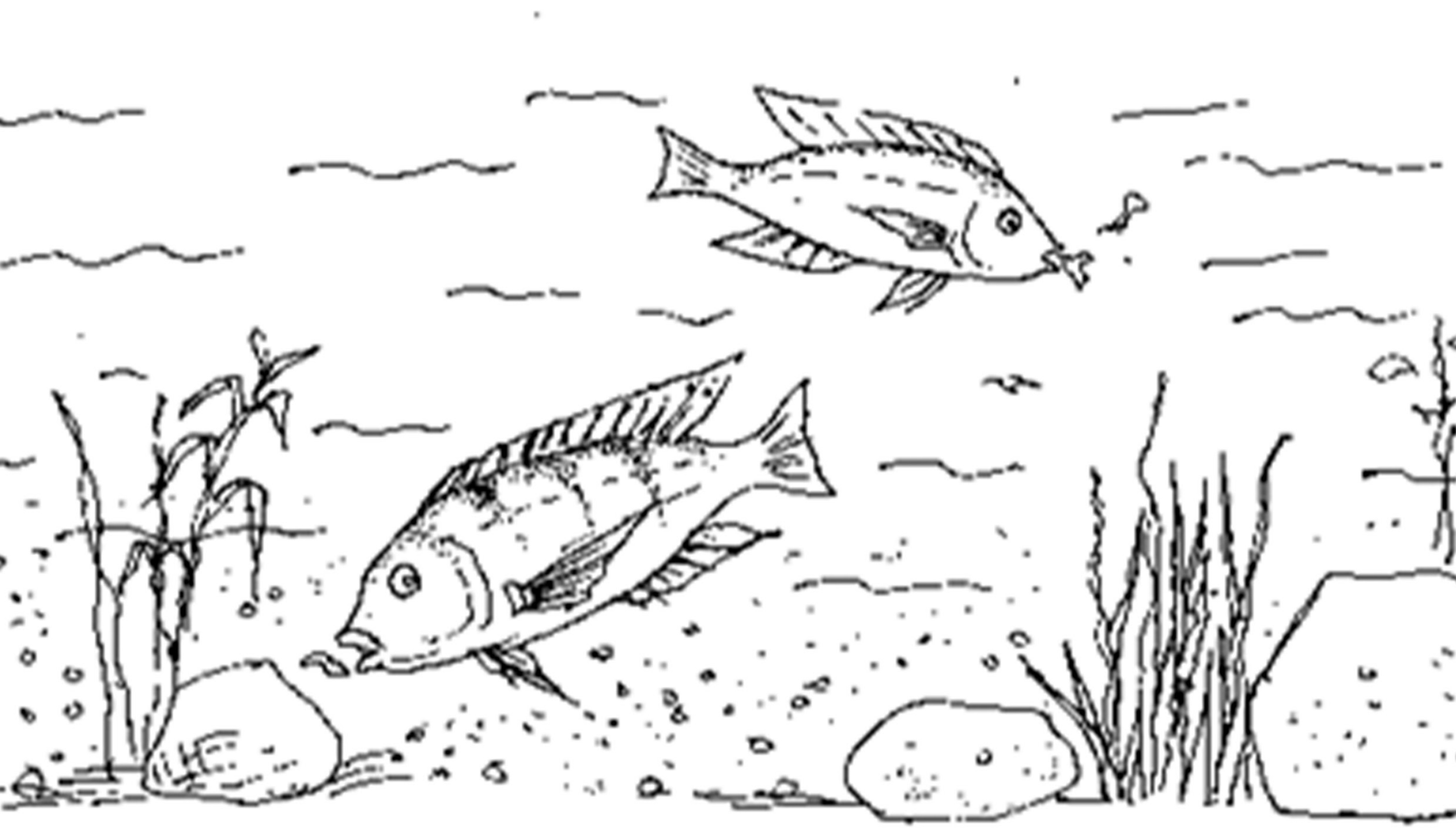

FISH FEEDS AND FEEDING

Module IV of 8

Fish Feeds and Feeding

Module IV

FOREWORD

The growing demand for fish in Malawi and the Southern African Development Community (SADC) region requires additional efforts by the governments to increase fish production from aquaculture. All Malawi's development policies (Malawi Vision 2063, Malawi Growth and Development Strategy III 2017-2022, National Fisheries and Aquaculture Policy 2016, National Aquaculture Strategic Plan 2021) emphasise the need to promote aquaculture development in order to enhance production from aquaculture to supplement the dwindling capture fisheries production and cannot satisfy the ever increasing demand for fish. The development policies also emphasise the need to pursue sustainable practices and climate smart technologies.

Up until now, there were many reference materials which extensionists from both government and non-governmental organisations have been using to train farmers in aquaculture principles and practice. These manuals, however, were not coherent, often providing conflicting recommendations and were not vetted by the Department of Fisheries under the Ministry of Forestry and Natural Resources as proper training materials for aquaculture. Hence, it is timely that this new aquaculture manual has been developed for use in the aquaculture practice. This manual will become a nationally recognised tool for training in aquaculture practice.
The target users of this aquaculture manual are extensionists from government and non-governmental organisations, fish farmers and trainers of these groups. The manual contains technical information as well as training plans to help the trainers to conduct training in an orderly manner.

The Ministry of Forestry and Natural Resources remains committed to foster the development of aquaculture in the country for nutritional and food security, income generation and job creation.

Yanira Ntupanyama, PhD.
Secretary for Forestry and Natural Resources

PREFACE

This Technical Manual for Trainers on Good Pond Aquaculture Practices has been developed to address the gap that existed when the country did not have a universal, nationally recognised manual as basis for training our extension agents, fish farmers and for use by non-government organisations engaged in the aquaculture sub-sector. This manual will be a reference material for guiding aquaculture practices in Malawi. Accordingly, the manual has been developed to support the implementation of the National Fisheries and Aquaculture Policy 2016 which highlights sustainable aquaculture development as policy priority number 2 and the National Aquaculture Strategy (2021-2029).

There are several challenges that exist in the aquaculture sub-sector that need to be addressed for the benefit of fish farmers and extension workers. The major challenges include: lack of harmonised approaches and information to guide all players in the value chain, inadequate supply and access to inputs i.e. quality fingerlings and feed, unavailability of market structures to aggregate production and measures to increase the resistance of the sector against risks related to climate change.

It is expected that this aquaculture manual will become the necessary tool for all actors along the aquaculture value chain mainly for technical know-how regarding aquaculture production. Where possible, trainers or users may be guided by the aquaculture experts from the Department of Fisheries under the Ministry of Forestry and Natural Resources.

Friday Njaya, PhD.
Director of Fisheries

ACKNOWLEDGEMENTS

The Department of Fisheries (DoF) in the Ministry of Forestry and Natural Resources is grateful to all stakeholders, too numerous to mention, who contributed to the development of the nationally recognized Technical Manual for Trainers on Good Pond Aquaculture Practices. The DoF acknowledges the financial and technical support from the Aquaculture Value Chain Project for Higher Income and Food Security (AVCP) funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit GmBH (GIZ).

The Department also acknowledges the efforts and technical contributions from all the government officers, academicians, technicians and practitioners who took part in the development of this manual. Thanks should also go to the team that finally edited the manual.

Special recognition and gratitude are extended to the GIZ Food and Nutrition Security Program (FNSP) for contributing the chapter on nutritional benefits of fish and all individuals who were involved and contributed in the development of this manual.

INTRODUCTION

Fish feeding is considered one of the most basic factors in increasing fish production in farms, and its importance depends on the levels of culture. For example, fish feeding is more important in intensive culture rather than in semi-intensive culture. Due to the need to consider those under semi-intensive culture systems, the development of inexpensive, balanced diet formulations is of great importance. This will support aquaculture to satisfy the increasing demand for affordable, safe, and high-quality fish products. Fish meal is often used as a source of animal protein in fish diets though it is costly. A variety of other protein commodities are being considered as partial or complete replacement for fish meal, especially use of plant protein sources such as soybean meal. Plant based protein sources are increasing while fish meal production has dropped largely attributed to overfishing and serious decline in wild stock. This is making fish meal costly and it is estimated that about 67% of the actual feed cost can be attributed to the fish meal protein fraction. Considerations on the use of alternative unconditional feed ingredients as suitable replacements for fish meal in artificial diets for fish feed formulations have been presented.

The module encourages fish farmers to use innovative approaches to explore the wide variety of processing by-products potentially available as nutritionally valuable ingredients in specific aqua feeds. Regardless, the final processed aqua feed must meet specific physical standards, such as water stability and palatability, as well as satisfying the fish needs. The module further highlights the importance of proper fish feeding for improved fish growth and increased incomes. Recognizing that fish feed represents 50 - 60% of the production costs, an economic analysis on use of different feeds have been made, profit margins and payback period presented.

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Nutritional requirements of fish

1

Introduction

Good nutrition in fish production systems is essential to economically produce a healthy, high quality product. In fish farming, nutrition is critical because feed represents 40-50% of the production costs. Of late, fish nutrition has advanced greatly with the development of new, balanced commercial diets that promote optimal fish growth and health. The development of species-specific diet formulations is supporting the aquaculture sector as it expands to satisfy increasing demand for affordable, safe, and high-quality fish and fish products. These prepared or artificial diets comes are either complete or supplemental. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) necessary for the optimal growth and health of the fish. Most fish farmers use complete diets, those containing all the required protein (18-50%), lipid (10-25%), carbohydrate (15-20%), ash (<8.5%), phosphorus (<1.5%), water (<10%), and trace amounts of vitamins, and minerals. In contrast, supplemental (incomplete, partial) diets are intended only to help support the natural food (insects, algae, small fish) normally available to fish in ponds or outdoor raceways. Supplemental diets do not contain a full complement of vitamins or minerals, but are used to help fortify the naturally available diet with extra protein, carbohydrate and/or lipid. Fish, especially when reared in high densities, require a high-quality, nutritionally complete, balanced diet to grow rapidly and remain healthy.

This chapter looks at nutritional requirements of tilapia and catfish which are aimed at improving good growth of cultured species. Sources of different required nutrients for the cultured fish sources have been explored. Feeding behavior of both tilapia and catfish has been explained

Aim

The aim of the chapter is to enhance participants' knowledge and understanding of the basic nutritional requirements of tilapia and catfish. The chapter further seeks to enhance the participants' skills in minimizing nutrients loss when feeding fish.

Objectives

- <u>Participants know</u>
  - What is fish feeding
  - Nutritional requirements of tilapia and catfish
  - Sources of nutrient ingredients for fish
  - Tilapia and catfish feeding behaviors

- <u>Acquired skills</u>
  - Amounts of nutrients incorporated into diets for growing fish
  - Proper developing of a hatchery calendar

- <u>Acquired attitudes</u>
  - Good nutrition is essential for good fish growth

- <u>Relevance to fish production</u>
  - Good feeds are key to improved fish growth and increased profits

This chapter has one session

Session 1: Nutritional requirements of fish

Mode of delivery

- Lectures, group discussions
- Duration : 60 minutes

1.1 Fish feeds and feeding

Feeding involves series operations (swallowing, digesting, and absorption), by which a living being could obtain and synthesize necessary nutrients for growth, reproduction and maintenance of body tissues. Fish growth and yield in a culture facility is a function of food availability, fish size and stocking density in culturing facility. Proper fish feeding goes with feeding fish with quality feed, in right quantities and at the right time. For increased profitability, knowledge on the availability of natural food in ponds during the early stages of semi-intensive culture, delaying feeding with commercial formulated feed or supplemental feed sources to latter stages, can be practiced. It has to be known that delaying supplemental feeding is more economic for small scale fish farmers.

Therefore, feeds that are given to fish, falls into several categories which are natural, supplementary and complete feeds. Supplementary feeds are further categorized into local and complete feeds. Some of the complete feeds which are made into pellets can also be called extruded feeds so that they float for effective ingestion by fish. These types of feeds will be well explained in this module.

Tilapia fish feeds on a low trophic level and are somewhere between herbivore and omnivore in terms of feeding behavior. They consume a wide variety of natural food organisms including phytoplankton and zooplankton, algae, some aquatic macrophytes and benthic invertebrates. They also feed on other fish larvae, detritus, and decomposing organic matter. Tilapias are often considered filter feeders because they can efficiently harvest plankton from the water. They efficiently browse on live benthic invertebrates and bacteria-laden detritus. Tilapias are not piscivorous though fry and fingerlings may consume larvae of other fish. Tilapia also feed on invertebrates in the water column. Natural food may account for 30–50% of tilapia growth even when they receive heavy supplemental feeding. The nutritional value of the natural food supply in ponds is important, even when fish are cultured intensively, especially in outdoor systems.

1.2 Nutritional requirements and Feeding behavior of fish

Nutritional considerations are of prime importance for good growth of cultured fish and depend on the stage of species and growth of fish. All fish require the following nutrients for good growth in different proportions:

Table 1.1: General amounts of nutrients incorporated into diets for growing fish

Nutrient Details Requirement (% by dry diet)
Proteins (10 Essential amino acids Lysine, phenylalanine, arginine, valine, leucine, isoleucine, methionine, threonine, tryptophan, and histidine 32–45%

Fat Used as a source of energy and polyunsaturated fatty acids. In general, freshwater fish requite fatty acids of the linolenic (w-3) and linoleic (w-6) series. 4–28% (should contain at least 1–2% of the w-6 or w-3 essential fatty acid series)
Carbohydrates: These are an inexpensive source of energy and a binding agent. No essential requirements have been identified. These are poorly digested when fed raw. Highest digestibility is achieved when cooked. Major carbohydrates are starch, cellulose, and pectin 10 – 30%
Minerals: Some 20 inorganic mineral elements, including calcium, phosphorous, magnesium, iron, copper, manganese, zinc, iodine, and selenium. 1.0–2.5% fed as a multi-mineral premix

Vitamins: These are inorganic substances required in trace amounts that can be divided into fat-soluble (vitamins A, D, E, and K) and water-soluble (vitamins C and the B-complex [(thiamin, riboflavin, pyridoxine, pantothenic acid, cyanocobalamin, niacin, biotin, folic acid, choline, and myoinositol]]. 1.0–2.5% fed primarily as a multi-vitamin premix. Vitamin C and choline are added separately from the premix because of their chemical instability.

Source: (Royes and Chapman, 2003)

However, even though all fish require the foregoing nutrients, there are variations in the quantities of protein required at different life stages of the fish. The following table summarizes the protein requirements required at different life stages in the fish's life;

Table 1.2 Protein requirements for tilapia in fresh water

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

1.2.1 Tilapia Feeding Behavior

Tilapias are known to be herbivorous or consume feed materials of plant origin. This is especially true at the early stages where they feed on phytoplankton or plant plankton. However the tilapias also actually feed on periphyton, zooplanktons (animal plankton), other larval fish and detritus. Hence if these are to be reared in lake-based cages, one has to know if the lake is eutrophic or has natural food (phytoplankton, zooplankton) in abundance and if so, perhaps full feeding using artificial diets may not be necessary. The same is true for fertilized ponds. Tilapias are often considered filter feeders because they can efficiently harvest plankton from the water.

- Tilapias effectively browse on live benthic invertebrates and bacteria-laden detritus.
- Are not piscivorous though fry and fingerlings may consume larvae of other fish.
- Also feed on invertebrates in the water column. Natural food may account for 30–50% of tilapia growth even when they receive heavy supplemental feeding.
- Nutritional value of the natural food supply in ponds is important, even when fish are cultured intensively, especially in outdoor systems. Dietary nutrient requirements are presented in Tables 2.3 and 2.4

Table 1.3: Dietary protein, carbohydrate and lipid requirements of tilapia

Description	Stage	Dietary Requirements
Crude Protein	Fry	45 – 60%
	Fingerlings	35 – 40%
	Grow-out	25 – 35%
	Broodstock	25 – 35%
Carbohydrates	Fry/Fingerlings	<25%
	Grow-out	25 - 30%
	Broodstock	Not yet known

Protein :	Energy Ratio	ry/Fingerlings	120/110 mg/kg
	Grow-out	103 mg/kg	
	Broodstock	Not yet known	
Lipids :	Total	Fry	5 - 8%
	Adult	8 - 1%	
W -6 EFA	All stages	0.5 – 1%	
w- 3 EFA	All stages	0.5 – 1%	

Table 1.4: Optimum levels of vitamins and minerals for tilapia

Essential Vitamins	Dietary requirements	Minerals	Dietary requirements
A	2000 – 5000 IU	Ca	0.3 – 0.7%
B1	2 – 60 mg/kg	P	0.5 – 1.0
B2	5 – 60 mg/kg	I	6–1.1 mg/kg
B6	2 – 20 mg/kg	Mg	0.5–0.8 g/kg
C	50 – 1250 mg/kg	Zn	20–30 mg/kg
D	375 IU	Fe	<17.05 mg/kg
E	100 – 500	IU or	
	50 - 100 mg/kg	Cu	
		Cr	<1.27 mg/kg
			2 mg/kh

Tilapias digest animal as well as plant protein efficiently. Protein requirements for their growth mainly depend on the size of the fish and quality of protein in the feed being fed.

- For tilapia, the level of Crude Protein in the diet may be 40% or even higher for the younger stages, like in fry and fingerlings.
- Tilapias require the same ten essential amino acids as other warm water fish, and as far as has been investigated, the requirements for each amino acid are similar to those of other fish.
- The digestible energy requirements for economically optimum growth have been estimated at 8.2 to 9.4 kcal DE (digestible energy) per gram of dietary protein.
- Tilapia may have a dietary requirement for fatty acids of the linoleic (w-6) family and they appear to have similar vitamin requirements to other warm water fish species.
- Vitamin and mineral premixes similar to those added to catfish diets are usually incorporated in commercial tilapia feeds.
- Tilapia can even feed on home-made mash or dough more efficiently than do catfish, but most commercial tilapia feeds are pelletized to reduce nutrient losses.

As tilapias grow, they can also be trained to eat artificial diets such as the commercially available tilapia feeds that contain plant and animal protein among other ingredients that are sources of nutrients such as lipids, carbohydrates, vitamins and minerals. Several commercial feeds for different tilapia growth stages (e.g. feeds for tilapia fry, fingerlings and juveniles) are available locally. A farmer need to be guided on the crude protein (CP, usually ranging from 28-56%) requirements of tilapia at every growing phase. Fish feed companies usually provide a feeding guide and sometimes, offer technical support as they sell their artificial diets to fish farmer clients. Both the feed ration (based on fish biomass) and the CP requirement is adjusted (usually reduced) with the age and size of the tilapias as the culture period progresses.

1.2.2 Catfish feeding behavior

Catfish (Clarias gariepinus) are considered to be omnivorous or predators. They normally feed on aquatic insects, fish and higher plant debris. The major feeds for catfish are crustacean, terrestrial and aquatic insects are an important part of the diet of juvenile and adult catfish. However, molluscs, diatoms, arachnids and plant debris are considered to be minor food items they consume. Zooplankton becomes more important with increasing fish size and predominated in the diet of the largest fish. Catfish is therefore considered as a slow-moving omnivorous predatory fish which feeds on a variety of food items from microscopic zooplankton to fish half its length or 10% of its own body weight. Because of its feeding behavior, we can combine the feeding methods when feeding it.

In order to feed on this wide variety of food organisms in different situations, C. gariepinus is equipped with a wide array of anatomical adaptations for feeding under low visibility including:

- A wide mouth capable of considerable vertical displacement for engulfing large prey or large volumes of water during filter feeding
- A broad band of curved teeth on the jaws and pharyngeal teeth preventing prey from escaping
- An abundant network of sensory organs on the body, head, lips and circumoral barbels. These barbels are extensively used for prey detection and fixation.
- A wide, rounded caudal fin typical of fish which ambush their prey.
- Long gill rakers on the five bronchial arches
- A short and dilatable esophagus which opens into a distinct muscular stomach (mechanical digestion) and a simple thin walled intestine.

Table 1.5: Dietary protein requirements for African catfish (Clarias gariepinus)

Fish size	**% Crude Protein Requirement**
Fry	50
Fingerlings	40
Juveniles and adults	35

Source www.iaffd.com/html?v=3.13.

Lipids are particularly good energy sources for catfish. Starches are not digested as well as lipid by catfish. The level of carbohydrate in the diet appears to affect starch digestion. The predominant sources of carbohydrate in catfish feeds are grain products, which are 60–70% digestible. Generally, phosphorus from plant sources is only about 30–50% available to catfish; phosphorus from animal sources is about 40–80% available.

All animals require protein, vitamins, minerals, lipids, and energy for normal growth and other physiological functions. The primary goal in processing feedstuffs into a feed is to maximize the nutritional value of various feed components to meet nutrient requirements. Nutrient requirements for catfish have been well defined. In formulating and manufacturing catfish feeds, it is essential that the finished feed meet nutrient requirements and be in a form that is readily consumable and is digestible. Feed processing may have a profound effect on certain nutrients and little effect on others. It may make certain nutrients more available and others less available. However, the feed manufacturing process should produce a feed pellet of good quality with the least amount of detrimental effects on the nutrients present.

- **Catfish feeding**

When it comes to catfish feeding, there does not appear to be one "best" method for feeding catfish, particularly considering that numerous factors (most of which cannot be controlled) affect feeding. Feeding rate for catfish is determined basing on the percentage of fish body weight. Feeding a prescribed amount of feed based on fish biomass in a particular pond works best when the biomass in each pond is known and an accurate estimate of feed conversion can be made.

- Catfish can be fed once a day to what is commonly called "satiation". However, feeding to satiation is highly subjective and is often difficult to achieve in ponds containing a high standing crop of fish without adversely affecting water quality. Thus, to maximize production and profits, catfish should be fed a feed that meets their nutritional requirements using a feeding strategy that is adapted to the specific culture conditions at any given time. That is, under normal conditions catfish should typically be fed daily as much feed as they will consume without adversely affecting water quality.

- Depending on water temperature and other water-quality parameters and on the health of the fish, it may be prudent to restrict the daily feed allowance or to feed less frequently. How much to feed and the frequency of feeding are decisions that must be made daily by catfish producers based on each pond of fish.

- No two ponds of fish are exactly alike, thus feeding behavior in individual ponds may differ greatly or feeding activity in a particular pond may vary greatly from day to day. The following recommendations given should be considered as guidelines only. No single feed or feeding method is suitable for all circumstances.

- If a fish is provided with nutrients above its maintenance requirement, there is a net retention of nutrients in the form of body products such as muscles, bones among others. This feed conversion efficiency is dependent on both genetic and environmental factors.

In order to know the feed type a fish species requires, we need to as well understand the feeding behavior of the fish. For example, omnivorous require different feed type and nutrient levels than carnivores. In the same argument, column/surface feeders require floating pellets while bottom feeders require sinking pellets.

Fish body weight or growth is a factor as a result of nutrient provision to the fish. There are two ways in which nutrient requirement influences body weight or growth namely:

a. Relationship between growth phase (exponential, linear and asymptotic) and nutrient requirements.
b. Short term nutrient requirement

Absolute or Relative Feed/ Nutritional Requirement

Total nutrient requirement is known to increase with increasing body weight while the relative nutrient requirement (g/kg body weight) decreases.

Environmental factors

Environmental factors of the culture facility, for example feed intake is influenced by the water temperature, dissolved oxygen and, stress factors.

The quality of catfish feed should have both desirable nutritional and physical characteristics. The feed should contain all the nutrients required by the fish, in the right proportions for good growth and health. The fish should as well be easily consumed and digested by the fish. For example, the feed should not easily be disintegrated in the water. The following are nutritional requirements of catfish are presented in Table 1.6.

Table: 1.6: Basic nutritional requirements for catfish

Nutrient Uses Desirable Range Levels in Diet
ProteinProvides the required amino acids
Necessary for the building muscle, blood, enzymes, hormones etc.
Diets lower than 28 % protein result in fatty fish. 32%
Dietary EnergyRequired to drive chemical reactions for tissue maintenance, growth and activity.
Excess energy in diet reduces diet intake resulting in fatty fish which reduces dress out yield and shortens shelf-life of frozen products. 8.5 – 9.5 Kcal/g protein
Fats Major source of energy for fish.
Means by which fat soluble vitamins such as E and D can be absorbed by the body
Flesh texture and flavour depend on fattiness of the fish
Fats add flavour to diet and act as an attractant
Too much fat in diet results in fatty fish
Fatty diets are difficult to pellet and they spoil easily. 4 - 6 %; increases as protein level increases
Carbohydrates Complex carbohydrates are not well digested by fish, but they are cheap fillers.
They are cofactors and/or activators of enzymes
They are osmo-regulators and acid- base balance 20-35%
Minerals and Vitamins Minerals are the inorganic component of the diet
They are structural components of hard and soft tissues
They are cofactors and/or activators of enzymes
They are osmo-regulators and acid- base balance Vitamin mg/kg
Fiber High fibre content of diets reduces their digestibility
Excess fibre in diet increases pollution of the pond water. <4%
Grind the ingredients into very small particles for the young fish (fry) and medium-size particles for the larger fish. The fish should be fed to satiation at the same location of the pond.

Summary

Fish feeding is considered one of the most basic factors in increasing fish production in farms. And if fish cultured fish is to grow, it has to be fed with balanced feeds. Good nutrition in fish production systems is essential to economically produce a healthy, high quality product. As fish feeds with good nutrition are costly, the development of inexpensive, balanced diet formulations is of great importance. This will support aquaculture to satisfy the increasing demand for affordable, safe, and high-quality fish products. As fish meal is often used as a source of animal protein in fish diets though it is costly, considerations on the use of alternative unconditional feed ingredients as suitable replacements for fish meal in artificial diets for fish feed formulations especially use of plant protein sources such as soybean have been presented.

It has been seen that supplemental diets do not contain a full complement of vitamins or minerals, but are used to help fortify the naturally available diet with extra protein, carbohydrate and/or lipid. Fish, especially when reared in high densities, require a high-quality, nutritionally complete, balanced diet to grow rapidly and remain healthy.

The module encourages fish farmers to use innovative approaches to explore the wide variety of processing by-products potentially available as nutritionally valuable ingredients in specific aqua feeds. Regardless, the final processed aqua feed must meet specific physical standards, such as water stability and palatability, as well as satisfying the fish needs. The chapter has highlighted the importance of proper fish feeding for improved fish growth and increased incomes. Feeding behavior of both tilapia and catfish has been explained

Types of Feeds

2

Introduction

For many farmed fish species, their good growth and production is totally dependent on feeding. A fish farmer would use different types of feeds depending on the purpose of culture, level of management and even financial capacity. This chapter looks into details the different types of fish feeds which includes local, supplemental and complete. Sources of the different feed types, benefits and their limitations on their use have been presented.

Aim

The aim of the chapter which has one session on types of fish feeds is to increase participants' knowledge and understanding of the different available fish feeds, their importance and limitations in their use. Skills on how to use these feeds will be improved.

Objectives

- Participants know
  - Different types of fish feeds
  - Importance and challenges of each feed type
  - Sources of the feed types

- Acquired skills
  - Proper use of the feeds for improved fish growth
  - How to use a combination of the feed types

- Acquired attitudes
  - Proper use of fish feed types improves fish growth

- Relevance to fish seed production
  - Alternative feed types can increase fish production

- Session Overview

  The Chapter is comprised of one session which is looking at the different types of fish feeds

  Materials: Flip- chart paper, markers, study notes, fish feed samples (different types)

  Mode of delivery: Lectures, group discussions
- Duration : 60 minutes

2.1 Types of Feeds

· **Natural Foods**

These are living organisms that are produced in the water where the fish live. These are comprised mainly of phytoplankton (microscopic plants), zooplankton (microscopic animals) but also including insects and certain other plants. The application of fertilizer increases the abundance of these natural foods.

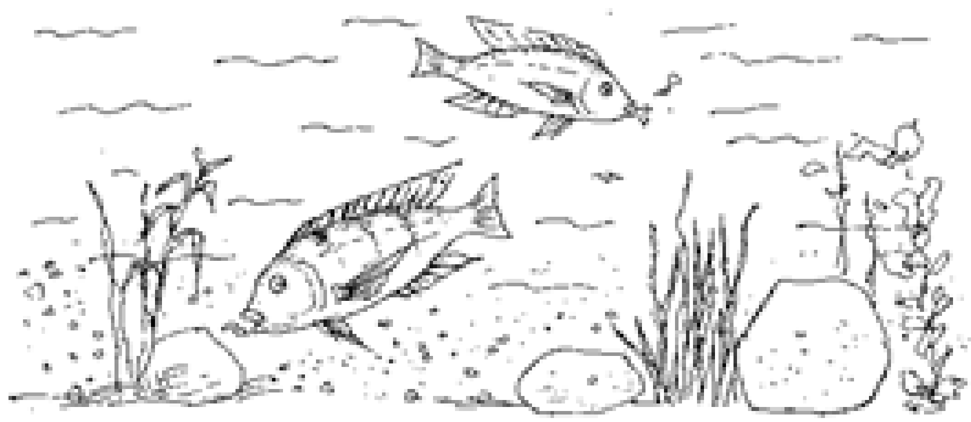


Fig 2.1: Fish feeding on natural food in a pond

Natural food is an important source of essential nutritional elements necessary for the growth of fish. The importance of artificial feed depends on the type of cultured species as fish have different feeding habits. For example, herbivorous fish feed on plant sources in the pond which provides a great amount of natural feed that could cover their nutritional requirements. This means it will not need artificial feed such as tilapia. On the other hand, carnivorous fish require artificial feed because it cannot absorb natural in the pond.

· **Supplementary Feeds**

These feeds are not nutritionally complete and are used when natural foods are not available in sufficient quantity to provide adequate nutrition for fish growth. Supplementary feeds will not adequately support fish growth in the absence of natural foods. Natural food organisms in the water provide essential nutrients. Some examples of supplementary fish feeds are agricultural products and their by-products like wheat bran, rice bran, maize bran, cotton seed cake and even kitchen wastes

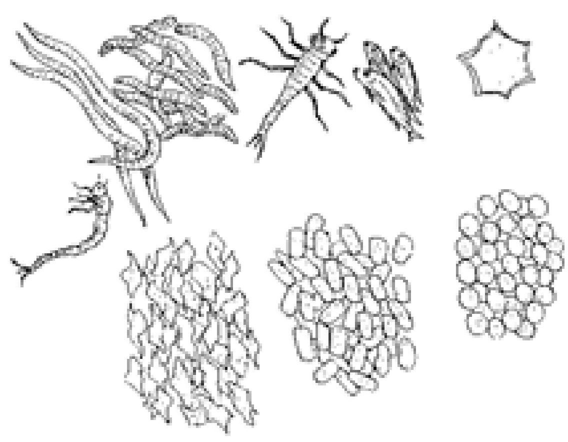


Fig 2.2: An example of both natural and supplemental feed

- **Complete feeds**

These feeds provide all the necessary nutrients for fish growth and other biological functions. They are nutritionally complete manufactured fish feeds that contain all essential nutrients and vitamins. These feeds are commonly used in high technology, intensive culture systems.

2.1.1 Local feeds:

Fish feed can either be natural or supplemental. The culture system contains a critical standing crop (CSC) when natural food is fully utilized for the maintenance and maximum growth. The natural feed for fish can be improved by pond fertilization with either inorganic or organic fertilizers. Above the CSC, nutritional deficits develop and fish should be provided with sufficient nutritional demands through supplemental feeds for high yields. For optimum growth and profits, fish need to be fed with a protein-based supplemental feed. However, where natural food is not available in the culture facility locally available supplemental feed is required.
Examples of Local feeds

Local feeds are what a farmer can easily find within his or her locality to feed fish. These feeds can be used either as single feed or combined with several feedstuffs. These feedstuffs can include the following:

- Maize bran
- Rice bran
- Termites
- Beer wastes
- Chisoso
- Mwamuna aligone
- Chigwada
- Kholowa
- Luni
- Cocoa
- Fruits
- Kitchen leftovers
- Leaves
- Grass
- Soya bean flour
- Sun flower cake
- Other leafy vegetables

As the module is promoting best aquaculture practices, a farmer can formulate his/her own feed using locally available ingredients such as agricultural products or their by-products. For instance, the farmer can make a supplemental feed with approximately 18% crude protein by simply mixing 70% ground maize bran and 30% ground soybean. Rice bran can replace maize bran in areas where rice is more abundant.

These supplemental feeds which has a simple combination of locally available inputs, have a diet which contain some nutrients fish will require for a healthy growth of fish hence a high yield. Fish farmers in Malawi can produce their own fish feeds locally than purchase high quality imported feeds. Farmers are advised and taught on how to make their own fish feed since commercial feeds are very expensive and sometimes not easy to be accessed. It is believed that if farmers were to make their own fish feed using locally available ingredients, they could reduce the cost of production by over 50%.

Water hyacinth – an Example of Locally Available Feed

The hydrophylic water hyacinth (Eichhomia crassipes) is a pest. It is a fast growing plant found throughout in many water bodies in Malawi. Water hyacinth is a feedstuff for farm-mixing of feed and simple farming systems where labour is easily available at low cost. It is a feedstuff for herbivorous/omnivorous freshwater fish, but unsuitable for carnivorous fish. This plant is also used as soil fertilizer, compost and biogas production, mushroom cultivation, cardboard manufacture and for making handicrafts

The limiting factors for its use are its high crude fibre and ash content. The most suitable inclusion rate depends very much on the farming system practised.

A recommended guideline follows:

- Supplementation of basic feed, e.g. rice bran, broken rice, chicken manure
  = 25.0 to 50.0%
- Replacement of protein sources in a formulated feed (fish meal, vegetable oil meals/cake)
  = 5.0 to 10.0%

Processing

- The swollen petioles or leaves that float on water are used as feed. They are fed fresh or have to be cooked, compos ted or dried.
- Processing of the petioles is a backyard procedure. There is no particular method of processing although some have resorted to composting by mixing dried and freshly chopped water hyacinth.

2.1.2 Pelletized feeds

The fish feeds which are in the form of granules or pellets provide the nutrition in a stable and concentrated form. They enable the fish to feed efficiently and grow to their full potential within a desired time. Production of pelleted feed is a popular technique of making fish feed among others. Pelleting is to process the mixture of feed ingredients under high temperature, moisture and high pressure within a fish feed pellet mill. As there are different ways of producing pellets, in the local setting, farmers can use tins or sheets with holes. They can put their dough and press it on the facility and small granules will be collected under the locally fabricated pelletizer. This does not require high temperatures and sophisticated equipment.

- **Palletisation involves**
- Compressing small particles to create larger ones called pellets, and during this process, moisture, temperature and pressure are employed.
- Producing stable granular to disintegrate in water. Ingredients are ground so finely using a hammer mill.
- The process of pelleting involves:
  - o Grinding
  - o Mixing
  - o Palletisation
  - o Drying
  - o Fat coating
  - o Cooling

- **Prices and nutritional composition of pellets**

The formulation of farm-made fish feed is relatively simple, often comprising of locally available ingredients such as fish trash, rice bran and vegetables. Nutritional content of any formulated fish feed depends on:

- Fish species
- Stage of the fish
- Purpose of the fish – like broodstock conditioning

- Table size fish fattening
- Rearing method - pond based, hapa, tank or cage based farming
- Capacity to produce such feed

It should be noted that nutritional content should always be higher in feed for fry and juveniles and also for broodstock. This is to ensure fast growth for the fry and juveniles and for the broodstock to ensure that they are ready for spawning within a reasonable time and to ensure that good quality seed is produced. Prices of pelletized fish feeds go together with nutritional content of each fish feed produced and of course size. The higher the nutrition content of any formulated fish feed, the higher the cost. This is as a result of the higher cost of ingredients added to the feed like fish meal.

Advantages of pelleting fish feed

a. Pelleted feed is readily available
Except for the production of extruded floating fish feed, the technology for large-scale manufacture of dry pellets exists in most of developing countries. With minor modifications feed mills equipped for manufacturing pelleted poultry feed can also produce sinking-type dry pelleted fish feed. The minor modification is on the hammer mill screen which needs to be changed to one of smaller hole diameter for finer grinding of ingredients;

b. Long shelf-life.
Since the produced pelleted feed is dry, it has a fairly long shelf-life. Dry pelleted feed has a shelf-life of at least two months under good storage conditions in the tropics; and

c. Easy application
Dry feed is easy to dispense. Control of feeding can also be easily exercised to ensure adequate feeding and minimum feed wastage.

Major disadvantage of dry pelleted fish feed

It has a high cost of production as it uses conventional ingredients which are on high demand in production of feed for livestock and sometimes people. However, because good quality compound feeds are usually more efficient, they may be more cost effective than traditional type feeds.

2.1.3 Extruded fish feeds

Extrusion is a high temperature short time (HTST) heating process. Extrusion refers to cooking the mixture of feed ingredients under high temperature, high moisture and high pressure in the extruder. This process is done on a fish feed extruder which is an ideal machine designed for processing floating or sinking aquatic feed just by adjusting the formula. In the extrusion process feed is compressed just as in palletisation as well as cooked. As such the process requires higher levels of moisture, temperature and pressure than palletisation. The extrusion process is increasingly becoming a popular method of producing desirable floating fish feed especially those that are feeders in the water column unlike bottom feeders. The process is capable of producing a variety of floating feed that is buoyant, fast or slow sinking, depending on the needs of each species. The higher temperatures are for a short period of time to minimise nutrient loss while improving the digestibility of starches and proteins compared to pelleted food. Extrusion in feed minimizes the degradation of food nutrients while improving the digestibility of the protein and starches. These feeds which are made by firms are normally called commercial feeds.

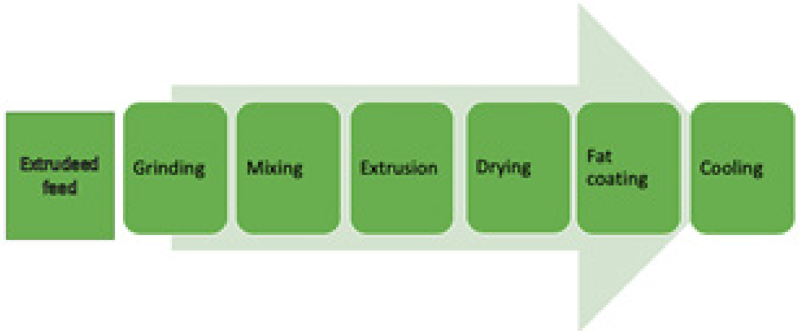


Fig 2.1: Process of floating or extruded fish feed

Purposes of extrusion processing

- For cooking to realize starch gelatinization and deactivating anti-nutritional factors
- For sterilization to eliminate the pathogens in raw materials
- For expansion to improve the feed quality
- For texturization to get porous structures
- For product shaping to form pellet that fish can feed easily

Advantages of extruded feed

a. Lower levels of pollution
The high temperature and pressure kill most of the pathogens.

b. Longer stability in water
Extruded feed causes starch to glue the feed particles together even stronger due to high temperature and pressure. The extruded feed particles can stay intact for 12 to 36 hours while maintaining all its nutrients.

c. Greater digestibility
The cooking of the feed during extruding increases feed digestibility thereby allowing fish to make most of the feed.

d. High efficiency and a high conversion rate
Since extruded feed are highly digestible then it follows that feed utilization is very high hence fish absorb most of the nutrients in the feed. This results into high feed conversion ratios. As a result, extruded feed is a higher quality product that increases the profitability of fish farms.

e. There is low moisture content which makes its shelf life to be longer.

Disadvantages of extruded feed

This feed has a high cost of production hence are very expensive than the rest of the feed types. As such although the feed is good but has very low acceptance or adoption among fish farmers.

Summary

The chapter has looked at the different types of fish feeds a farmer can use. The importance and disadvantage of each of the fish feed types has been presented. Costs for each of the feed types have been elaborated. An example on extruded feeds is that the feeds have lower levels of pollution, longer stability in water as it can stay intact for 12 to 36 hours while maintaining all its nutrients. It has greater digestibility and high efficiency and a high conversion rate. The main challenge is that it has a high cost of production hence are very expensive than the rest of the feed types. As such although the feed is good but has very low acceptance or adoption among fish farmers. Simple steps on how a farmer can make pellets for a simple formulated feed have been presented.

Feeds Formulation and Production

Introduction

Formulation of fish feed at commercial and local level aims at coming up with good feeds which will be acceptable by the fish and lead to improved fish growth. For one to formulate a good feed, he or she has to know the nutrient requirements on the cultured fish species, size of the fish and its use whether fry, juvenile or broodstock. Knowledge on the methods for feed formulation like the use of Pearson square has to be available. For a successful feed formulation enterprise, it is important to consider all the necessary feed formation steps for successful and sustainable fish feed formulation. In the chapter a variety of other protein sources which are being considered as partial or complete replacement for fish meal, especially use of plant protein sources such as soybean meal and other ingredients has been articulated. Other raw materials that one can purchase for feed formulation have been highlighted. Proper packaging and storage of the feed so as not to compromise their quality is necessary.

Aim

The aim of the chapter is to enhance participants' knowledge and skills in feed formulation using different methods and also packaging and storage. Participants will increase understanding on how to formulate cost effective feed and feed which will not negatively affect water quality.

Objectives

- Participants know
  - Different methods of formulating feed
  - How select ingredients
  - Proximate composition (% dry matter) of some of the locally available ingredients
  - Factors to consider when rationing (formulating) fish feed

- Acquired skills
  - Feed formulation
  - Use of person square method
  - Calculating cost benefit analysis of feed

- Acquired attitudes
  - Farm fish feeds can be easily formulated

- Relevance to fish production
  - Strategies and tools to plan intensification on the formulation and use of good feeds for fish growth improvement

This chapter is divided into two sessions
Session 1: Fish feed formulation and Selection of ingredients
Session 2: Packaging and storage

- Mode of delivery
  - Lectures, group discussions, practical

- Materials: flip chart, markers, lecture notes, feed raw materials, ingredients, fire, pots
Duration: 80 minutes

Session One

3.1 Feed Formulation

Feed preparation and production has several stages and procedures which need to be critically followed. Outlined below are the stages and procedures which have to be followed.

3.1.1 Selection of ingredients

It is necessary to know the right and available ingredients one is to use to make fish feed. An ingredient is a component part of any mixture. Different feed ingredients contain moisture, protein, carbohydrates, minerals & vitamins. Knowledge on their composition is of utmost importance because fish requires nutrients in specific quantities.

When selecting these ingredients it is important to also consider the following;

- **Feeding preference of the fish**: select ingredients according to the fish's feeding habits in its natural habitat. For example; if the fish is omnivorous, ingredients can be selected from both plant and animal origin, if it is a herbivore ingredients should only be of plant origin and so forth.
- **Cost**: select ingredients that are of low cost. This way the overall cost of your feed will be reduced and this in turn will reduce your production cost.
- **Availability and accessibility**: This will is easier and cheaper to make the desired feed and in the required volumes whenever it is required.

Table 3.1: Proximate composition (% dry matter) of some of the locally available ingredients

Ingredients	DM	CP	EE	CF	T. Ash
Fishmeal	93.80	42.00	6.00	6.00	31.50
Groundnut Oilcake	95.40	42.00	9.00	8.50	6.90
Soybean meal	91.80	48.30	21.20	6.50	8.00
Rice bran	92.30	12.80	13.80	13.80	10.50
Sun flower		40.00		12.20	8.10
Wheat bran	89.90	13.90	4.00	10.50	6.90
Cotton seed cake	91.90	26.00	8.00	21.00	14.00
Maize	91.00	9.00	4.00	2.20	1.90
Spent yeast	94.10	43.00	0.50	N	7.60
Azolla	89.80	13.00	1.20	9.00	17.60
Brewery grain waste	91.40	26.00	15.50	15.30	3.00
Rice polish	89.90	12.20	1.80	13.20	13.80
Snail	30.26	52.50	4.00	0.80	16.00
Earth worms	17.25 4	9.00	14.00	0.40	13.20

Source: ICAR – Central Coastal Agriculture Research Institute

When it comes to plant protein source, soya bean meal contains the highest protein content and has the best essential amino acid profile. However, it is deficient in sulphur-containing amino acids (methionine, lysine and cysteine). It also contains endogenous anti-nutrients, including protease (trypsin) Inhibitor.

Prices for these ingredients always vary according to seasons, locality, demand and supply on the market in a particular year. It is therefore advisable for farmers to either grow or buy the product when it is in abundance as guided by the farming calendar. This will minimize expenses on fish feed production. To ensure the production of quality fish feed, it is necessary to buy quality ingredients as they will always affect the quality of the fish feed to be produced. Good quality ingredients will lead to a good quality feed which will translate into good fish growth and profits.

Table 3.2: Proximate analysis for some animal protein sources

Ingredients	Crude Protein %	Crude Fat %	Crude Fibre %	Ash %
Fishmeal	55 – 78	4 - 11	0.8 - 1.5	11 – 26
Blood meal	76	1.1	2.30	4
Bone meal	26	2.66	2.30	53
Feather meal	77 – 92	3.96	0.57	5.41

Table 3.3: Nutrient Composition of Different Feeds (FAO, ND)

Type of Feed	Weight of Fish (g)	Crude Protein %
Fine fry mash	0.20 - 1.00	45 - 50
Fry mash	1.00 - 5.00	40 - 50
Crumble	5.10 - 15.00	40
Starter Crumble	15.1 - 40.00	30 - 35
Starter Pellet	40.0 - 100.0	28 - 30
Grower Pellet	100.1 – 200.0 2	8 - 30
Finisher Pellet	>200.1	28 - 30
Broodstock Feed		40 – 45

On nutrient composition of different fish feeds, the general trend is that the higher protein content is required for feed meant for younger fish and broodstock than the ordinary older fish. The protein percentage, therefore, gradually reduces as the fish grow older. The higher the protein content, the higher the cost price of the feed too. Fishmeal has become an expensive feed ingredient all over the world, due to limited availability and competition between different animal production sectors. Available alternative cost effective protein sources can therefore be used.

Plant leaves

The main types of plant leaves commonly used as protein source alternatives to fishmeal in fish diets include leaves of moringa (Moringa oleifera), cassava (Manihot esculenta), and sweet potato (Ipomoea batatas). The crude protein (CP) content of plant leaves from 311 to 349 g CP kg-1 dry matter (DM) in moringa leaves, and 288 g CP kg-1 DM for unprocessed and 290 g CP kg-1 DM for processed cassava leaves, sweet potato leaves can be used as an energy source in catfish diets. However, plant leaves are high in fibre and other anti-nutritional factors that may hinder their potential for fish growth and may affect fish

Aquatic plants

The major aquatic plants that have been studied as replacements to fishmeal in fish diets include aquatic ferns (Azolla spp.), duckweed (Lemnoideae spp.) and water lettuce (Pistia stratiotes). These ingredients have a good nutrient profile with respect to protein, vitamins and minerals. Seasonal availability, none of these ingredients is commonly used in commercial fish feed production.

3.1.2 Feed formulation and production

Feed formulation and feeding practices are crucial for the development of aquaculture in Malawi. As feed constitutes more than 50% of the total fish production costs, good feed which will improve fish growth is necessary. When producing a fish feed, the producer needs to have the right information on (a) cost of feed ingredients; (b) nutrient concentrations in feedstuffs; (c) nutrient requirements; (d) nutrient availability from feedstuffs; and (e) nutritional and non-nutritional restrictions. Several constraints limit the wider adoption and use of least-cost formulation of catfish and tilapia feeds in addition to the lack of a sufficient number of suitable feedstuffs. These include a lack of knowledge of the nutrient levels that result in maximum profit as opposed to levels that maximize weight gain, a lack of capacity to formulate and make good feeds and scarcity of feedstuffs. This chapter therefore focuses much on how to formulate good feeds for fish, the required ingredients, packaging, storage and the different fish feeding practices one can follow.

3.1.3 Feed Formulation Methods

Farmers are encouraged to be making their own feed using locally available ingredients to significantly reduce cost of production. By formulating own feed, the farmer can reduce cost of production by over 60%. This will eventually increase returns. Formulation of fish feed at a local level depends on a number of factors. It is important to consider each of these for successful and sustainable fish feed formulation. After this has been done, materials can then be purchased and feed formulated. It is imperative that the final product of the formulation is cost effective. There are several ways on how a fish farmer can formulate own feed and these are:

- Pearson square method
- Least cost
- Try and error

These methods can be calculated by using excel spread sheets. Alternatively, software such as Winfeed may be used.

Important factors in feed formulation and production

- Availability or seasonality of the ingredients
- Unit cost of ingredients (price per kg)
- Processing procedure of that ingredient
- Anti-nutritional factors consideration
- Transportation costs of ingredients

i. Pearson Square Method

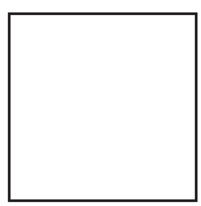
This method requires one to know the percentage of crude protein in the supposed ingredients. You can know this either by using book values (from literature) or by taking samples of the supposed ingredients to a Research Centre for analysis. Having the crude protein percentages of each ingredient you can formulate the feed as follows:

Solution: Take the following steps to formulate your own fish feed.

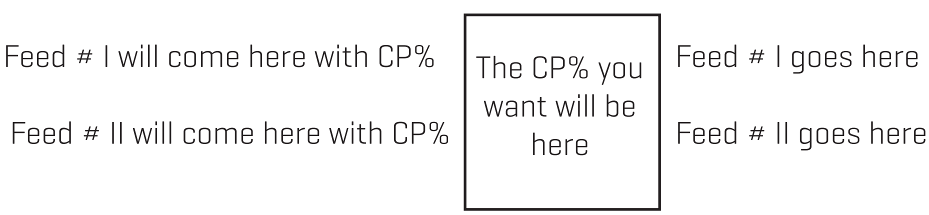
a. Draw a square
b. Place the crude protein percentage (CP %) you want your feed to have on the centre of the drawn square.
c. Draw diagonals of the square
d. Place the crude protein levels of the ingredients on the left
e. Subtract a small number from a large number diagonally across the square by using the crude protein on the left of the square and desired crude protein level on the centre of the square. The result is written on the right against its diagonal.
f. The result placed on the right of the square is the proportion of the amount of feed ingredients to be used in the mixture. The proportion of feed ingredient on the right belongs to the feed ingredient directly opposite to it on the left.

The process of using the Pearson Square Method

Step 1: Draw the square



Step 2: Set up the square and label it



ii. Try and Error method

The farmer is required to have basic knowledge of different nutrients in an ingredient and nutrient requirement of their species of fish cultured. The farmer uses the basic knowledge of functions of different nutrients such as proteins by simply mixing available ingredients to make the feed. In this regard, different proportions of feed components are either increased or reduced based on the performance/response of the fed fish. The name of the feed made is based on source of protein included. For example, if soya bean was used to formulate fish feed, the name of feed formulated will be soya bean based diets or rations.

- Factors to consider when rationing (formulating) fish feed

Feedstuffs contain protein amounts ranging from about 15% - 50%. This falls within the range of protein requirements for optimum growth of different fish species. Proteins derived from vegetable sources are

somewhat deficient in several key amino acids such as lysine, methionine, and tryptophane. A fish diet must provide a suitable energy source and be in proper balance with respect to:
- Proteins
- Carbohydrates
- Minerals
- Lipids
- Vitamins and growth factors

As we are now formulating the feed, some of the factors to be considered include the following:

i. **Composition**
- The commodity must have a composition that allows it to be compounded into a balanced diet
- For example, higher water quantity will make the feed difficult to be compounded

ii. **Palatability**
- The feed formulated should be tasty with a good smell to be appetizing to the fish.
- Feedstuff that smells nice and is tasty is consumed in large quantities while feed less tasty and smelling bad are rejected by the fish.

iii. **Digestibility**
- As much as we are saying use locally available ingredients make sure that the fish should easily digest and absorb the nutrients in the feed.

iv. **Texture**

The feed should have the texture preferred by the fish according to the size of the mouth. For example the feed should have fine texture if it is for juveniles.

Fig 3.1 and 3.2: Good feed size will necessiate easier feeding

v. **Type of fish cultured**

Fish like tilapia are omnivores and can be given either plant or animal-based feed.

vi. **Life history stage**
- Young fish require a lot of proteins than mature ones hence fry or juvenile require feed rich in proteins than adult fish.
- Fry or juvenile fish need high level of proteins for body building and repair of worn-out tissues while adult fish require proteins only to repair of worn-out tissues.

- At the same time please note that adult fish or large fish feed a lot since they have a higher feed requirement to maintain their metabolic activities
- Stunted fish, fry or juvenile which are small in size eat less due to their smaller feed requirement.

vii. **Physiological status of the fish**

- Sick fish need feed with a high protein levels to maintain their worn-out tissues than healthy fish.
- Fish during spawning or brood stock need a larger nutrient level such as protein in their feed to satisfy nutrient requirement for both the parent and the gonad development.
- Hungry fish need a lot of feed than fish that are not hungry.

viii. **Familiarity**

- Fish should be given feed they are used to eat since new feed is usually rejected
- For good acceptance and to maintain good water quality, new feed type should be gradually introduced to the fish

ix. **Fish feed ingredients, nutrient composition and availability**

- Stability during storage – this primarily relates to the vitamin stability and the stability of lipid protein that may oxidize either in dry or frozen storage
- Toxic factors – of all the feedstuffs found as alternatives to fishmeal in aquaculture diets, soya bean has received the most attention

- Fish Feed Formulation Challenges
  Nutritive requirements of fish do probably offer less flexibility than do those of most land animals. Most of the selected cultured fish species are carnivores therefore requiring a diet of high protein content. These fish species have very poor utilization of carbohydrates as an energy source. Technical challenges in mixing the right ingredients in right proportions affects quality of fish feed produced.

Feed Milling Process

Feed manufacturing and the associated quality control programs are keys to a successful fish culture. Profitability of fish farming should not be just a chance but by following the necessary steps as not to compromise on quality.

Dry feed may be grounded, sifted, screened, mixed, compressed, expanded, textured colored and flavored. By one or more of these processes, a variety of ingredients can be prepared into a standardized product. We have to remember that fish has preferences on size, texture and they even react to color, odor and flavor. These therefore have to be considered when preparing a fish feed.

- Grinding – ingredients pass through a grinder with several reasons
- Clumps and large particles are reduced in size
- Some moisture is reduced due to aeration
- Additives such as antioxidants maybe blended
- Grinding improves feed digestibility, acceptability, mixing properties, palatability and increases the bulk density of some ingredients

Mixing – why mixing?

- To start with a certain assortment of ingredients called a “formula”, adding some definite weight
- Ensures that each small unit of the whole, either a mouthful or a day’s feeding has the same

proportion as the original formula

- Three mechanisms are involved in the mixing process and these are:

a. Transfer of groups of adjacent particles from one location in the mass to another
b. Diffusion: distribution of particles over a freshly developed surface
c. Shear: slipping of particles between others in the mass.

- **Extrusion**

Extrusion refers to cooking the mixture of feed ingredients under high temperature, high moisture and high pressure in the extruder. Floating or sinking feeds are made in the process

- **Drying**

This is the process of removing excess moisture in the feed. This can be done either by sun drying or drying in a machine.

- **Fat coating**

Fat or oil coating is done after pelletizing. The oil ration in pellets can be increased enough without influencing the pellet solidness. This is done when water has been evaporated

- **Cooling**

This involves lowering the high temperature of the feed as it comes out of the feed machine before it is packaged.

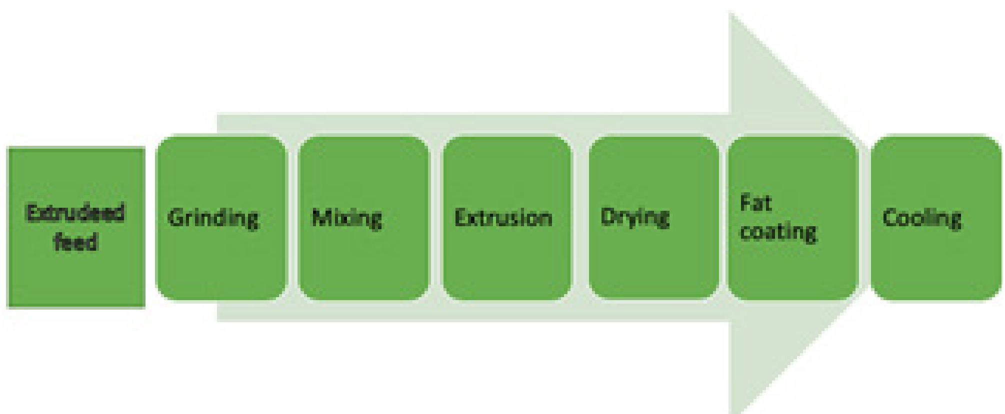


Fig 3.3: Feed making process

3.1.4 Forms of fish feed

Most of the locally made single ingredient fish feed are not complete as they do not supply all the nutrients a fish might need in its diet. As such it is important to formulate a feed from two or more ingredients in the home setup or commercial feed formulations. A diet may be formulated to supplement natural foods already available in the production system or as a complete formulation when no other foods are provided. A complete diet must be nutritionally balanced, palatable, water stable, and have the proper size and texture.

- **Dry Feeds**

Feeds can be formulated to be dry, with a final moisture content of 6-10%, semi-moist with 35-40% water or wet with 50-70% water content. Most feeds used in intensive production systems are commercially produced as dry feeds. Dry feeds may consist of simple loose mixtures of dry ingredients, such as "mash or meals," to more complex compressed pellets or granules. Pellets are often broken into smaller sizes known as crumbles. The pellets or granules can be made by cooking with steam or by extrusion. These pellets can be made to sink or float depending on feed requirement of the fish.

- **Semi-moist and wet feeds**

Semi-moist and wet feeds are made from single or mixed ingredients, such as trash fish or cooked legumes, and can be shaped into cakes or balls. Fish feeds are formulated in a number of ways however; most of them begin with formulation of a dough-like mixture of ingredients. Ingredients can be obtained from local markets, feed stores, grocery stores, pharmacies, and specialty stores such as natural food stores. The dough is made by blends of well ground dry ingredients. The dough is then kneaded and water is added to produce the desired consistency for a particular species of fish.

The same dough may be used to feed several types of fish, such as catfish. The dough is then rolled into pellets or flakes, respectively. The amount of water, pressure, friction, and heat greatly affects pellet and flake quality. For instance, too much heat will lead to overcooked pellets while too little moisture in the pellet will cause them to crumble. Proteins and vitamins will be denatured by high temperatures as such do not store ingredients at higher temperature of above 70° C (158° F) and do not prepare dry feeds with water at temperature higher than 92°C (198° F).

- **Fish feed production tools, equipment & structure**

Fish feed processing will require basic tools and equipment basing on the level of production. There are a number of options a farmer can employ to process fish feed which can be tools and/or equipment. These can be electric or petrol/diesel engine driven machinery as well as use of hands and feet and other locally available materials. The range of equipment which can be used within each processing operation can be summarized as follows:

Table 3.4: Options for feed processing equipment

Process operation	**Equipment**		**Raw material/product**
Size reduction	**Mortar and pestle**		Dry or moist grinding or blending
	Mincer		Wet materials i.e. trash fish
	Hammer mill		Coarse-fine dry materials i.e. maize
	Plate mill		Coarse-fine dry materials
Blending	Physical	Hand	For small quantities variable efficiency
		Feet	
	Mechanical mixers	Bowl	Moist dough
		Horizontal	Dry powders or moist crumbs
		Vertical	Dry powders
Forming	Hand		Dough ball
	Mincer		Moist noodles
	Pelleter		Dry pellets
	Cooker extruder		Semi-moist/dry pellets or noodles
Drying	Solar		Variable efficiency
	Mechanical		Controlled drying

Source: Wood, 1993

Importance of some of the tools and equipment used to prepare the ingredients

- **Grinders/Pounders/Hammer Mill**
  - o Grinding helps in reducing the clumps, large fragments to desired size and, some moisture is removed
  - o Grinding of ingredients improves feed digestibility, acceptability and ensures uniform mixing.

- **Mixer or Hands**
  - o Feed mixing ensures a proper distribution of nutrients so that each small unit of the whole is the same proportion as the original formula
  - o For better mixing, mix small ingredients first and larger proportions last

  Pelletizer or Hands
  - o Used for making fish feed pellets
  - o Almost complete uptake of fish feed is ensured by pelletizing feed

  Weighing Scales
  - o For weighing ingredients and completed feed.

- **Processing feed ingredients – treatment**

The selected ingredients must be processed in order to be applied to the fish feed. The choice of equipment to be used will be limited firstly by financial resources, secondly by raw materials availability, thirdly by the required scale of feed manufacture. The most common processing operations can be summarized as:

- Raw material drying; all the necessary ingredients must be properly dried so as not to compromise the feed quality.
- Raw material size reduction; can be done to ensure that the ingredients are well sized for easy consumption or ingestion as well high digestibility. Small sized ingredients mix well with other ingredients in a diet.
- Raw material blending; it is very important that feed ingredients blends well together so that the little feed consumed should be very representative with all essential nutrients put in the feed. One can use hands or feet to do that but machine mix well.
- Feed forming; the way the feed is presented to the fish will determine the way the ingredients are processed. The feeding of fish with pellets requires that the feed ingredient be processed by a pelletizer. If the fish are to be fed with powdered feed, then a hammer mill is adequate to process the feed ingredients.
- Feed drying; the drying of fish feed is necessary and is determined by the nutrients require to be preserved in the feed. The drying of feed on the open sun may lead to lose of nutrients as the drying process could be too quickly and too much.
- Packing and Labeling: the prepared feed has to be properly packaged and labeled. Labeling will not help the feed producer to know when the feed was produced, nutrient content, type of feed and size.

These details will also help the final user to make informed decisions when using the feed.

Fig 3.4: Soya has to be roasted before mixed to other ingredients Fig 3.5: Cooking soya flour

3.1.5 Fish Feed Mixes

There are several fish fed mixes in fish feeding and these include the following:
Simple Mixtures – meal form where the feed is formed by mixing the powders of various ingredients

Compound feed: This falls into

- Crumble making
  - Mix the ingredients as the formula chosen
  - Add a binder e.g. cassava meal or flour as a proportion of the ingredient
  - Add water to the mixture
  - Make sure every part is thoroughly wet
  - Make flat chunks or paste dolls
  - Spread them out in the sun to dry

- Pellets
  - Mix the ingredients as the formula chosen
  - Add cassava meal, flour or any other binder as a proportion of the ingredient
  - Add water to the mixture
  - Make sure every part is thoroughly wet
  - Use a pelletizer or an extruder to make either slow sinking pellets or floating pellets
  - Dry the feed in direct sun light or dryer
  - Pack the feed after drying
  - Label the packed feed for easy identification

3.1.6 Processing Feed Ingredients

Even though final profit may not vary, farmers are usually afraid of using high-priced feed. In most cases, high-protein feed may result in high growth and higher profit whereas low-protein feed may result in low growth and low profits. Low profits come about because more low-protein feed will be required to achieve the same growth. Nevertheless, low-protein feed is normally more cost-effective as tilapia can make up the extra protein they require from eating natural food. This will happen if the ponds are adequately fertilized. The known fact is that commercial pellets are quite expensive and in many cases farmers may not be able to make the expected profits after the production cycle. This is why they should try to prepare home-made feed, although the lack of knowledge, skill and the unavailability of some inputs becomes a challenge.

The Pearson Square Method

Table 3.5: A simple Pearson's Square technique can help, as shown in Table 4.6 and described below.

Ingredients		% CP	Required CP	Parts	Calculation	Composition of the feed %
Mix 1	**Protein Source:** Fish meal, Sunflower, Soybean meal	42	25	25-7=18	18/35 x 96=	49.4
Mix 2	**Carbohydrates:** Rice bran, Maize bran, Cassava flour	7		42-25=17	17/35 x 96=	46.6
Others	Soybean oil	2%				2
	Mineral mix	1%				1
	Vitamin mix	1%				1
			Total		35	100

A simple feed formulation method for homemade feed

Table 4.6 shows the assumptions that the listed ingredients are locally available and their compositions are known, but now the question is what amounts should be mixed to produce reasonable fish feed. When using soybean as an ingredient, it should be well roasted to remove anti-nutritional factors. A farmer can use the following guideline to formulate fish feed using soybean and maize/rice bran as described above based on feeding a 100 m2 pond and a 200 m2 for 4 months.

In order to find out the appropriate proportions of available ingredients in a feed that is required to have at least 25% CP, a simple Pearson's Square method can be used as follows.

Step 1: Group the ingredients into two:

- Those that contain higher protein levels than the required CP in the feed to be prepared (i.e. 25%) as a protein source
- Those that have lower CP as a carbohydrate source. For example, fishmeal, soybean meal and mustard cakes are protein sources; rice bran and cassava flour are carbohydrate sources.

Step 2: Make Mixture 1 from protein-rich ingredients.

- For example, among the available ingredients fishmeal, soybean meal and mustard oilcake, fishmeal is the most expensive and sometimes unavailable in many rural areas.
- Some farmers may therefore want to avoid it. However, if it is available it is good to use because it has the best profile of amino acids, some of which may not be available in plant proteins.

- Therefore, it can be included at a level of 5%, with the remaining 95% distributed equally between soybean meal and mustard oil cake. Therefore, the protein level of Mixture 1 can be calculated as follows:

Protein % of Mixture 1 = 5 × 60% + 95/2 × 44% + 95/2 × 38.5
= 3 + 20.9 + 18.3
= 42% (approximately)

Step 3: Similarly, make Mixture 2 from a combination of carbohydrate-rich ingredients such as rice bran and cassava flour.

- Cassava flour has very low protein, but high starch serves as a binder. If cassava cannot be obtained, other starch-rich ingredients have to be explored.
- Mixture 2 can be 25% cassava flour and 75% rice bran. The protein content of Mixture 2 can be calculated as:

Protein % of Mixture 2 = 75 × 8% + 25 × 1.4%
= 6.8 + 0.21
= 7% (approximately)

Step 4: Apply the Pearson's Square method to find the proportion of each mixture, placing the required protein (25% CP) in the middle.

Table 3.6: List of ingredients and their protein level

Ingredients Available	Crude Protein (%CP)	%Composition	Price
Fishmeal	60.0	?	?
Mustard oilcake	38.5	?	?
Soybean meal	44.0	?	?
Rice bran	8.0	?	?
Cassava flour	1.4	?	?
Soybean Oil	0.0	?	?
Vitamin mix	0.0	?	?
Mineral mix	0.0	?	?
Total		**100**	**?**

Step 5: As a rule of thumb,

- Keep 2% for soybean oil, 1% for vitamin mixture and 1% for mineral mixture;
- Therefore, the remaining 100 – (2 + 1 + 1) = 96% from the ingredients from Mixture 1 and Mixture 2.
- When calculating the proportion, use a factor of 0.96 to multiply by as shown in Table 4.5.

Table 3.7 shows the composition of feed that contains only 5% fishmeal and the highest amount of rice bran, i.e. 39.6%.

- After finding out the composition of a diet, a farm operator may want to check the price of the feed and also whether the protein level is close to that required.
- Table 3.6 shows the detailed calculation, and shows that the feed has close to 25% (24.6%) CP and the price of feed is $0.71/kg, which is reasonable.
- If the price is higher than expected, reformulation is needed by reducing the proportion of high-price feed.

- Once the feed formula is acceptable, farm operators will use it to prepare feed.

As an example, when making a feed of 5 kg:

Step 1: Arrange ingredients and check their quality.
Step 2: As shown in Tables 3.6 or 3.7 weigh the amount of fishmeal, soybean meal, mustard oil cake and rice bran (Fig. 3.8) separately and mix them together in a large container of over 5 kg capacity.

Step 3: Weigh minerals and vitamins separately, and then mix with the mixture of above-mentioned ingredients in step 2.

Table 3.7: Ultimate feed composition obtained from the above exercise.

Ingredients	Calculation	Composition %
Fishmeal	5% set aside	5.0
Mustard oilcake	(49.4 – 5)/2	22.2
Soybean meal	(49.4 – 5)/2	22.2
Rice bran	46.6 x 85%	39.6
Cassava	46.6 x 15%	7.0
Soybean Oil	2% set aside	2.0
Vitamin mix	1% set aside	1.0
Mineral mix	1% set aside	1.0
Total		**100**

Step 4: Weigh the cassava flour and add 2.25 l of clean water.

Step 5: Heat the cassava in a large pan gradually and keep churning with a shovel or a cooking stick (Fig.)

Step 6: When it starts to become glue-like, i.e. gelatinized, stop heating and pour into the mixture of ingredients.

Step 7: Mixing should be continued until it becomes uniform in color and a firm dough.

Step 8: Pass through the extruder or mincer to produce long noodle-like pellets.

- In some cases the mixture may not appear as pellets but crumbles, which means not enough water has been used; add about 10% water and repeat the process from step 7.
- In other cases, pellets may appear too soft which means too much water has been added. Add more ingredient mixture in the same proportions and repeat the whole process from step 7. For the next batch of feed, reduce the water by 5–10%.

Step 9: Gently break the long pellets into shorter ones and spread them out on a tray.

Step 10: Put the tray in a drier at low temperature, i.e. 50°C for about 6 h or until it is dry. It should not be too dry and too hard, but not too soft either.

Step 11: If a drier is not available, drying can be under shade in the tropics, which may take a day or two to adequately dry the feed (moisture 10–12%), but in temperate regions, a simple and cheap drier to be run by energy from the sun or firewood can be developed using plastic sheet and black zinc sheet

Step 12: After drying, put the feed in paper bags of the required size and store in a cool place protected from rats and insects.

- Home-made feeds can be in powder, crumble or dough form and they sink into the water
- Therefore, it is advisable to use a feeding tray (Fig 4.6.) so that feed does not stick to the mud at the bottom and farmers can also monitor whether fish are eating the particular type of feed or not.

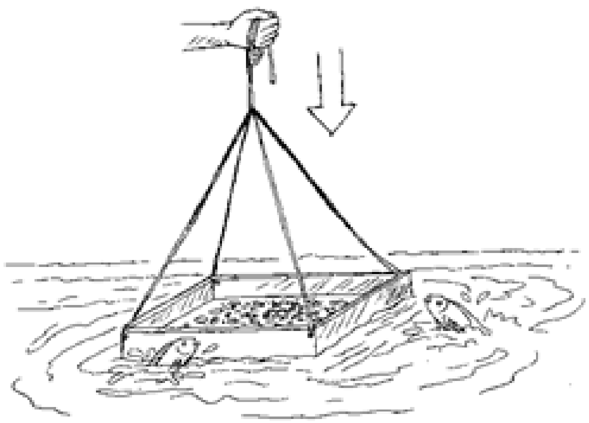


Fig 3.6: Suspended fish feed tray

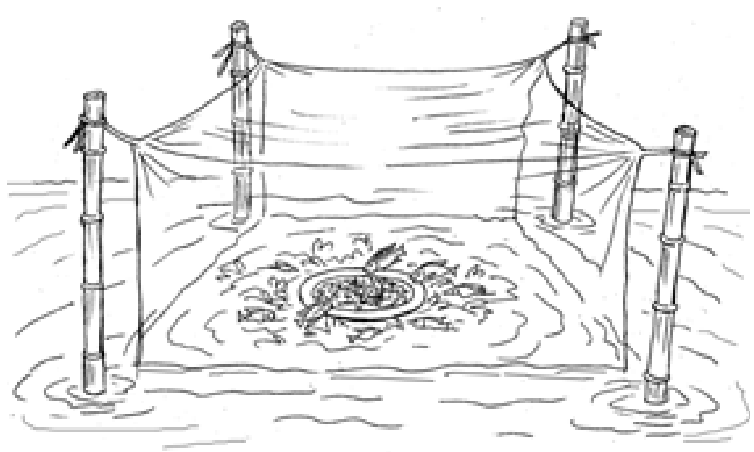
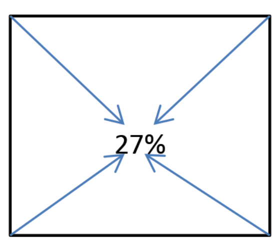


Fig 3.7 Bamboo set to hold a feeding mat

- Feeding trays can be made using nets or can simply be bamboo mats tied at the four corners and hung from a stick or a bamboo pole as shown in Fig 3.7

Rice bran 8.2% 17



Soya bean meal 44% 18.8

To make the 27% crude protein fed, we must mix 17/35.8 of rice bran with 18.8/35.8 soya bean meal.

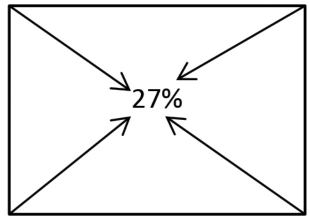
- Rice bran	17/35.8	= 47.5%
- Soya bean meal	18.8/35.8	=52.5%

Now to make 100kgs of this feed we must mix 47.5kgs of rice bran with 52.5 kgs of soya bean meal.

If more than two ingredients are to be used, they may be grouped into basal feeds (CP <20%) and protein supplements (CP >20%). These ingredients are then:

- Averaged within each group and entered into the Pearson square method
- For example, suppose fish meal and maize were available, the crude protein levels of fish meal (52.7%) and of maize (10.2%) are averaged with soya meal and rice bran respectively.

Basal feed 9.2% 21.35
(Rice bran CP + Corn CP)



Protein Supplement 48.35%
(Soya bean meal CP +Fish meal CP) 17.8

The Calculation

Basal feed	=21.25/39.15	=54.53%
Protein supplement	=17.8/39.15	=45.47%

This means, to make 100kg of this feed one will mix the following ingredients in these measures:

- Rice bran = 27.265kg
- Maize = 27.265kg
- Soya meal = 22.735kg
- Fish meal = 22.735kg

The square method is helpful to provide novice feed formulators because

- It can get them started in diet formulation without a need to resort to trial and error
- It be used to calculate proportion of feedstuffs to be mixed to achieve the desired dietary energy level as well as crude protein level

The square method can also be used to calculate the proportion of feedstuffs to mix together to achieve a desired dietary energy level as well as a crude protein level.

The terms that one needs to understand to formulate practical fish diets are:

- Crude protein level
- Energy level, either expressed as Metabolizable Energy (ME) or Digestible Energy (DE)
- Specific amino acid levels
- Crude fibre level
- Ash level

It is advisable to farmers to interchange one feedstuff with another as cost and availability change. Thus, it is assumed that there is no "ideal formulation"' but a rather almost infinite number of possible feed formulations that meets the nutritional needs of the targeted fish equally well.

When formulating feed, we have to know the size of fish to be fed and also season of the fish. For example, the proximate composition of fish meals changes during the spawning season. Generally, the lipid levels increase before spawning and decrease after spawning. This will alter the percent of protein, ash, and carbohydrates in fish meal as the season change. Similarly, many plant feedstuffs vary in proximate composition with their stage of maturity at harvest, location grown, and other environmental conditions such as weather. This means that, in fish feed formulation, an awareness of the potential limitations involved is necessary so that allowances can be made in diet formulation. With this, problems can be anticipated and avoided.

Binding Agents

Any fish feed which is being formulated has an element of a binding agent as one its ingredients. The binding agent provides stability to the pellet and reduces leaching of nutrients into the water. Careful consideration must be made to ensure that the right ingredients are being used as binder.

Summary

The session has presented several areas on the selection of fish feed ingredients, sources and their preparation for effective utilization. As an ingredient a component of any mixture, it is necessary to know the right and available ingredients one is to use to make fish feed. Different feed ingredients contain moisture, protein, carbohydrates, minerals & vitamins. Knowledge on their composition is of utmost importance because fish requires nutrients in specific quantities. Feeding preference of the fish, cost, and availability and accessibility of the ingredients must be considered.

On the processed feeds, even though final profit may not vary, farmers are usually afraid of using high-priced feed. In most cases, high-protein feed may result in high growth and higher profit whereas low-protein feed may result in low growth and low profits. Low profits come about because more low-protein feed will be required to achieve the same growth. Nevertheless, low-protein feed is normally more cost-effective as tilapia can make up the extra protein they require from eating natural food. This will happen if the ponds are adequately fertilized. The known fact is that commercial pellets are quite expensive and in many cases farmers may not be able to make the expected profits after the production cycle.

Feed pellets have to be eaten and should not fall apart before they are ingested by the aquatic animals. The water durability of aquaculture feed, therefore, is important. Manufacturers of aquaculture feed have to consider the eating habit of the aquatic animals when processing feed. The slower the animal eats, the more water-durable the pellets should be. Proper labeling of formulated feeds must be followed

Session Two

Aim

The aim of the session is to increase participants' knowledge and understanding of the importance of good packaging and storage of fish feeds. Skills on feed storage will be enhanced.

Objectives

- Participants know
  - Importance of fish feed packaging and storage
  - Importance of labeling fish feeds

- Acquired skills
  - Proper pancaking of fish feed
  - Proper storage and usage of feed

- Acquired attitudes
  - Fish feed producers and farmers carefully package and store their feed for effective utilization
  - Fish farmers should always actively check and monitor their bought or stored feeds so as not to compromise fish growth

- Relevance to fish seed production
  - Fish farmers should be aware that wrongly packaged feed and poorly stored feed can negatively affect their fish and lead to income losses

- Session Overview

  The session is comprised of two sessions which are feed packaging and storage

  Materials: Flip- chart paper, markers, study notes, fish feed samples (different types)

  Mode of delivery: Lectures, group discussions
- Duration: 30 minutes

3.2 Packaging and Storing Fish Feeds

3.2.1 Packaging fish feed

Any feed that has been produced must be properly packaged. This helps in maintaining the quality of the feed for a longer period. Pelleted feeds have to be put in right bags and quantities that farmers can easily access them. The pelleted feeds are generally distributed in bags of 10kgs, 25kgs and 50kgs. The reused sack bags should not be contaminated by toxins for the health of the fish to be fed.

- Bags may be filled directly from cooler or from holding bins and may be weighed on a scale balance.
- Bags are hand/machine stitched or tied with a string.
- Polythene bags should not be used for storing feeds because of the risk of sweating and growth of mould.
- Use of eco-friendly feed packaging materials should be promoted

3.2.2 Storing Feeds

Quality of fish feed can be maintained or compromised depending on how the feed is being stored. Good quality feed can lose its quality if poorly stored. It is advisable not to keep some feed materials or formulated feed longer than a month. In any feed store, these procedures should be followed:

- Check the stores room for any traces of moisture/water on the floor resulting from leakage or seepage. Get a mop and dry the floor. Check the ventilators on the walls if they are blocked. Usually this may lead to condensation (sometimes referred to as 'dew') that eventually results into water dripping from the roof (iron sheets). This can be observed in the morning hours. Any of such incidents should be reported to the office immediately.

- Check if there is enough ventilation in the stores room. Open all the windows but also keep in mind that you should shut all the windows whenever rains are imminent. If you are not around, please delegate this task to anybody who is likely to be available when need arises.

- Check the temperature of the feed as well as the ingredients by touching the either sides of the bag. If it feels relatively hotter, move that particular bag out of the stores and have the contents spread on a tarpaulin for examination. The rise in temperature could be that some fungi have attacked the feed. If it gets hotter as you touch the contents towards the inside centre of the bag then it is a sign of fungal attack. If it is confirmed that the feed has some fungal infections, i.e. moulds growing on the feed, then a decision has to be made quickly to either discard or dry the feed based on the severity of the problem. Fungal infections can be passed on hence the need to quickly move the feed/ingredients out of the stores and quarantine it. This feed MUST NEVER be taken to farmers.
- Sex reversal feed should be stored at Store at 40C

- Check the number of bags of each ingredient/feed and record the numbers at start and end of day. Write notes against any variations in these numbers.

- Check if there is ingredients/feed that needs to be dried on that particular day. Some ingredients such as fish meal and low fat soy require periodic drying in order to avoid rancidity problems. It's advisable to store them processed/milled to push up their shelf life.

- Check the stores room for pests such as rats, termites, cockroaches and/or their feacal material if you cannot physically trace them. Rats may bring in some infection to the feed/ingredients which may eventually kill the fish. Spilt ingredients/feed on the floor attracts pests.

- All the feed and ingredients should be labeled in line with date of acquisition/ date of processing/ name or type. In case of ingredients, indicate whether raw or milled/mixed or not mixed. Also indicate the expiry date on the bags. It is advisable to keep different feed types separately to avoid spread of infection. The golden rule is FIRST IN, FIRST OUT so older stocks should be dispatched first!

- Do not store and use pesticides or other toxic materials near the feeds

- Rough handling of feeds should be avoided

- Do not stack bags of feed directly against a wall or on a concrete floor. Bags of feed should be on pallets, away from the floor and wall to allow air to circulate around them, and to prevent moisture from coming in contact with the bags

3.2.3 Feed purchase and handling

- Always check labels and buy the freshest diet in the store
- Purchase only the quantity of diet that will be consumed within 4 to 6 weeks
- During transportation and handling, protect the feed from moisture, heat and direct sunlight

It should be remembered that fish feed starts losing water – soluble vitamins, such as vitamin C as soon as it has been opened. Therefore

- Vitamin loss can be prevented by properly storing your fish feed
- Al fish feed must be kept in air tight container or bags.
- Fish feed must be kept in a cool dry place out of the sun

Feed Inventories

Complete records should be kept for each batch of fish feed produced or delivered to the farm. These should always include details of date of delivery, manufacturer, feed type(s), batch numbers, quantity, cost, and any observations on the condition of the feed on receipt.

Summary

Feed has to be properly packaged and labeled for easy use. Properly packaged feed helps in maintaining the quality of the feed for a longer period. Pelleted feeds have to be put in right bags and quantities that farmers can easily access them. When packaging, feed for different fish sizes has to be clearly indicated so as not to confuse the user. Proper storage has to be maintained at all times so as not to compromise the quality of the feed. Records at all levels must be kept. These include for packing, purchase, storage and use.

Pond fertilization and Fish Feeding

4

Introduction

In subsistence and semi-intensive practice, fish feeding goes with pond fertilization. Fertilization improves the availability of natural food which includes zooplankton and phytoplankton. In some instances, some farmers practice delayed feeding by only fertilizing their ponds. This allows them to cut costs on feed and yet achieving the same result by the end of the production cycle. There are organic and inorganic sources of fertilizers one can use. As they can compromise fish growth and survival, good husbandry practices must be followed when applying them in culture facilities.

This chapter therefore aims at introducing the different types of fertilizers a fish farmer can use in ponds, their sources, how to use them in ponds and their implications if not properly used.

Objectives

- Participants know
  - Types and rates of fertilizers that can be used
  - Sources of fertilizers
  - Seasonality of using fertilizers
  - Factors to consider when applying fertilizers

- Acquired skills
  - Calculation of fertilizers for right application
  - Use of secchi disc
  - Measuring turbidity in ponds

- Acquired attitudes
  - Right use of feeds and manure can minimize feed costs and increase yields and profits

- Relevance to fish production
  - Know whether you are making good profits from the use of feeds or a combination of feeds and manures.

This chapter is divided into two sessions
Session 1: Pond fertilization
Session 2: Fish feeding

- Mode of delivery
  - Lectures, group discussions, practical
- Materials: flip chart, markers, lecture notes, feed raw materials, ingredients, fire, pots
  Duration: 80 minutes

Pond fertilization and Fish Feeding

4.1 Subsequent Pond Fertilization

Fish feeding goes hand in hand with pond fertilization. The most important factor in the rearing of tilapia and catfish is maintaining a green pond. The greener the pond, the more natural food will be available and the faster the fish will grow. However, too green is detrimental as well. The greenness of the pond or tank is measured by using a Secchi disc. Optimal transparency/turbidity of the ponds should be indicated by a reduction in visibility of the Secchi disc between 20 and 30 cm.

If a pond is too green (<20 cm), it may cause fish mortality due to low oxygen levels at dawn and early in the morning. The green color in the pond is controlled by fertilization with chemical fertilizer and/or animal manure. The more fertilizer added, the greener the pond will be. The amount of fertilizer to be applied needs to be calculated and should be determined by water colour.

- If the pond is not very green (>30 cm Secchi disc visibility) then increase the amount of organic or inorganic fertilizers.
- If the pond is too green, and fish begin gulping in the morning, fertilizing must be stopped.
- If the pond is too green, add fresh water in the pond and in most cases, there is an increase in fertilizer/manure requirements throughout the growth period.
- Depending upon the availability and the choice of farmers, Table 5.1 can be used as a guideline for fertilizer/manure requirements. Some farmers convert these rates to daily and use them continuously for several days until plankton growth appears.
- Once the water becomes green, then they apply weekly. Chemical fertilizer should be applied weekly (or more frequently if possible) by dissolving it in water and then broadcasting the solution over the surface of the pond at least two locations depending upon the size of the pond.
- There are no strict guidelines for the application of animal manure. Most farmers either use general broadcast or they apply the manure to a few selected spots located around the edge of the pond.
- Frequent manuring in small amounts is advisable, but once a week can be sufficient. Some farmers put manure in bags and hang it on ropes.
- In colder season or cloudy days, pond fertilization must be minimized or even stopped

Table 4.1: Types and rates of fertilizers that can be used depending upon the availability and the cost –benefit analysis

Options	Type of input	Amount required (ha/week)
1	Fresh chicken manure	1000 – 2000t
2	Fresh chicken manure + Urea	1.2t + 20kgs
3	Urea + TSP or DAP	60kgs + 60kgs

4.1.1 Pond Fertilization

Producing natural food in the pond requires fertilization. This is done by preparing your pond to provide nutrients to the water, which stimulate the growth of algae (phytoplankton) and other organisms (zooplankton), such as insects that provide a nutrient source for your fish. When we fertilize our ponds,

- More natural food means faster fish growth, and less supplementary feed will be added.
- Fertilization provides phytoplankton with more nutrients, which leads to more phytoplankton growth.
- Zooplankton (tiny animals and water insects) will feed on phytoplankton, so will also flourish if fertilizer is added.
- Tilapia and catfish feed on phytoplankton and zooplankton, as well as any supplementary feed added to the pond. When fertilizing your pond, you can use either inorganic or organic fertilizers.
- Fertilization is good for extensive and semi-intensive systems but may not be necessary for intensive fish farming systems.

4.1.2 Main types of fertilizers that can be used

i. Natural Organic Fertilizers

They include manure of animals such as chicken, ducks, pigs, cattle, goats or horses. Fish will grow rapidly in the pond if the water is green; this can be achieved by fertilization using organic manures. However, the use of organic manure has been an issue in terms of health hazards, because:

- Chicken and pigs are fed with high levels of growth hormones and antibiotics.
- Animal manures have very low N and P concentrations.
- They are bulky and difficult to transport if they are to be procured from outside.

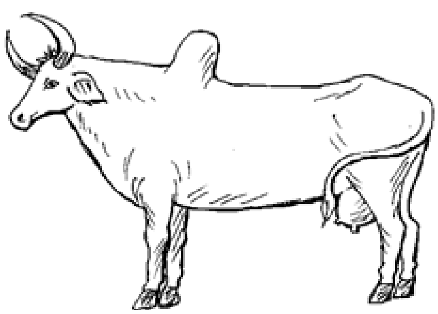


Fig 4.1: Cattle as a source of organic manure

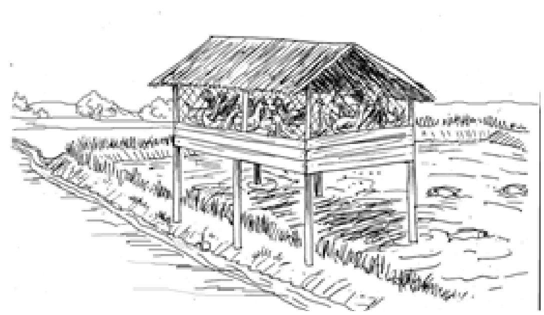


Fig 4.2: Poultry as a source of organic manure

Table 4.2: Organic manure application rates in ponds

Input	Mode and rate of application	
	Basal broadcast / Sac-filled (g/m2)	Top dressing (g/m2/week)
Chicken Manure	400	50
Pig manure	560	70
Cattle manure	880	110

Recommendation: it is advised to apply manure weekly

ii. Inorganic Fertilizers

May be single element fertilizers that contain a single nutrient like nitrogen (in ammonium sulphate, urea) or phosphorus, incomplete fertilizers that contain two nutrients such as nitrogen and phosphorus, or complete fertilizers that contain the three important plant nutrients, nitrogen (N), phosphorus (P), and potassium (K). Something about inorganic fertilizers

- Inorganic (chemical) fertilizers are nutrient dense and therefore easy to handle.
- They create better water quality, thus ensuring higher survival of the fish, and they enhance plankton growth. The process will take about 1 week, after which time fish can be stocked. –z
- Chemical fertilizers are considered safe and available even in rural areas for the use of crops and vegetables, e.g. urea and TSP or DAP. They are very common and produce green water rapidly.
- Urea contains 46% nitrogen (N) while TSP and DAP contain 20% phosphorus (P).

Fertilizing ponds with chemical fertilizers does not always produce a good bloom. A more dependable way to produce abundant natural food is to apply organic material directly to the pond. The organic material serves as a direct food source for insects and zooplankton, and it slowly decomposes to release plant nutrients that stimulate development of a phytoplankton bloom.

a. Methods of fertilizing

- Fertilizing method depends on the type of fertilizing agent used. If you are using compost manure, the heap of organic matter should be placed in an enclosure on the side where you have the inlet.
- If you are using inorganic fertilizer, mix fertilizer in bucket and stir using a stick until all the fertilizer has dissolved. Apply the fertilizer solution to the pond. For big ponds, fertilizers should be applied from different locations to get an even distribution.
- When the pond is not properly manured, it may negatively affect the water quality leading to stress and occurrence of diseases.

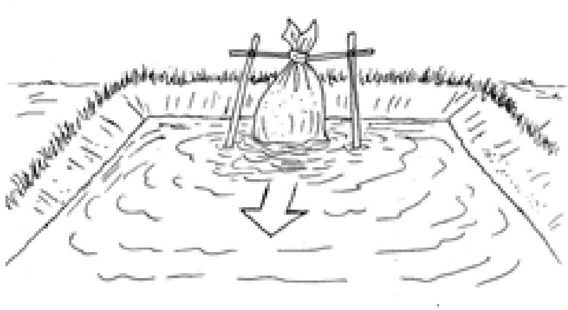


Fig 4.3: Hanging bag of organic fertilizers in a pond

b. Application Rates and Methods

- Apply inorganic fertilizer at the rate of 0.25kg per 200m2 every week.
- Weekly application of 28 kg N and 7–14 kg P/ha, which means about 60 kg of urea and 30–60 kg TSP/10000m2, is recommended.
- Fill water to some 20 cm to let mineralization of organic matter take place that cause plankton bloom. After 1 week complete filling pond water to capacity.
- These fertilizers should first be dissolved in water in a bucket before spraying into the pond water. If not dissolved, fertilizers will sink and stay at the bottom, attached to the mud.
- Ponds need to be fertilized weekly after that, using the same fertilizers at the same rate. However, depending upon the greenness of the pond water, the rate can be altered.

Calculating how much fertilizer is needed can be done as follows:

Amount of urea (kg) per week = daily rate/% of N in urea × 7 days
= 4/46% × 7
= 61 kg/10000m2

Amount of triple superphosphate (TSP) = daily rate/% P in TSP × 7 days
= 1 kg/20% × 7
= 35 kg/10000m2

If a farmer has a pond of 1000m2, he or she can calculate the amount required for weekly application to fertilize ponds:

Amount of urea (kg) = 61/10,000 × 1000 = 6.1 kg
Amount of TSP (kg) = 35/10,000 × 1000 = 3.5 kg

The amounts of other alternative fertilizers can also be calculated in a similar way using the percentage of nitrogen and phosphorus in them. For example, if NPK (16-20-0) fertilizer is available, farmers may choose it because it contains both N and P. First of all, the requirement to supply adequate P is calculated as:

Amount of NPK fertilizer required = 1 × 100/20 × 7 = 35 kg/10000m2/week

As it does not fulfill the N requirement, urea has to be added. This is calculated deducting the amount supplied by NPK, as shown below:

Urea = [4 × 7 – (35 × 0.20)] × 100/46 = 45.7 kg
This means the amounts of NPK and urea needed are 35 kg and 45.7 kg, respectively.

The amounts of other alternative fertilizers such as DAP can also be calculated in similar way. As DAP has 18% N and 46% P2O5 or approximately 20% phosphorus, the DAP requirement for P is calculated first. Then the amount of nitrogen supplied from that amount of DAP is deducted from the amount of urea to be worked out.

4.1.3 Checking for natural productivity of the pond – corrective measures

Fish differ from terrestrial animals in many ways, including the fact that they live in water, from where they get food and oxygen for their survival and growth. Therefore, the quality of the water we use to grow fish matters greatly. The most important water quality parameters in tilapia farming are temperature, DO, salinity and pH. These parameters should be monitored at around 6 am and 2 pm on the same day every week. At the lowest temperature, pH and DO will be lowest early in the morning and highest in the afternoon. Famers should always be mindful that over fertilization of ponds may lead to poor water quality resulting into stress of the fish even fish kills. Therefore;

- Daily check the pond for water quality changes. Use a hand by dipping it to the elbow level in the pond water.
  o If you are able to clearly see the palm of the hand, then you need to fertilize the ponds.
  o If you faintly see the hand, then its good water quality but if you don't see the hand after dipping, and then the pond is over-fertilized. You need to flush the water or topping up.

- Check water levels and top up if not full.
  o Check if there is any water leakage on the pond dyke. During the rainy season, you need to check the

water level to see if there is no flooding.

o Ensure there is no blockage to inlet and out let. Use a 180 μm sieve net to keep out wild fish or other predators from entering the pond when water is being added.

- Check fish activity, also to check or if fish are in good condition.

o Fish that are swimming sluggishly or swimming in an irregular manner or looks excited, you need to flush the water.

o The fish may be seen gulping for air on the surface or swimming towards the inlet because the incoming water will be carrying fresh air. To correct the situation, quickly add more water into the pond. Stop adding manure

Measure visibility

Measure Secchi disc visibility to assess the plankton growth in pond water. A Secchi disc can be made locally by painting a metal plate black and white, as shown in Fig. 5.4 Follow the recommendations as shown in Table 5.5.

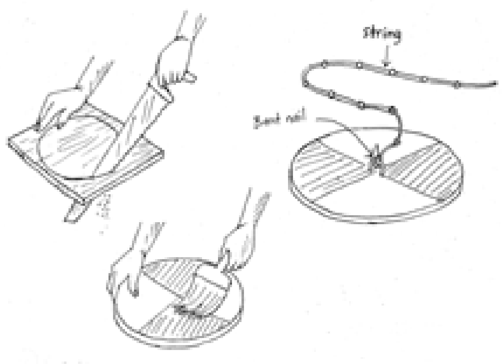


Fig 4.4: Making your secchi disc

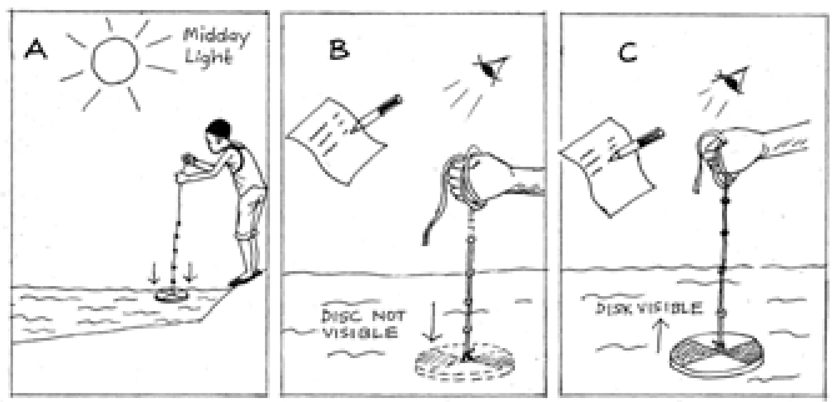


Fig 4.5: Steps for using a secchi disc

Table 4.3: implications of Secchi disc visibility or depth

Secchi disc depth (cm)	**Remarks**	**Recommendations**
<20	Too green	Stop fertilization and feeding for 1 week
20 – 30	Very green	Stop fertilization and reduce feed
30 – 40	Appropriate	Feed and fertilize normally
50	Too little plankton	Increase fertilization rate

4.1.4 Feeding Fish with Formulated Feeds

Better fish growth in commercial aquaculture requires supplementing the natural food with formulated feeds which have all the required nutrients for the growth of fish. A farmer needs to know the following:

- To enhance fish growth, feed the fish with formulated feed from a certified source
- Ensure the feed is appropriate for the size/age of the fish
- Your fish will eat more as they grow but be careful not to overfeed

- Feed your fish at selected or identified feeding locations so that you can observe activity levels –
- Feed your fish to satisfaction (by continually giving them small portions until they stop feeding) or
o Based on their body weight (quantity of feed per day = biomass x % body weight, where biomass = average weight x total no. of fish)

Example

No of fish stocked = 1000
Average weight = 5g
Biomass = 1000 x 5 = 5000
% of body weight =3
Required feed = 5000 x 3/100
= 150g

- Feed your fish at least twice a day – they will grow better if you feed them regularly
- The bigger your fish grow, the more food they will need
- Uneaten food could indicate a problem (e.g., poor quality feed or deteriorated feed, low water temperature, sick fish)
- Formulated feed comes in powdered form for feeding fry and fingerlings and pellets for feeding juveniles and adult fish
- For fingerlings and juvenile fish, use feeds with protein levels of 38% and above
- As fish age, feed them with grower feeds of crude protein below 38%
- A feeding protocol is provided to assist you in feeding (Table 4.4)

Recommended feed sizes for different development stages:
- Fry and larvae (0.01 - < 1 g): powdered feed;
- Fingerlings (1–5 g): Particle size, 0.5-2 mm (granules or crumbles);
- Juveniles (5–50 g): Particle size 2-3 mm;
- Adults (> 50 g): Particle size 3-6 mm.

Remember that small fish require more protein for their fast growing bodies which is reduced with growth.

Table 4.4: Feeding protocol for tilapia based on optimal water quality and water temperature of 28 - C

Initial Weight(g)	**Final Weight(g)**	**Feed Level(%BW/day)**	**Feed Size(mm)**
15	30	4.5	2
30	40	4.0	2
40	50	3.7	2
50	70	3.3	2
70	100	2.9	3
100	150	2.5	3
150	200	2.2	3
200	300	2.0	3
300	400	1.9	3 - 4.5
400	500	1.7	4.5
500	600	1.5	4.5
600	700	1.4	4.5
700	800	1.3	4.5
800	900	1.2	4.5

In order to ensure that feed is not just dumped in the pond, it is essential to test out any new feed inputs before using them extensively. Farmers should therefore consider:

a. If the feed is attractive to the fish or not;
b. If the additional feed inputs give enough return to cover the costs and labor; and
c. How safe they are to use.
d. Impact of the feed on water quality

Various commercial feeds (crumbles or pellets) are available in many countries to use as supplementary feeds such as:

a. Fry booster powder form (40 –50% CP);
b. Fish starter mass (35 – 40% CP);
c. Fish grower pellets (30 – 35% CP); and
d. Fish finisher pellets (25 – 30% CP).

4.1.5 Fish feeding practices

Better fish growth results are always obtained when fish are fed correctly using the right techniques that ensure all fish have access to the feed. When this is followed, the fish's nutritional needs are met and no excess feed is fed. Feeding fish appropriately means:

- Giving feed of the correct nutritional quality for the specified age of fish,
- Feeding the right feed size for easy consumption,
- Feeding the correct amounts,
- Feeding at the right time(s) each day

When fish are fed correctly,

- Growth rates are good
- Uniform across the population,
- FCRs are low
- Pond water quality is better managed.

- **Determining the amount of feed**

The average body weight of the fish is used when determining the amount of feed to be given feed the fish, the average body weight is used at an appropriate feeding rate e.g. 10% for fry, 5% for fingerlings and 2 or 3% for adult fish but ad libtum would be appropriate. It is advisable to reduce the amount of feed in winter as feed consumption reduces.

Fish feeding methods

The primary objectives for most fish farmers are to produce high-quality fish at least cost. As such, they attempt to provide fish with all the required quantities of feed that fish can absorb. Therefore fish feeding methods per farm are made based on a diverse range of factors and experiences. The widespread availability of durable dry feeds in Malawi has led to the introduction of numerous fish feeding methods.

Not only would excessive feeding cause the farmer to have financial losses but also problems both in breeding and in production ponds. Increased amounts of feed make it hard to dispose of feed leftovers which now compromise on water quality. Therefore, it is essential to recognize the right quantities of feed, number of feeding times and methods of feeding the fish under different culturing systems, in order to achieve high rates of growth and feed conversion.

There are several fish feeding methods that can be applied. Any chosen methods must be used efficiently to ensure maximum utilization of feed. The methods include:

- Broadcasting by hand
  Feed is thrown right into the pond by hand.

Advantages

- o Distributing feed by hand allows close observation of the appetite and feeding behavior of those fish species which feed actively at the surface, and are grown in fertilized pond or hapa systems.
- o An experienced operator can scoop feed evenly over a limited surface area, in response to the apparent demands of the fish
- o Problems associated with overfeeding can generally be avoided if feeding is gradually reduced as the fish approach satiation.
- o The main advantage of hand feeding is that when carried out carefully it is sensitive to the changing feed requirements of the fish. Appetite can change in response to a wide range of both physiological and environmental factors and significant daily fluctuations can occur.
- o The practice of hand feeding also ensures that the behavior of the farmed fish is regularly observed and that any abnormalities can be addressed.
- o For floating feeds, observing the fish whilst feeding not only helps the farmer whether the fish are feeding or not but also scaring other predators which eat the feed such as birds.
- o Farm managers may, for example, feed 70 - 80% of estimated daily feed requirements depending on daily variations in fish's appetite. One can easily record the amount of feed fed on a particular day

Fig 4.6: Feeding by broadcasting

Disadvantages

Careful considerations must be made when using the method as;

- o Effective hand feeding necessitates some initial training and experience if food wastage is to be avoided.
- o Feed can just be sinking on the bottom if fish is not eating the feed or poor timing when broadcasting the feed.
- o A farmer can broadcast the feed when fish were not on the side where the feed had been broadcasted. Make sure that fish is closer to you before you broadcast the feed.
- o It is labor intensive and time consuming and may be limited in its application on large farms.

- Use of feeding trays or tables
  For those using sinking feeds, feed trays can be placed on strategic points in the pond where fish can feed from.

- This allows fish to feed from the fixed tray and not this minimizes feed wastage as all uneaten feed is left on the tray.
- A farmer has an added advantage of seeing whether fish are feeding or not and even to know if too much or less feed was provided.

The use of feeding trays is widespread to enable direct observation of the feeding activity of the shrimp. A percentage (usually 1-3%) of the daily ration allotted to the pond is spread between several feeding trays. Feeding trays consist of a wooden or metal frame across which is stretched a fine mesh net. The frame dimensions vary between 70 cm x 70 cm to 1 m x 1 m. The numbers of feeding trays used varies considerably between farms. Table 4.5 gives recommendations for numbers of feeding trays.

- Feeding trays rest on the pond bottom and may be serviced from walkways and the pond dikes, or from boats.
- Food is placed on trays at the same time that food is broadcast across the pond. After several hours the trays are carefully lifted and an estimate made of the quantity of food remaining.
- The next feeding ration is then adjusted in light of the average amount of food remaining on the trays of each pond.
- Feeding trays should be installed immediately after stocking to permit observation of the condition and growth of the fish, and to detect the presence of any pests or predators.
- In positioning trays, areas should be avoided which are close to aerators or where the pond bottom is uneven or sloping, since food may be washed or tipped off the trays.
- Areas should also be avoided where there are localized buildups of sediments.

Below are tables giving a possible guide on number of fish feeding trays that can be put in a pond in relation to its size, amount of feed% to be placed in feeding trays and the corresponding consumption period and Table Feeding Rate Adjustments on the Use of Feed Trays

Table 4.5: Recommended Number of Feeding Trays for Different Pond Sizes

Pond Size in m2	No. Feeding Trays
200 - 500	2
600 - 2000	3
3000 - 5000	4
6 000 - 7000	5
8 000 - 10 000	6 – 8
20 000	10 - 12

Table 4.6: Amount of feed % to be placed in feeding trays and the corresponding consumption period

Weight (g)	Amount of Feed in Tray (%)1	ConsumptionPeriod (hour)
3-4	3.6	2.5
5-8	4.1	2.5
9-12	4.5	2.0
13-19	5.0	2.0
20-28	5.4	1.5
29-34	5.9	1.0
35-40	6.2	1.0

Note: 1 Quantity evenly distributed by number of feeing trays placed in the pond

Table 4.7: Feeding Rate Adjustments on the Use of Feed Trays

Average Amount of Unconsumed Feed on Trays	Adjustment Consumption Period (hour)
0	Increase 5%
<5	No change
5 - 10	Decrease 5%
10 - 25	Decrease 10%
>25	Suspend 2 feed rations; reinitiate at 10%

- **Feeding rings**

For floating feed, floating rings can be mounted in the pond and feed placed on that spot.

o This prevents wind from blowing the feed to several directions of the pond.
o Fish feeds from localized points in the pond
o Birds and other predators feeding on the fish can be easily prevented

- **Using feeding bag**

o Feed is placed in a B-net (32 mm mesh size) feeding bag and tied in poles.
o The bag is suspended in pond water surface. Fish obtain feeds by picking or suction.
Feeding ratio

It is the amount of feed that you should feed daily to the fish. It is also expressed as percentage of fish biomass. Feeding rates are affected by water temperature. Fish of all size eat less and stop taking feed as water decreases or increases beyond their optimum range.

Feeding frequency and rates

Feeding frequency for fish depends on a number of things which includes size or stage of fish, purpose of feeding the fish and also the financial capacity of the fish farmer. The daily food ration may be fed as a single meal or more typically is divided into a number of separate feeds spread throughout the day. The optimal feeding frequency for fish may vary depending on species, age, size, environmental factors, and food quality. Optimal frequencies have been reported in fish, which range from continuous feeding like in African catfish fry, Clarias gariepinus. For Tilapia fry, daily rations can be divided into even more than four meals per day as shown in Table 4.8.

Table 4.8: Possible fish feeding frequency in relation to size

Size of Fish	Feeding Frequency Per Day
Fry	Minimum of 4 – 8 times
Fingerlings	2 – 6 times
Juveniles	2 – 4 times
Adults 2 – 4 times	

Feeding fish twice a day at temperatures of 25oC has shown to lead to increasing feed consumption which translates to higher growth rates. Each and very farmer can decide feeding frequency, however, this is up to the farmer who estimates the extra cost for increasing feed consumption.

- The right timing for fish feeding is relevant to dissolved oxygen levels in water, as we have to take into consideration dissolved oxygen at different times during the day.
- It should be noted that oxygen demand for fish is highest after four to eight hours from feeding. Therefore, feed should be given to fish just after sunrise and before noon where the water temperature in summer is above 32oC as this put more pressure on fish.

Feeding rates

There are several factors that affect the amount of feed consumed by fish such as temperature, size of fish, water quality, and energy level in the diet.

- Standard feeding ration in all production ponds is 3% of the total weight of fish and others decrease it to 2% most especially in the month they are harvest the fish.
- During the production period, feed is adjusted after every four weeks. In winter, where temperatures are below 15oC, fish are fed at a much lower rate (1% of the total weight of fish) for maintenance of fish.

Table 4.9: Fish Feeding Strategies

Feeding Strategies	Size of Fish	Feeding % body Weight
Fertilization + Supplemental Feeding	Fry	10 - 5
	Fingerlings	5 – 3
	Juveniles	3 - 2
	Adults/Market Size	3 - 2
	Broodstock	3 - 2
Complete Feeding	Fry	30 - 15
	Fingerlings	15 - 10
	Juveniles	10 - 5
	Adults/Market Size	5 - 2
	Broodstock	5 - 2

Particle size of feed

Different fish species prefer varying physical shape, texture and the size of pellet to some extent because of their feeding behaviors. For instance, tilapia dislike hard pellets and likes feeding from the water column as such they prefer floating feed over sinking feed. Optimum particle size increases with the fish size as such grading fish is important. Catfish can feed with easy even at the bottom of the pond as well larger sized feed particles unlike tilapia species which prefers small sized feed particles. The recommended particle sizes of pellets for Tilapia species and catfish are listed in Table 4.10 below.

Table 4.10: Recommended particle size for tilapia and catfish

Fish Age	Feed Type	Feeding Rate (% Body weight)
1st – 2nd week	Mash	10%
3rd - 4th week	Mash	8%
5th - 6th week	Mash	5%
7th - 8th week	Mash and Pellets	5%
9th - 10th week	Mash and Pellets	5%
11th - 12th week	Pellets	4%
13th - 14th week	Pellets	4%
15th - 16th week	Pellets	4%
17th - 18th week	Pellets	3%
19th - 20th week	Pellets	3%
21st - 22 week	Pellets	2%
23rd - 24th week	Pellets	2%

4.2 Brood stock feeding - Breeding Protocols

Broodstock need to be given the right feed quantities for good results. Nobody should be confused about the proper management and being convinced that more feeding will enhance early maturity along with greater numbers of eggs and milt.

- This results in the formation of a dense scum on the surface with resultant super saturation of oxygen, leading to mass mortality of brooders particularly during afternoon, indicated by surfacing behavior.

- Qualitative feeding with the right and required ingredients along with periodic health management are important aspects should be undertaken with the utmost care. Depending on the available criteria, fish exhibit considerable variations in the number and quality of eggs that develop, i.e., fecundity varies. As fecundity refers to number of eggs/kg of body weight, it is easy to assess the feed requirements of brood stock for the production of a specific number of eggs.

- Deficiencies of certain dietary ingredients, such as fatty acids (PUFA), vitamins, and trace elements, exerts a negative impact on maturation, breeding, spawning, larval vigor, and survival.

- As we know that nutritional requirement varies according to species, proper formulation of the right feed for individual broodstock (species) so that the supply of quality seed to the farming sector is ensured.

Feeding schedule:

- It refers to the specific time and frequency at which the feed allowance is given to the fish.
- Fish are suited to deal with regular supplies of feed or little and often your fish can be feed by the following feed methods:

Determination of Average Body Weight (ABW), Daily Feeding Rate (DFR), Total Feed Requirement (TFR) and Feed Conversion Ratio (FCR)

a. ABW (g) = Total Weight of Fish Randomly Sampled / Number of Sampled Fish

b. DFR (g) = ABW x Stocking Density x Feeding Rate

c. TFR (g) = DFR x Feeding Duration

d. FCR = Amount of Feeds Consumed (kg) / Weight Gain of Fish (Kg)

Note: The closer the FCR to 1.0kg, the better the feed. Good feeds have FCRs of between 1.5 to 2.0kg

Formula for Calculating Fish Feed

Biomass of pond multiply by the % body weight of fish = Quantity of feed to be fed per Day
Biomass is the total weight of all the fish in a pond and may be calculated as follows:

i. Weight of fish x estimated number of fish in the pond or
ii. Estimated number of fish in pond divided by "count per Kilogram"

An example
You stocked a pond with 20, 000 fry each weighing 1g. Determine the amount of feed required per day in grams for the first two weeks. Note that for the first two weeks, fry is being fed 10% of their body weight.

- **Step 1:** Calculate the Biomass of the pond
  - o Stocked fry = 20 000
  - o Average body weight (g) = 1
  - o Total weight 20 000 x 1g = 20 000g

Therefore 20 000g /1000 = 20kgs
Pond Biomass = 20kgs

- **Step 2:** Calculate the amount of feed that is required per day
  - o The amount of feed = Biomass x % body weight
  - o 20kg x 10% = 20 x 10/100
  - o Feed required = 2kg

As this amount is the daily feed to be given to the fish, a farmer can now divided this amount in equal shares accruing to the frequent chosen to feed the fish. If fry are being fed 4 times per day, the amount of feed to be fed at any provided time will

o 2kg/4 =0.5kg (500g)

Calculate feed conversion rate

Growth is an easy indicator for evaluating retained (net) energy for ingested nutrients. However, since the growth curve for fish is S (sigmoid) shaped (Fig. 1.2), a suitable index should be used according different stages of growth.

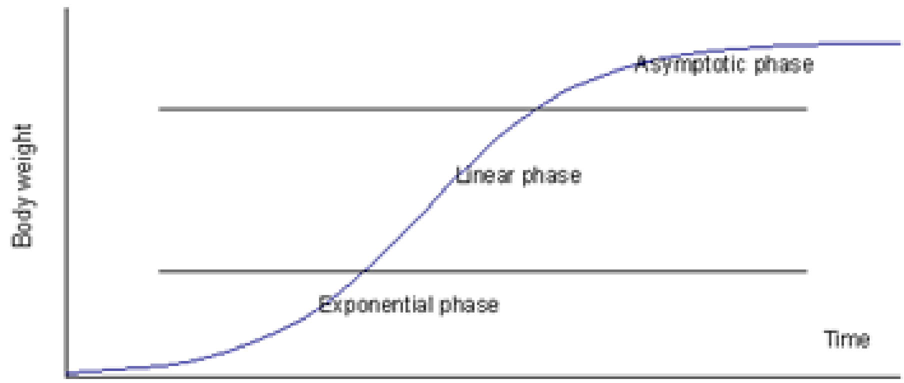


Fig 4.7: A generalized growth curve of fish

For example, you can use the feed conversion ratio (FCR) to calculate feed utilization in fish. Amount of dry food required to produce a unit weight of fish.

$$FCR = \frac{\text{Dry Food Fed (g)}}{\text{Wet Weight gain (g)}}$$

4.2.1 Feed utilization

Feed evaluation is an important element which enables one to determine the utilizations of feed with respect to growth of the fish. The food conversion ratio which is the amount of feed used in kg to raise 1 kg of fish is calculated after the harvest as follows;

- FCR/FCE
- FCR = Total amount feed (kg)/Total fish weight gain (kg)
- FCE = 1/FCR

Feed Waste Detection

Any chosen fish feeding method should be careful monitored to detect any feed wasting. Careful hand feeding or the use of hand-operated mobile feeders, in culture systems with good water visibility should minimize the risks of overfeeding fish stocks to the point where food remains uneaten and is wasted. To avoid feed wastage:

- Always feed the fish at the same time and in the same part of the pond. Fish will learn where to go to get their food.
- Do not overfeed.
- Too much food will not be eaten but will decay and will use up oxygen during decaying process.
- Monitoring the dissolved oxygen of the pond regularly.
- Ponds with low DO concentrations, fish will eat less and they will not convert

If fish are not responding to feeding, feeding must be stopped until the appetite of the fish in the pond returns. Uneaten feed will lead to

- Increased deterioration of the water quality
- Poor fish growth due to poor water quality
- Possible introduction of pathogens and diseases
- Increased FCR due to the lost feed
- Increased operational costs, reduced profits

Feed cost of production of fish

Unit cost of feed x FCR = Amount spent on the feed to produce each kg of fish

Economics of Using Feeds

5

Introduction

Fish feed producers need to calculate their costs versus incomes in order to know whether their business is growing. This is the same with fish producers; they have to calculate the amount of feed used versus the final harvested fish weight. Feed being used should produce the right quantities of fish for profit to be realized. Record keeping is vital in calculating economic benefits of making fish feeds and producing table sized fish.

This chapter presents an outline on the economics of making well formulated fish feeds and using such feeds for the growth of fish. Related risks for fish feed producers and fish farmers have been outlined. Monitoring of both the growth of the fish making business and growth of fish has been presented

Objectives

- Participants know
  - Economics of formulated feeds
  - Related risks in sue of formulated feeds and how to address them
  - Net Feed Making/Farm Income

- Acquired skills
  - Calculation of gross margins and payback period
  - Simple calculations for fish growth and business growth

- Acquired attitudes
  - Right use of feeds and manure can minimize feed costs and increase yields and profits

- Relevance to fish production
  - Know whether you are making good profits from the use of formulated feeds

This chapter has one session which looks into investment and reward, related risks and need of growth monitoring

- Mode of delivery
  - Lectures, group discussions, practical
- Materials: flip chart, markers, lecture notes, calculator
  Duration: 60 minutes

5.1 Economics of Using Feeds
5.1.1 Investment and reward

It necessary for any investor in fish feed making and fish production to weigh the possible reward against the risks of any investment they are considering. Once an investor understands the relationship between the risks and the rewards, he or she will put in place mechanisms to help in addressing any risks that might be encountered along the line of production. If one is using the investment profits as income for further operations, he or she needs to put ways on how to ensure that the profits area realized.

Calculating investment rewards

- Profitability

Profitability is calculated generally by subtracting total costs from total revenue. It is measured from the income statement. However, net farm income can be further partitioned into returns or profits attributable to each of the four primary factors of production: inputs, land, labor, capital, and management. Returns to capital can be further partitioned into returns to equity capital (capital owned by the feed producer, fish farmer) and returns to debt capital (borrowed capital).

Profit margin

Profit margin is the amount by which revenue from sales exceeds costs in a business. Two profitability ratios commonly calculated include the gross profit margin and the net profit margin

- **Gross profit margin**: calculated by dividing the gross profit by the sales and multiplying by 100. The gross profit margin measures the sales and production performance, can be tracked over time, and can be used to compare performance of other similar aquaculture businesses.

- **Net profit margin**: Divides net profits (gross profit minus operating costs) by sales and multiplies by 100.

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 MWK 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.

Net Feed Making/Farm Income

The primary measure of feed making or fish farm profitability is net feed making or farm income. Net feed making income or farm income measures the return to operator's equity, capital, unpaid labor, and management. It is measured from the income statement. Net farm income is measured as follows:

Total revenue – total expenses
= net farm income from operations
± gain/loss on the sale of capital assets
= net farm income

- **Cost of Producing Feeds**

For increased profits, costs must be minimized. Farmers formulating feed must have information on the cost of feed ingredients, the nutrient concentrations in feedstuffs, the nutrient requirements and the nutrient availability from feedstuffs. 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.

- **Financial analysis**

A financial analysis is the assessment of the practicability, stability and profitability to merit investment in a fish feed production business. It is used to figure out a long-term plan to draw business activities. There are several methods of financial analysis and we are going to look at cost-benefits analysis (CBA), profit margin, and return on investment (ROI).

Cost-benefits analysis

A CBA is a process by which a feed producer 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. 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 enterprise. It can be expressed in either monetary or qualitative terms.

More about the CBA

- The 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.
- If for example, a BCR of 1.20 means that for every MWK spent in costs there is a financial gain of an additional MWK 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:

a. If separate, unrelated projects are being assessed and the budget for funding the projects is not limited, use an NPV or BCR.
b. 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.

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. 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. Good record keeping is therefore if this is to be achieved. 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.

These costs can be broadly classified to direct and indirect costs.

Direct costs

These include raw materials such as fish meal, minerals, vitamin premixes and some form of starch or energy source. These will form the actual feed. Other direct costs will be in form of wages and salaries of people making the feed.

Indirect costs

Indirect costs include: 1 supervisory and management overhead expenses; (2) electricity; (3) supplies other than feed ingredients such as gasoline and machine oil, if any; (4) repair and maintenance; (5) depreciation of fixed assets such as equipment, buildings; and (6) other incidental expenses required in manufacturing the feed.

5.1.2 Related risks

Aquaculture is a high-risk enterprise; both in fish feed making and the actual production of fish. So targeting at least 15% profit margin is a good idea. In related risks there are both controllable and less controllable factors.

a. Related risks in feed making

- Controllable factors in feed making
- Availability and accessibility of raw materials:
- Scarcity of raw materials on the market hence making them expensive hence pushing up cost of production. This reflects on higher selling prices for the feeds
- Some inputs are seasonal and as such, the producer will need to procure such raw materials in bulk.

This will save on costs and try as much as possible to stabilize price for the produced feeds. Growing your own raw materials like soya bean will help in minimizing expenses.

- Input costs, input supply, prices
  - Inconsistency in quantity and quality of raw materials leads to inconsistency of the nutritional value of the farm-made feed and fish production. Bulk buying of usually scarce materials is ideal. Than can help to stabilize price of the feeds being produced.
  - Rate of returns on produced feeds can take longer as many farmers would not be willing to buy the feeds
  - Packing fish feeds in smaller packs which is costly again can help farmers buy in smaller quantities
  - One very important feed and feeding constraint that often restricts semi-intensive culture systems is that farmers do not have enough money to buy feed or raw materials to make their own feed. This makes the feeding regime inconsistent.
  - Manufacturing compound feeds generally requires more capital than making moist feeds, as a hammer mill and mixer are required in addition to a mincer.

- Management of feeds and raw materials
  - Dumping of fresh feed materials into the fishpond, causing deterioration of water quality.
  - Moreover, without proper storage, fresh feed spoils easily and its quality can deteriorate.
  - Poor quality feeds or poor stored fees increases the risks of transmitting disease.

- Power, labor and technical
  - Labor costs can be controlled by a good plan for activities and having a well trained workforce which would deliver on time
  - Having a standby generator as an alternative source of power would help in the continuity of feed production.
  - Breakdowns, and unanticipated extended periods of adverse weather conditions

b. Related risks in fish production

- Controllable factors in fish production
- Management
  - Fish stocking size, densities, survival, feeding rates and frequencies, fertilizing levels and frequencies, water quality.
  - Seepage of ponds, theft, predation and presence of fish pathogens

- Less controllable factors
  - This includes unanticipated extended periods of adverse weather conditions which might negatively affect fish growth.
  - Incidences of disease outbreaks like Epizootic Ulcerative Syndrome (EUS)

- Economic status of fish farmers
  - This can negatively affect the purchasing power of farmers on produced fish feeds
  - Farm-made feeds are less stable in water and inconsistent in nutritional value in comparison to commercial feed. This is because farmers do not have proper equipment to produce high-quality feed

Record keeping risk analysis

Records are also important when it comes to risk not only for the development of enterprise and partial budgets. Risk analysis requires data on the variability of key parameters. For this to be possible record keeping is necessary at all stages of operations. In the manufacturing of fish feeds and actual fish production, these key parameters often include the price of the product, the price of feed, and the yield (kg/m2 of production.

To manage risk, additional records will need to be maintained for the various alternative production and management options that have potential to reduce risk in the business. Detailed information on the seasonality of prices of products with potential to diversify the operation along with details on the variation in yields of alternative crops will provide the basis for identifying risk-reducing alternatives.

Summary

Aquaculture businesses must successfully manage a variety of risks. This session chapter discussed several risks related to fed making and fish production using the feeds being produced. A variety of techniques that can be used to manage these risks like having skilled managers and teams, which can use flexible production techniques have been highlighted. Diversifying the business can help to offset production risks. Good management at all levels is key to avoiding and managing risks

5.2 Need for growth monitoring

In the feed production business, the feed producer will need to monitor the growth of the fish feed production business and also fish growth as an indicative impact of the feed.

Investment return on using formulated fish feeds

o Growth and yield analysis

A farmer is always encouraged to make simple economic analysis whenever any fish feed is being used to calculate the economic efficiency of the feed being used. This will also helping in determining of the profitability of the feed being sued. The things to be considered include cost of feed, fingerlings and total revenue generated from harvest. As one way of testing the viability and the economic efficiency of the fish feeds we are producing, we need to know the following parameters before and after harvesting our fish. Some of the things to be analyzed include:

- **Food Conversion Ratio (FCR) calculated as**: FCR = dry weight of feed consumed (g) / wet weight gain (g). The lower the ratio, the more efficient the feed happens to be.
- **Mean Daily Weight Gain**: Final Weight at Harvest – Initial Weight at Stocking / by Duration of Culture.
- **Relative Weight Gain, (RWG %)**: Final Weight at Harvest - Initial Weight at Stocking x 100/ Final Weight at Harvest
- **Gross and Net Yield**: Calculated as the product of the average final weight and the total number of survivors. The net yield was estimated as the biomass harvested minus the biomass stocked. It is expressed in kilograms.
- **Economy of Weight Gain (EWG)**: Calculated as cost of feed consumed / weight gain.
- **Profit Index**: Calculated as value of fish crop / total cost of feed
- **Incidence Cost**: Total cost of feed used/ weight if fish produced. FCR doesn't take into account the cost of feeds and the economic efficiency of using the feeds. Incidence cost has been adopted as the method of measuring the cost efficiency of the feed, which is the cost of producing a unit weight of fish.

In comparing two feed formulations available to a fish farmer, the feed with a lower incidence cost is more economically efficient and, therefore, more beneficial to the farmer. Another method of measuring economic efficiency of feeds is to look at the value of the fish produced and the cost of feeding. This is called the profit index, which indicates the profit for every unit cost of feeds incurred. This is computed using the following formula;

- **Profit index**: Calculated as total value of the fish produced - Total cost of feeds total cost of feeds/ total cost of feeds
- **Returns on Feeds**: Calculated as Net Profit/Cost of feeds. This indicator determining the economic efficiency of feeds is the returns on feeds. This indicator shows the rate of return on investment on feeds

This section aims to introduce concepts and methods in doing economic analysis applicable in aquaculture in general with emphasis in feed production and feeding in aquaculture farms.

Table 6.1: Calculating the economic profitability

Economic Parameters	Pond 1	Pond 2	Pond 3
Price of Fingerlings			
Cost of Fingerlings			
Price of Feed/kg (MWK)			
Total Feed Fed (Kg)			
Total Cost of Feed			
Harvested Fish Weight (kg)			
Value of Harvested Fish			
Profit (MWK)			
Profit Index			
Economy of Weight Gain			

Table 6.2 shows how to capture details and calculate the economic profitability in using fish feed in a number of ponds one can have. Profitability calculations will only be possible if records are kept at any stage of our operations. We should ensure that records for all the following things are kept:

- Price of fingerlings/seed
- Cost of fingerlings
- Price (MWK) of feed/kg
- Total Feed Fed (kg)/pond
- Total Weight of harvested fish (kg)
- Value of harvested fish (MWK)

Such details will help us to know whether total feed being applied in ponds is low or high, hence knowing the profitability. If revenue realized from a specific pond is low, a farmer will need to ask why and then come up with corrective measures to improve the situation. As fish will be weighed before being sold, average weight of fish has to be known and feed conversion rate too. Total weight of harvested fish and total weight of fish feed used will helped in calculating the FCR.

Summary

It is estimated that 60-80% of total variable costs for growing tilapia is attributable to feeds. Those that are in the fish feed production business therefore should be making good profits. This is attributed to the fact that fish have to be fed at all cost. For the feed producers to know that their business is growing, monitoring of their business operations is very important. Use of more cost-effective ingredients like eliminating of fishmeal from diets and its replacement with a cheaper animal protein might provide additional cost savings to feed and fish production. Well formulated diets using locally available, cheaper and more sustainable source of protein minus fishmeal has similar daily weight gain, specific growth rate, and survivorship as fish fed fishmeal diets. Good record keeping and calculating expenditure versus income has to be a routine practice. As for fish growth, a farmer has to always monitor growth of the fish. This has to be done almost after every 30 days to see if the fish are growing as expected on not and change the feeding rate or quantity depending on fish size. The cost effectiveness of the feed will be measured by the returns in the feed which is the weight gain of fish against administered feed. As all fish feed might not be consumed, good feeding practices must be followed so as to have a true reflection on feed conversion ratio and the economic benefits. Optimizing risks is one the strategies a fish feed producer and farmer must think about when making feeds or producing fish. All risks possible risks must be identified and possible interventions put in place to avoid or address them. We should always remember that aquaculture economics is a bio-economic process; if the all processes works efficiently at less cost, the economics will also work. One should

- Clearly understand all factors affecting production and the cost at each stage of production.
- Know that profitability is not the same as Cash flow.
- Profitability analysis gives you a snap shot at the enterprise
- Cash flow analysis shows liquidity; ability to meet financial obligations

FISH FEEDS AND FEEDING

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