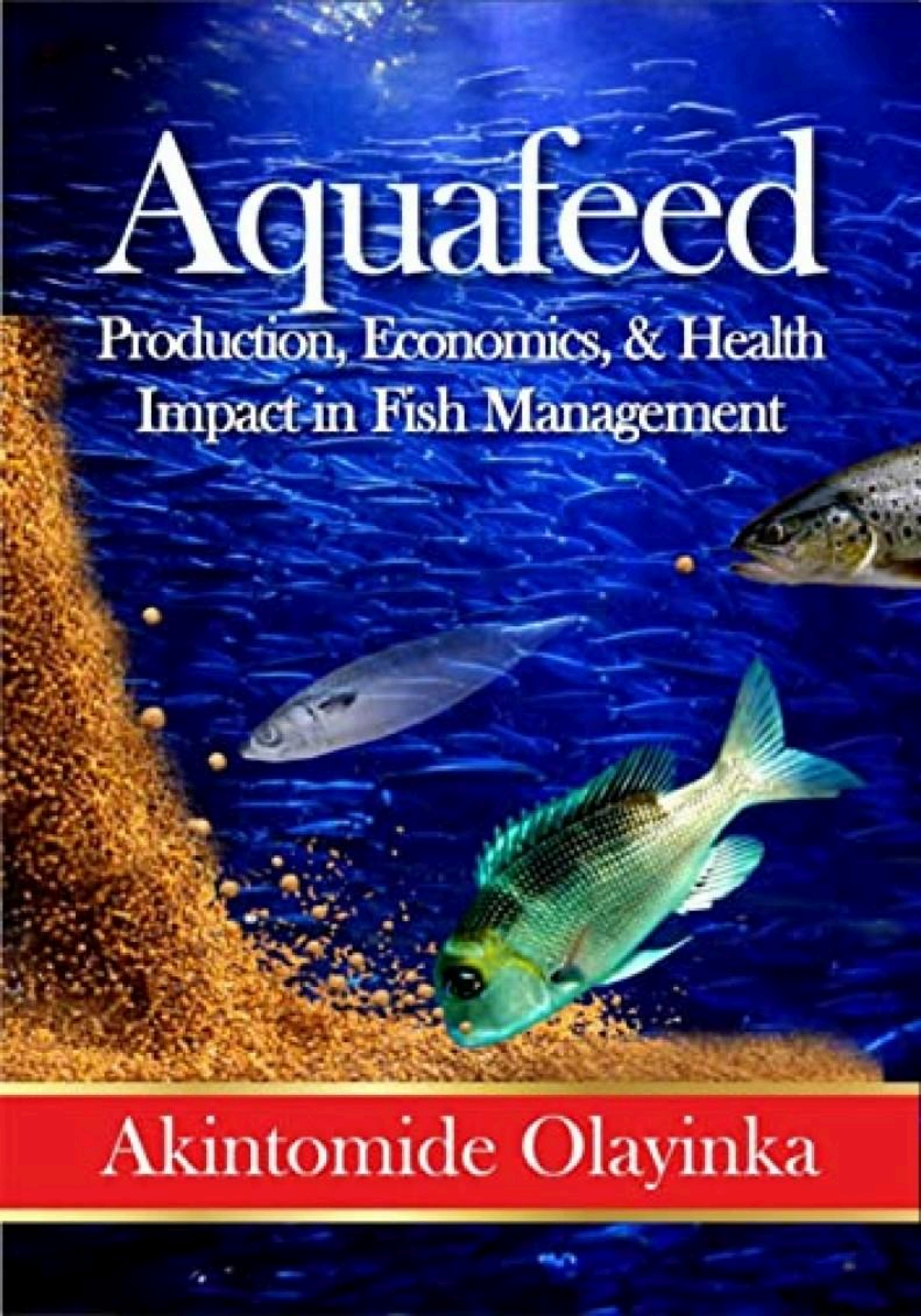
Aquafeed
Production, Economics, & Health
Impact in Fish Management
Akintomide Olayinka

Aquafeed Production, Economics & Health Impact In Fish Management

(Revised Edition, 2022)

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Dedication

This book is dedicated to Our Almighty King (GOD) who reveals the secrets of life and endows with great knowledge, and has made this publication a reality and success.

For,

"Success comes through Knowledge and Wisdom, and these are from GOD".

Acknowledgements

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To my parents and family, and everyone who has contributed in a way or the other to the success of this publication, I am indeed grateful. May your kindness be rewarded by the good Lord in multiple folds.

A hearty gratitude to my widespread readers and fans, along with all that love Nigeria and seek her glory.

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Preface

Aquafeed Production, Economics & Health Impact in Fish Management" is one of the educative literatures inscribed to foster intensive aquaculture and viable farming practices. It is the 13th in the series of books produced by OAKman, though the 7th on aquaculture-related topics.

There are four basic requirements in producing healthy fish– good fish seed from a good source, quality feed, culture facilities and a healthy environment (water). Being aware of the fact that 60 to 80% (or sometimes more) of most farms' re -current expenditure is expended on feeding fish that are intensively produced, this piece is fashioned towards exploring various economic means of producing quality fish feeds by incorporating some useful, cost effective natural / agricultural / industrial products, by -products and wastes as feed materials, without compromising the feed standard.

Included in the text are detailed highlights (with case studies) on the use of unconventional feed materials, what it takes to produce quality fish diets, feed production analysis and economics, field feed assessment techniques, proper fish feed management, aquaculture waste management and utilization techniques, nutritional health management, and a host of other aquafeed-related topics. The book is thus designed to educate practising and prospective fish farmers (cum aquafeed investors) in understanding some essential details in quality aquafeed production and its economic viability.

It is written as a compendium to enhance aquaculture practices for global growth and health.

Please enjoy and reap the fru it of this work as you discover the "golden eggs" herein.

OAKman

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Chapter One

Introduction

Introduction to Fish Feed

All living organisms feed to survive. They maintain their normal body physiology, and derive strength to move and grow from consumed food. Well-fed animals are normally energetic and vibrant. They have good rate of development and excellent body features such as bright appearance and shiny skin. On the contrary, those poorly fed have poor development, look dull and are usually more susceptible to disease conditions. Fish, like other animals, should be fed on adequate quantity of good quality diets to improve their growth rate, wholesomeness and business profitability.

Animal feeds are compressed pulverized mixture of plant and animal feedstuffs. Such feeds are augmented with additional stuffs (termed feed additives) to ensure a standard feed ensues. Standard quality feeds have been developed to meet the nutritional requirements of some fish species, although they are expensive. The cost of feeding adequate quantity of good quality diet to fish that are intensively farmed, often forms the larger percentage (about 60 - 85%) of the cost of production. This implies that the cost of feeding will significantly influence the productivity and economics of aquaculture. If the cost of feed input is considerably reduced without compromising the final feed quality, the business of farming fish will become more rewarding and less capital intensive, hence making aquaculture a more profitable venture to farmers and handier for consumers.

The analysis required in determining the ideal stocking density of a culture system, proper feeding for optimum result and stock management – as they relate to feed intake – are important base-line requirement for any meaningful aquaculture practice. Farmers should thus be able to estimate the quantity of fish, feed and faecal waste that their production system can support, and how to manage probable short-falls. Assessing the quality of available commercial aquafeeds with the aim of determining the economically viable one is important, just as being able to forecast the quantity of feed required for production within a given period for cash management.

Good farming should be targeted at maximizing production through the use of relatively cheap but high quality feeds and growth promoters (natural oils and probiotics) – to ensure low feed conversion ratio (FCR) and good business returns. However, the implication of each step taken in ensuring this goal must be well understood in order not to complicate issues. Though a good quality feed is expected to improve production and increase production cycles per year, proper handling of such feeds must be ensured to avoid microbial contamination and feed degradation. Thus, a good farmer should know why, how and when to introduce, adjust or change a feed.

Forms of Fish Feeds

Fish feeds on diverse edible materials that may be categorized in two ways:

- Natural or Artificial feeds
- Conventional or Unconventional feeds

1. Natural and Artificial Fish Feeds

A. Natural Fish Feeds

Nature has its own way of producing edible materials for fish. This type of edible living feed is referred to as live fish food. Plankton, a collective term used for small natural live fish food, consists of phytoplankton and zooplankton that live in water. The term phytoplankton represents edible, small water food plants produced by nature for fish e.g. algae, floating duckweeds, leaves of young reeds, lupin and yeast. On the other hand, moina, artemia, daphnia, rotifers, copepods, krill, and water insects and worms are natural live fish food animals (zooplankton) living in water. Other aquatic food animals are water snails, tadpoles of frogs / toads and small-sized fish.

A group of plankton may be carefully selected from the wild, hygienically cultured in separate tank(s) and scooped to feed cultured fish. The type and size of plankton to be selected depend on the feeding habit and mouth-size of fish to be fed. The propagated zooplankton may be maintained on micro-algae, smaller water animals, organic matters and or micro-capsulated feeds. In this way, "baby" fish are adequately managed on a variety of cultured zooplankton.

Zooplankton, such as artemia and (enriched) rotifer, are now being cultured, packaged and sold across the globe as canned, natural fish larval food. Though this packaged baby fish food will save time, ease hatchery management (feeding) and promote larvae production, the cost incurred and the possible health risks associated with the importation of live organisms (zooplankton) without proper monitoring, must be carefully considered. The economic importance of such imported fish food should thus be compared to locally cultured, rich edible zooplankton – when the handler is conversant with the technique. Nevertheless, the use of decapsulated cysts may be preferred where the level of hygiene is uncertain.

B. Artificial / Formulated Fish Feeds

Artificial fish feeds are produced as concentrates (often termed aquafeeds or fish diets) that come in diverse forms and sizes, depending on the species, size, age group, feeding pattern and environment of the fish in question. Aquafeed is produced from a calculated selection of natural food materials, synthetic products, by-products and or wastes. The concentrate ingredients may be a combination of meal / gluten of grains (mainly corn and wheat), fishmeal, oilseed by-products (such as full-fat soy, soybean meal, groundnut cake, cottonseed cake and sunflower meal), poultry by-products, di-calcium phosphate, salt and premixes. Fish feeds are often packaged and sold as dry or semi-solid granulated, flaked or capsulated feeds, which may float or sink in water.

2. Conventional and Unconventional Feeds

A. Conventional Fish Feeds

These are natural foods that are generally accepted for use as fish food, and standard feeds produced from combinations of internationally recognized (i.e. conventional) feed ingredients. Examples of such foods / feeds are outlined below.

I. Fish seedling (fry, fingerling & juvenile)

Some widely used and accepted phytoplankton (algae), zooplankton (artemia, daphnia and rotifers) and formulated diets may be classified as conventional feeds for this group of fish.

Formulated diets should be specific for each fish type / age group. It is expected to be rich in protein (essential amino-acids), energy, vitamins and minerals. The nutrients should not be locked up, but available to fed fish. Special micro-bound, micro-coated and micro-encapsulated diets — with fortified enzymes (e.g. protein hydrolysate) and other additives— are being produced for fish fry as concentrates. Optimal particulate sizes, quality and quantity of feed are essential.

II. Growers and adult fish

Standard concentrates of varied sizes and shapes, which are produced from globally accepted feed ingredients, are considered as conventional fish feeds for these two fish groups.

B. Unconventional Fish Feeds

These are natural foods and some feedstuffs (and their combinations) that may be directly used as fish foods / feeds, but are generally unacceptable as standard fish feeds, and their use is often restricted to few localities e.g. use of egg-yolk and micro-worms as fry feed, duckweeds, sea-weeds and pellets made from an unusual combination of feed ingredients as fish feed. Unconventional feedstuffs are sometimes incorporated as ingredients in standard fish diet production e.g. poultry-by-products.

The need to source for cheap fish feeds of high dietary values arose from the expensive nature of processed natural foods and commercially formulated fish diets – due to the routine use of expensive conventional feed ingredients (e.g. fishmeal) in the formulations. Depending on the locality, some feed materials may be sourced cheaply or cultured as substitutes to some expensive conventional feed items. Such relatively cheap unconventional feedstuff(s) should be analysed in a standard laboratory to determine its nutrient value and anti-nutritional factors, adequately processed and included as ingredient in fish feed production.

Sources and examples of unconventional feedstuffs

Unconventional feedstuffs may be sourced as edible by-products or wastes derived from human food materials, untapped or poorly utilized resources, or are specially produced as fish feed materials. The availability and acceptability to fish, nutrient content, anti-nutritional factor(s), quality (including microbial load) and cost implication of such feedstuffs (in each locality) should be carefully considered and compared with available conventional feed ingredients to determine their worth as substitutes. Some identified feed items that may be considered for use in feed production are discussed below.

1. Poultry

By-products (useful wastes) that are obtainable from poultry related sources may be processed as fish feed ingredients (termed poultry by-products, PBP). These processed unconventional feedstuffs may be directly used or incorporated in formulated fish feed. The feed items are relatively common and generally high in protein content. PBP must be adequately processed to forestall disease transfer / outbreak. Proper processing may also help in increasing the palatability and nutrient availability.

Some of the considered by-products of poultry origin that may be gainfully utilized in the production of quality fish feed are the feather, head & feet, and offal. Other possibilities are (cracked) eggs and culled birds.

2. Hatchery

Hatchery by-products may serve as valuable, alternate, quality-protein feedstuffs for feed formulation. The by-products, like poultry by-products, must be adequately processed to forestall the spread of any communicable disease and ensure nutrient availability.

Some notable examples of hatchery by-products are infertile and unhatched eggs (as egg powder); dead-in-shell embryo; very weak and dead chicks. Hatchery egg shells (obtained from hatched chicks) may be utilized as calcium source in feed formulation.

3. Abattoir

Animal "wastes" that may be gainfully utilized as abattoir by-products are blood, offal and unwholesome meat from animal slaughterhouses. They may be processed and hygienically recycled as viable feed ingredients such as blood meal, meat meal, meat-bone meal and bone meal, or collectively processed as abattoir by-products. Occasionally, the rumen / G.I.T. content, when well processed, may be considered as an ingredient.

4. Plants and animals

Some cheap viable plants and highly productive animals of good nutrient values may be produced or harvested locally, adequately processed and stored for future use as ingredient concentrates.

The choice of plant / animal based feedstuff selection (for feed production) should be based on factors such as:

- Being locally available in commercial quantity.
- Having the ability to proliferate fast.
- Having the ability to adapt to that environment – for successful propagation.
- The nutrient content and its availability.
- The overall cost of producing (or getting) the feedstuff.

Some viable plants and their by-products that may be considered for use as feed ingredients include meals and cakes of algae, seaweeds, duckweed, water velvet, water hyacinth, yeast, sunflower, lupin, rapeseed, peas, canola, and by-products of grains (rice, corn wheat, barley and millet) and breadfruit. Mushroom, tomato, vegetable, melon and albizia seed are other possibilities. Unutilized farm produce (and edible local market residues) may also be gainfully considered. They may be processed and stored as meals, cakes or puree (tomatoes) prior to their use in formulated diets. The protein content of some plant s may be concentrate d (to over 50% protein content) as plant protein concentrates — corn gluten, wheat gluten, pea protein concentrate, rapeseed protein concentrate and water hyacinth leaf protein concentrate — and used as (calculated) substitute for fishmeal and soybean meal.

Animals that may be harvested or cultured, processed and utilized as feed ingredients include some miniature aquatic animals (water crustaceans, water insects and trash fish), micro-worms, earthworms, insect larvae (e.g. housefly maggots and blackfly larvae), insects (termites, cockroaches and farm-flies), tadpoles, snails and rodents (mice, rats an d guinea-pigs). Selected animal protein source(s) should be well managed and processed in other to have pathogen-free food / feed ingredient.

5. <u>Food processing industries</u>

By-products (wastes and residues) obtained from industrial food processing plants and food vendors may be re -cycled into valuable feed materials for use in fish diet production. Some of these items may serve as good energy substitutes, some as protein sources, while some others may serve as vitamin / mineral supplements. They may or may not require much processing, depending on how and where they were sourced.

Some useful "wastes" that may be obtained from food processing industries are broken rice, baby cereal waste, corn flakes waste, wheat flour dust, biscuit dust / waste,bakery waste and cassava flour / flakes waste. A number of these "wastes" may also serve as good feed binders. Other useful factory by-products (wastes) include milk dust, fragmented groundnut, industrial puree wastes (e.g. tomato puree waste), and processed by-products / wastes obtained from fruit juice industries and some eatery residues.

6. Miscellaneous unconventional feedstuffs

Some new materials are increasing being included as probable feedstuffs in order to side-track some expensive ingredients or where future scarcity of such ingredients is envisaged. These feed materials include:

- Single-cell protein – bacteria, algae, yeast and fungi proteins.
- By-products / extracts of feedstuffs e.g. corn gluten meal, corn germ meal, wheat gluten, soy protein concentrate, leaf protein concentrate and so on.

Some examples (and obtainable prices) of conventional and unconventional feedstuffs are given in table 1.1.

Table 1.1. Some conventional and unconventional viable feedstuffs

Unconventional Feedstuffs	**Price (N/kg)**	**Conventional Feedstuffs**	**Price (N/kg)**
Energy Source			
Rice meal	N/A	Corn meal	220
Potato meal	N/A		
Breadfruit meal	N/A		
Guinea corn meal	N/A		
Barley dust	N/A		
Sorghum meal	N/A		
Biscuit waste	N/A		
Bakery by-product	N/A		
Wheat dust	N/A		
Noodle waste	N/A		
Baby cereal waste	N/A		
Cassava meal	N/A		
High protein source, >50% (mainly animal origin)			
Earthworm meal	N/A	Fishmeal	1,860
Snail meal	N/A	(72%)	
Blood meal	N/A		
Hatchery by-products	N/A		
Poultry by-products	N/A		
Feather meal	N/A		
Insect meal	N/A		
Tadpole meal	N/A		
Corn gluten	N/A		
Wheat gluten	N/A		

Moderate protein content, <50% (mainly plant origin)			
Sunflower meal	N/A	Soybean meal	375
Groundnut cake	360		
Cotton seed cake	N/A		
Full-fat soy	N/A		
Soybean cake	N/A		
Rapeseed meal	N/A		
Canola meal	N/A		
Brewery's yeast	N/A		
Milk (factory waste)	N/A		
Albizia seed meal	N/A		
Tomato puree (factory waste)	N/A		
Duckweed meal	N/A		

Price source: Feedmills in Ibadan metropolis, Nigeria (May, 2022).

N/A: Unavailable, suggested, common unconventional materials that may be converted into good use, depending on location.

Advantages & disadvantages of using unconventional feedstuffs / feeds

Advantages of using unconventional feedstuffs / feeds

- Cheap source of protein and energy
- A careful selection and inclusion of such feedstuffs in feed production should guarantee least production cost, thus ensuring business cost-effectiveness.
- Commercialization of such feed items should foster job creation and source of livelihood e.g. production of oils and meals of duckweed, earthworm, tadpole, insect and snail.

- More agro-investors will be encouraged to invest in aquaculture and the feed industry.
- Encourages waste re-cycling, thus ensuring less environmental pollution.
- Less dependence on common human food materials.
- Provision of more varieties of feedstuffs to select from.
- Creation of more job opportunities.

Disadvantages of using unconventional feeds

- Processing of unconventional feedstuffs may be space and time consuming, thus may retard the full strength of production i.e. distraction from primary assembling of feedstuffs and production.
- Increase in labour strength as more hands may be required for the production / harvesting / purchase, processing and management of such by-products.
- Disease contaminants may be introduced through the use of unprocessed, improperly processed or contaminated "wastes" e.g. inclusion of improperly processed cultured maggot or hatchery by-product meal in non-extruded fish diet.
- Extra cost of analysing such (unconventional) feed material.
- Acceptability of product by cultured fish (due to its palatability) and consumers may be a challenge e.g. use of maggot meal in production.
- More land space and processing equipment may be required for by-product processing and storage.

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Chapter Two

Fish Fry Nutrition

Introduction

Most tropical cultured fishes (e.g. African catfish and carp) go through six developmental stages after being hatched out from their eggs — yolked larva (sac fry), post-yolk larva (swim-up or young fry), advanced fry, fingerling, juvenile and adult. Depending on the size of the egg, the yolked larval stage lasts between three days to three weeks, or even more. The Atlantic salmon eggs are usually large, and consequently yield large yolk sac supplies that are sufficient to provide endogenous (reserved) food for the first three weeks of their larval development. However, the relatively small sized eggs of the Gilthead sea bream, the Carp and the African catfishes yield small yolk sac supplies that provide endogenous food for the first three days.

The salmonids are able to consume formulated feed particles as large as 1mm at their 3 weeks post-yolk larval stage, while the gilthead, carp and African catfishes are only able to take food substances of only 0.1mm on their first exogenous feeding day. Besides the 0.1mm feed particles limitation, the 3 or 4 days old catfish larva's digestive track is short, not well developed and secretes specific peptidase enzyme which can only digest simple protein. For proper growth, African catfish larvae and its likes will have to rely on food sources with the following qualities.

- Partially digested and easily digestible feed i.e. the feed should contain large amount of free amino acids and oligopeptides instead of indigestible complex protein molecules.
- The food substance should contain enzyme systems that allow autolysis i.e. self-digestion of food particles.
- The food should supply in abundance all the essential nutrients required by the young fry.
- The ability of such food being easily detected by the larvae is also important. This is because the eyes of post-yolk fish larvae usually only contain cones in the retina, resulting in poor vision.

Most natural live fish foods (zooplankton) meet these required specifications, in addition to triggering an enhanced perception of the feeding larvae by their continuous movement. The swimming activity of live food organisms also assures their good distribution in water column and more frequent encounters with fish larvae which in most cases may have low mobility.

Plankton (Natural Live Fish Food)

Plankton, commonly referred to as natural live fish food, is made-up of microscopic organisms which are suspended in water. They are made-up of phytoplankton (tiny green plants), zooplankton (tiny animals) and bacteria. Being autotrophic in nature, phytoplankton (chlorophyllous) uses inorganic salts, carbon dioxide, water and sunlight to produce its own food, but zooplankton feeds on living or dead phytoplankton and other tiny particles of organic matter in water.

The common phytoplankton species are grouped into Chlorophyceae (green algae), Myxophyceae (cyanobacteria or blue-green algae), and Bacillariophycea (Diatoms). Microalgae such as Spirulina (60 to 90% protein) and *Crypthecodinium cohnii* are being used as rich protein, live fish food. The common planktonic animals are grouped into Protozoan (Sarcodines, Flagellates, and Ciliates), Rotifers (e.g. *Brachionus species*, *Asplanchna species*, *Keratella species* & *Polyarthra species*) and Crustaceans — Cladocerans (e.g. *Moina species*, *Daphnia species*, *Cida species* & *Ceriodaphnia species*), Copepods (e.g. *Calanoida species* & *Diaptomus species*) and Ostracods. Other live foods are Artemia, Nematodes and Trochophora larvae.

Periphyton, a complex matrix of algae, cyanobacteria, heterotrophic microbes and detritus, is an easy to culture natural feed diet for herbivorous 'baby' fish. It may be cultured on white, rough, submerged surfaces as fish larval diet in semi-intensive systems. Setting up a submerged chain of strata or net materials just beneath the water surface (as illustrated in plates 2.1 & 2.2) may produce enough periphyton that may replace up to 50% of the required feed for fry production.

Plate 2.1. Strata arrangement for periphyton production

Plate 2.2. Use of strata in periphyton production

Source: Harpaz S., 2011.

Phytoplankton may be utilized directly by some herbivorous fish species, but mainly serve as food for zoo plankton – the complete natural food of many species of fish larvae. The qualities that make live food (zooplankton) ideal for the feeding of fish larvae are:

- Easy availability

- Reproduction of large number of offspring within a short period of 1 to 5 days from egg hatching to adult, depending on the species involved and environmental condition.
- Good nutritional qualities such as:
  - They are easily digestible, having large amount of free amino acids and oligopeptides.
  - They contain enzyme systems which allow autolysis i.e. self-digestion of food particle.
  - They supply the essential nutrients required, and are of appropriate size for easy ingestion by fish larvae.

Larvae of some culturable fish that readily accept zooplankton are catfish, tilapia, carps, gilthead sea bream, and large-sized shrimps and prawns.

Production and Application of Zooplankton

Plankton species are naturally occurring in low densities in water bodies. Sufficient quantities of plankton may however be raised in enclosures such as plastic tanks, wooden tanks, fibreglass / fibreglass coated tanks, tarpaulin / tarpaulin coated tanks, stainless steel, concrete tanks and earthen ponds. However, the use of tanks is preferred to earthen ponds for easy management. Corrosive metallic tanks (e.g. uncoated iron tanks) should be avoided. Although the size of each of these water holding receptacles varies, small sized tanks are better and easier to manage than large tanks. A tank dimension of about 2m x 2m x 1.5m may be adopted for use. Where concrete tanks are intended to be used, such tanks should first be "cured" to reduce the chemical effect of cement.

The two widely accepted methods of zooplankton propagation are the "Trawl to Inoculate" and the "Spreading" methods.

1. The Trawl to Inoculate Method

- Acquire and fill the water holding receptacle with water from a good water source such as borehole, to a depth of about 1metre.
- Using inorganic or well managed organic fertilizer (or a combination), fertilize the tank and leave for about 3 to 5 days for bacterial and phytoplankton growth.
- With the aid of a microscope or magnifier, examine water samples obtained from existing water body(-ies) for choice zooplankton, early in the morning or late in the evening.
- Trawl for the choice zooplankton from the sited zoop lankton-rich water body to seed and inoculate the culture tank.

2. The Spreading Method

- Acquire a viable culture tank
- Separate and spread the resting eggs of choice zooplankton or simply spread earthen sediments containing zooplankton cyst / resting-egg / ephippia on the bottom of the tank.
- Add water from a good source and keep the water level at about 1metre depth. If the available water is turbid, allow it to get settled or pass through an appropriate solid filter (e.g. sand filter) before being used.
- Fertilize the culture unit and watch-out for bacterial growth, followed by phytoplankton growth and climaxed by zooplankton production within 3 days to a week.

Note

Resting eggs may be obtained from the tank sediment of an established zooplankton culture sys tem (usually from about a week old or more culture system), and stored in a refrigerator at 4 oc for about a year or more, for future propagation.

Once the culture system is established, there is the need to maintain a good micro-algae level for a continuous optimal zooplankton production, through the careful use of fertilizers. Alternatively, other zooplankton feeds such as micro-encapsulated feed and organic matters may optionally be considered or combined with micro-algae feeding in maintaining the culture.

Periodic examination of the zooplankton for viability and culture progression is important. To do this, a scoop of the organism is harvested into a clean transparent glass container, and examined with the naked eye or with the aid of a hand lens. Zoopl ankton appears whitish and could be observed to be darting around in the container when held against a light source.

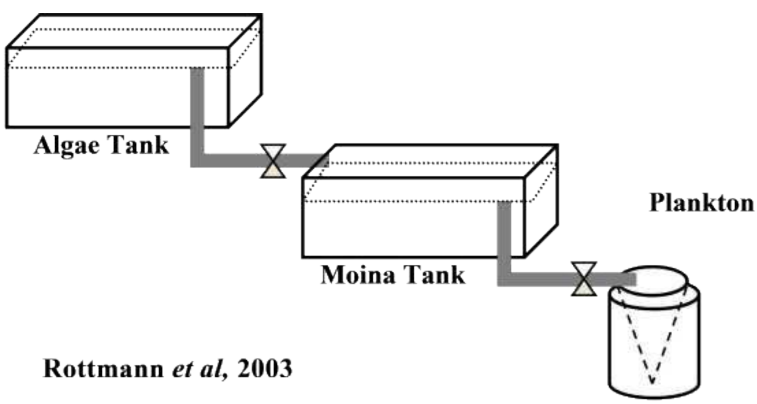

Figure 2.1. Moina species production

Fertilizer Application in Zooplankton Production

Fertilization of culture medium can be carried out using inorganic or organic fertilizer. Inorganic fertilizers are artificial (or synthetic) fertilizers, examples of which are Nitrogen, Phosphorus & Potassium (NPK), Ammonia, Urea and Super-phosphate fertilizers. Organic fertilizers that may be used include animal manure and wastes (e.g. chicken droppings, blood meal and fish offal), crop residues and compost. Organic fertilizers are cheap, good and natural fertilizers, though great care should be taken to avoid probable contaminants, thus necessitating some level of processing. Inorganic fertilizers are commonly broadcasted, while the “sac” and “fermentation” methods are usually applied for manure / organic fertilization.

Harvesting of Zooplankton

This is commonly carried out with (imported) standard nets, though suitable local fabrics may be substituted to manage the cost. Harvesting is initiated by dipping and towing a zooplankton harvest net within the culture from one side of the tank to the other. The harvest of each of the several trawls is emptied into a bucket of fresh water to obtain a good concentrated zooplankton harvest and to keep them alive. The harvest is then processed by sifting it through a sieve (coffee sieve and mosquito netting sieve may be improvised) to remove mosquito larvae, aquatic insects and other debris. The filtrate could then be used in feeding the fry in fry holding tanks.

Commercial Zooplankton

Some of the known natural fish larvae foods have been commercially pre-processed and packaged to ease larvae feeding process. Cyst of artemia and rotifer are the commonly parcelled zooplankton for larviculture. Of the two, artemia is the most favoured, though its use as the first larval feed is sometimes limited by its size – bigger than what some fish larvae can pick.

Artemia composition is 60.5 ± 3.3% protein, 14 to 15% carbohydrate, 13 to 19% fat, and 3 to 15% n-3 HUFA (Sathasivam & Abd_Allah, 2019). When the HUFA content is low, artemia can be enriched with omega yeast, vitamins (E, D, C and B_{12}), marine oils, vitamin B_{12}-producing bacteria, and commercial enrichment media. It is important to feed fish larvae with newly hatched artemia nauplii to take advantage of the yolk and stored nutrient in freshly hatched Instar I nauplii. Also, freshly hatched nauplii are dark orange coloured, and are thus easier to see than the transparent older nauplii. As the nauplii advance in age, they sometimes become too large and move so fast that the fish larvae find them difficult to catch and eat.

Artemia Cyst Decapsulation

Commercially sold artemia cysts often come as decapsulated or non-decapsulated cysts. Decapsulation is the process by which the outer shell (chorion) of the cyst is chemically removed. The process for decapsulation of artemia cysts is as follows:

- Hydrate cysts in fresh (or salt) water containing transparent, cylindro-conical container at room temperature for about an hour. Cysts should be kept suspended by continuous aeration.
- Harvest hydrated cysts on 125 micron filter.

- Transfer the cysts into hypochlorite solution to activate cyst decapsulation. Ensure adequate aeration, and maintain low temperature and pH of not less than 8.0.
- As the process continues, the cysts change colour from brown to grey, then white and later to bright orange colour. This signifies the complete removal of the hard shell. The process takes a few minutes, depending on temperature.
- Remove the cysts by draining through a 125µm sieve, and thoroughly rinse with fresh water to remove all traces of hypochlorite.
- Optionally dip the cysts (in the sieve) in either 0.1M HCl or in 0.1% $Na_2S_2O_3$ solution to ensure complete deactivation of the process / neutralisation of the chlorine, and rinse again with clean water.
- Decapsulated cysts may be drained and fed to fish, incubated for immediate hatching, or dehydrated in saturated salt solution and stored at very low temperature for future use.

The advantages of decapsulated artemia cysts over the non-decapsulated are:

- Decapsulated cysts may be directly consumed as an energy-rich nutrient by some fish and shrimp, unlike non-decapsulated cysts.
- The cysts are disinfected in the process i.e. reduced the likelihood of serving as disease vector.
- The challenge of separating indigestible cyst shells is removed.
- Nauplii resulting from decapsulated cysts are often more agile, since less energy is spent on hatching.
- Illumination requirement for hatching is lower.

Decapsulated artemia cysts may be fed directly to cultured fish larvae such as the African catfish (*Clarias gariepinus*), carp (*Cyprinus carpio*), marine shrimp (*Penaeus monodon*) and milkfish larvae. It may also be dehydrated in saturated brine and stored for future hatching, or further processed / cultured into free-swimming food (nauplii) before being served.

Feeding fish larvae with decapsulated cysts (where possible) have such added advantages as:

- It eliminates the hatching stress and requirements.
- The nutrient is kept intact.
- The micro-particulate size (usually 200-250 μm) makes it more acceptable as fish larvae food than the developed nauplii form (470-550 μm), though not all larvae can accept it as their 1st food.
- It does not affect water quality in anyway – no pollution nor oxygen demand.
- When dried, the cysts remain suspended in water for a while, and thereafter sink slowly.
- However, being immobile seems to be the main setback to its use as fish larvae food. Larvae food motility is believed to improve visual appeal.

Optimal conditions for cyst hatching are:-

- pH (8.0 to 8.5).
- Salinity (0 to 5ppt).
- Temperature (25 to 30^{o}c).
- Vigorous aeration (preferable oxygen content of not less than 5mg/l).
- Illumination.

Plate 2.3. Cylindro-conical zooplankton hatching holders

Feeding Fish Fry with (Uncapsulated Cysts) Artemia Nauplii

The underlisted guideline may be followed when feeding fish fry with uncapsulated artemia cysts.

- The weight of artemia cysts required in feeding cultured fish fry should first be determined. Assume a minimum cyst hatching rate of 50%.
- Hydrate and preferably decapsulate cysts.
- Incubate artemia cysts (about 2 grams per litre) in (conical / cylindro - conical) hatching tank for about 24hours. Ensure good illumination, water

temperature (preferably 26 -28ºc) and vigorous aeration to suspend the cysts.

- Harvest the free-swimming nauplii and unhatched cysts through the drain, while cyst shells float – for capsulated cysts.
- Separate the nauplii from the unhatched cysts by washing through a 200 micron screen.
- Estimate the number of hatched artemia.
- Estimate the number of uneaten artemia nauplii from previous feeding.
- Transfer the calculated quantity of artemia nauplii required for feeding into the larvae tank. The calculation is based on the daily nutrient requirement of the larvae, the age and estimated number of uneaten nauplii.
- Feed freshly hatched nauplii to fish larvae at 0.5 to 2g per ml.

Note

- Each gram of cysts contains about 200,000 to 300,000 cysts.
- Hatchability often ranges from 50 to 90%. Use 50% for nauplii estimation.
- Feeding rate may be slightly adjusted, depending on the stocking density and the rate of nauplii consumption.
- Uneaten nauplii may be flushed out if the size and nutrition are considered invaluable.

Other Baby Fish Food Preparations

Some other feed materials are occasionally used in feeding fish seedlings with some recorded success level, apart from using the conventional zooplankton and formulated diets. Sometimes these unconventional foods are fed along with zooplankton, formulated diets or combined with other unconventional feed materials. They are often served in their moistened or powdered form. Some of these other feed items are listed below.

- Steamed, mashed egg-yolk or powdered egg-yolk
- Egg custard
- Fish meal
- Dried / fresh yeast e.g. baker's yeast and torula yeast
- Milled or smashed worm e.g. red worm
- Shrimp head flakes
- Insect larvae e.g. mosquito larvae
- Frog / toad eggs and tadpole

Feeding Baby Fish

Fish larvae, after utilizing their yolk nutrient, start feeding on available (exogenous) feeds. Their first exogenous feed (detritus, artemia, other zooplankton and or concentrate) is frequently associated with gut complications that sometimes result in severe mortality. Such feeds are often regarded as foreign bodies – being strange on introduction, and may lead to gut microbial complexity. Likewise, a sudden change in fry zooplanktonic feed to concentrate may precipitate similar condition. These are the typical (nutrient -related) critical periods in normal fish hatchery production. When farming African catfish (*Clarias gariepinus*), these critical periods often fall between the third / fourth day (first day of exogenous feeding) to probably the sixth day, and about the 10th to 14th day (sometimes up to 3rd week) when quite a number of farmers change their baby fish feed to concentrate from zooplanktonic feed.

To circumvent such conditions, new feeds should be gradually introduced with or without the use of "gut -stabilizers". Gut -stabilizers are useful / advantageous microbes (probiotics), essential (plant) oils and other substances that may help in managing gut microflora, nutrient metabolism and or "toxic" (i.e. strange and harmful) metabolites favourably. Newly hatched larvae may thus be exposed to a recommended dose of proven beneficial bacteria (or plant oil) to stabilizetheir gut microbial composition, before being gradually introduced to their first feed, in order to prevent such condition and improve feed metabolism. Once the yolk is absorbed, zooplanktonic feed should be gradually introduced and the fish's response monitored.

In the absence of such "stabilizers" , non-polluting larval feeds should be gradually introduced, ensuring optimal water quality and well monitored health response. When changing feeds (i.e. life food to concentrate), the new feed should be gradually introduced while the out-going feed is gradually withdrawn. It is equally possible to start feeding with a combination of zooplanktonic feed and concentrate, and thereafter (about a week or two) gradually withdrawing the zooplankton. Thus, these critical periods are appreciably managed without tears.

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Chapter Three

Formulation of Fish Feed

Dietary Composition of Fish Feed

Aquafeed production is directed at satisfying the nutrient requirement of farmed fish either in part (supplemental diet) or totality (complete diet). To realize the dream of meeting human's increasing fish demand, cultured fish should be fed on complete diets for fast growth. The dietary requirements (carbohydrate, protein, lipids, vitamins and minerals) of some cultured fishes are known while others' are extrapolated from data obtained from related fishes.

Carbohydrates

Carbohydrates are poorly utilized as food-energy source in fish when compared with what obtains in terrestrial animals. Dietary carbohydrates, such as dextrin and starch, are better utilized by fresh- and warm-water fishes than cold-water and marine fishes. Its digestibility and utilization may be improved when extruded under high temperature and pressure to reduce the molecular complexity. Though often included at less than 25%

of feed weight (for fish feeds), they are important in feed gelatinization for proper binding (feed stability in water) and floating feed production. Examples of such feed items are ricemeal, cornmeal, wheatmeal and oatmeal.

Proteins

Proteins are complex aggregation of amino acids, which are utilized in body building, immune development and energy provision in fish. It is a major component and the most expensive part of fish feed. Most aquafeeds produced contain about 25 to 35% dietary protein for maintenance ration, and about 35 to 65% protein for complete diet, depending on the feeding behaviour (i.e. filter-feeder, herbivore, carnivore or omnivore), breed, age/size and expected growth pattern. Protein requirements for herbivorous and omnivorous fishes are usually lower than those of carnivorous fishes, just as fish raised under controlled, intensive systems usually require more (supplied) protein than those in low density, natural systems. Fish fry are normally fed with the richest diets,similar to algae and zooplankton nutrient content, while adult fish receives lower protein diets (table 3.1). For instance, the protein content of microalgae may be as high as 70% (*Spirulina maxima*is about 60-71% and Chlorella), while that of artemia is reported as 60.5 ± 3.3% protein (37-71% CP) of its dry matter (Peykaran *et al*., 2014; Sathasivam & Abd_Allah, 2019).

The essential amino acids required for healthy fish growth are given as lysine, methionine, leucine, isoleucine, phenylalanine, arginine, threonine, tryptophan, histidine and valine, and these are normally included in fish premix (Usydus *et al*., 2009). Aquafeed production usually requires the use of feed ingredients with low and high protein contents. High protein content (≥ 50% CP) feedstuffs include fishmeal, blood meal, poultry by -product meal and meat meal, while those of moderate protein content (20 - 49% CP) are soybean meal, soybean cake, groundnut cake, cottonseed cake, canola meal, rapeseed meal and sunflower meal. It should be noted however, that feedstuff's protein content and nutrient availability may be influenced by geographical factors (e.g. soil type) and processing method.

Table 3.1. Protein content of commercial finished feeds (carnivores)

Age Group	Crude Protein (%)
Fry	≥ 50 (50 – 70)
Advanced Fry	≥ 50 (50 – 60)
Fingerling	45 – 55
Juvenile	40 – 50
Grower	40 – 45
Adult	35 – 45

Note

- *Table 3.1 is more specific for intensively cultured carnivorous / omnivorous fish, aimed at obtaining fast production result.*
- *The higher the protein content & energy, the better the performance, and the shorter the production cycle.*
- *Maintaining a sound environment (culture medium quality) is important for optimum result.*

Lipids

Lipids are good energy source and fat-soluble vitamins conveyance. They are easily digestible with less metabolic stress. Simple lipids include fatty acids and triacylglycerols. Generally, unsaturated, long chain fatty acids of the Omega 3 and 6 groups are important to fish. These essential fatty acids are available in fish meal / oil and most other aquatic products / by-products, but not in terrestrial plants or animal tissues. Linolenic acid is another unsaturated, essential fatty acid of vegetable oils, which is important for normal fish growth.

Lipid requirement of fish is a function of its ecological base. Marine fishes require the long chain n-3 highly unsaturated fatty acids (HUFA) for optimal growth and health. Unlike marine fishes, most freshwater fishes can produce the n-3 HUFA, eicosapentaenoic acid (EPA:20:5n-3) and docosahexaenoic acid (DHA:22:6n-3) from linolenic acid. Fish species such as tilapia, require the n-6 fatty acids, while others such as carps and eels, require both n-3 and n-6 fatty acids.

These essential fatty acids are often added in the form of oils or sprayed as a coating on finished feeds. They are often added to increase the feed metabolizable energy to a desired level (usually > 3,500kCal kg^{-1}), and to provide the essential fatty acids required for healthy growth. Lipids are usually included at 0.5-2% of dry diet when manually done, while a range of 10-18% of the feed is often maintained in extruded feeds. Since much oil will make the feed to be flabby, it is applied topically as a surface coating in extruded feeds, thus increasing its water resistance. When poorly managed, high dietary lipid content may encourage feed rancidity, poor binding property and fat deposition in body organs such as the liver.

Vitamins

Vitamins are essential for normal body function, growth and health. They are not synthesized, so are required to be included (in small quantities) as feed additives. There are 15 essential vitamins for most fish, which may be grouped into two — water-soluble and fat-soluble vitamins.

Water-soluble vitamins include thiamine, riboflavin, folic acid, niacin, pantothenic acid, pyridoxine, nicotinic acid, biotin, cyanocobalamin, inositol, choline and ascorbic acid (vitamin C), while vitamins A, D, E and K are fat-soluble vitamins. Of these vitamins, vitamins C and E seem to be the most important, being antioxidants. They (vitamins C & E) are important in stress management.

Minerals

These are inorganic substances that are required for normal body function, osmo-regulation, and bone and scale formation. Its absorption may be from the surrounding water via the gills (primarily), as well as from the diet. Their absorption is influenced by factors such as the presence of other mineral matters and water parameters e.g. temperature and acidity. Minerals may be grouped as macro-minerals that are required in relatively large quantities when compared to micro-minerals that are required in traces.

Examples of macro-minerals are calcium, sodium, potassium, phosphorus, and chloride, while magnesium, copper, zinc, selenium, iron, iodine, chromium, cobalt and manganese are regarded as micro-minerals or trace elements.

Functional Feed Additives

The word “feed additives” is commonly used in animal feed industry. They are substances that are incorporated into finished feeds, in minute quantities, to improve the quality of the feed (in terms of palatability, digestion and nutrient availability), fish performance and health, and or to minimize the resultant waste impact on their environment.

Feed additives are often incorporated to augment certain essential nutrients (amino-acids, vitamins and minerals) or substances (digestive enzymes in larvae) that are required by the specific species for survival / optimal performance. Also, the palatability and consumption rate of some quality feeds are enhanced when they are carefully “treated” and “seasoned” with the right additive. Such is the case of a quality diet formulated with low (or zero) fishmeal content or having an ingredient with off-flavour scent / taste. The feed will most likely be poorly fed on unless the right additive is included to improve the feed scent and taste. This puzzle of feed palatability / acceptability may be played down through the use of feed flavours (attractants), low proportion of cane molasses (for taste) and other attractant products. Thus the type of additive added to a feed depends on the objective for which it was added – its functionality.

The functionality of feed additives in finished feeds may thus be categorized as outlined below:

- The ability of the additive to provide certain essential nutrients that are required in minute quantities, but probably lacking in finished feeds e.g. vitamin / mineral additives.
- The ability of the additive to enhance feed palatability, feed digestibility, nutrient assimilation and or its utilization, thus enhancing the feed

conversion ratio (FCR) and fish growth rate e.g. enzymes, hormones, probiotics, herbal extracts and feed attractants.

- The ability to manage (specific) anti-nutrient factors found in feed (ingredients) or minimize its effect, thus promoting feed utilization e.g. organic acids and enzymes.
- To manage nutritional deficiencies emanating from feed processing techniques – such additives are aimed at supplying thermo -labile nutrients (as seen in feed extrusion) e.g. vitamin additives.
- The ability to manage feed microbial contaminants / toxins of pathologic significance or to manage certain (endemic) disease conditions e.g. prebiotics, probiotics, bacteriophages, gut stabilizers, immune stimulants, herbal extracts and mycotoxin binders.
- The ability of some feed additives to minimize transport stress e.g. Moringa oleifera.
- The ability of the additive to improve water quality e.g. some probiotics and herbal extracts (ginger and garlic).
- The ability of an additive to improve feed shelf-life e.g. organic acids and probiotics.
- The ability to boost immunity and prevent gastro -intestinal disorders caused by stress e.g. immune stimulants and herbal extracts
- Other functional feed additives may include microalgae, organic acids, photogenic compounds and yeasts.

Feed additives are incorporated into finished feeds before being manually pelletized (for pelleted feeds) and after extrusion (for extruded feeds), except the substance is thermo-stable or better by-product results.

Formulating your Fish Diet

Fish diet may be formulated using both conventional and unconventional feed materials. Conventional feedstuffs such as corn meal, wheat meal, soybean meal and fish meal, in addition to others such as di-calcium phosphate, salt and premixes are commonly used in concentrate formulation. However, the inclusion of cheap, processed unconventional feed items into fish concentrates will make the practice a more rewarding business and a means to waste management.

In formulating fish feeds, the nutrient values (crude protein, energy, fat / oil, fibre … and mineral contents) of each feed item to be used should be known. The selected feedstuffs are mixed according to the pre-determined percentage of feed formulation. Feed formulation should be targeted at deriving a fish diet that will ensure the provision of the required nutrients for an outstanding production (or as desired), at the least-cost of production. Least-cost suggests that the final feed, when compared with other formulations of similar nutrient quality (i.e. energy, CP …), should have the minimum possible cost of production. In determining the least-cost feed formulation, the following parameters should be provided:

- Cost of feed items
- Nutrient content of such feed items
- Nutrient requirement of the fish
- Availability of the feed materials in substantial quantity
- Availability of the nutrient to the fish
- Maximum level of each feed item inclusion in the feed – to manage factors such as anti-nutrient and palatability

Various software programming and methods are availab le in determinin g the (feed items) mixing ratio. These are:

1. Computer Software (Linear Programming)

This is the easiest and most recent process being used in determining the proportion of mixture of feed ingredients, once the basic operational mode is understood. It is timesaving, requires neither calculation nor special skill in mathematics, and gives the least possible cost of concentrate formulation / production. Likewise, a number of variables / parameters may be inputted in a well-designed programme, unlike in other methods.

2. Algebraic Method

a. Harder mensuration

This may be employed in determining the proportion of mixture of three feedstuffs in a pre -determined feed formulation. Three feed variables (e.g. Crude Protein, Metabolizable Energy and Fat / Oil content) are considered in the calculation.

In the absence of system software, this method may be preferred, although it involves a lengthy calculation and re quires some mathematical skill.

b. Quadratic equation

It may be used in determining the proportion of mixture of two feed items in a pre -determined feed formulation. Two feed variables (e.g. crude protein and metabolizable energy) are considered in the calculation. The calculation involved is not as tedious as that of harder mensuration and requires just some basic understanding of algebra, although more variables / ingredients' proportionality are solved for in harder mensuration.

3. Pearson's Square

This method may be employed in determining the proportion of mixture of two feed items in such a way as to solve for one feed variable (crude protein).The limiting factor to the use of this method is in its solving for just 1 feed variable, since the protein and energy content of any feed are important, as other feed variables may be augmented with additives.

4. Trial and Error Method

This is a crude way to determine the proportion of mixture of feed items. It is often done out of experience, using prior knowledge of similar formulae. Such a formula is then verified by calculation to see if it will meet the desired requirement.

In locations where feed software is inaccessible, either for financial reason or otherwise, aquatic animal feed may be formulated using algebraic method. To have an understanding of the calculations involved in feed formulation, three examples will be attempted using Pearson's square and quadratic equation, and an example using harder mensuration. The concentrates will be formulated using both conventional and non-conventional feedstuffs of assumed feed values. Although 4 to 7 feed items (excluding vitamins / minerals supplements and other additives) are commonly combined by most commercial feed producers in aquafeed production, for proper understanding, 2 to 5 items will be work on in the examples that follow, starting with the easiest (two feedstuffs).

<u>Case Study</u>

Assumptions

Feedstuffs	**CP (%)**	**ME (kCal kg^{-1})**
Corn meal (CM)	10	3400
Rice meal (RM)	12	3200
Soybean meal (SM)	44	2700
Duckweed (DW)	39	2,450
Hatchery by-product meal (HBM)	60	5,000
Insect meal (IM)	60	4,000
Fish meal (FM)	70	2,800

Please note that the figures quoted are mere hypothetical values of the dry matter content.

<u>Case 3.1</u>

A farmer wishes to formulate some quantity of feed for his 3 months old fish (growers). What proportion of the ingredients has to be c ombined in order to produce a concentrate of 45% CP and 2900 kCal kg $^{-1}$ from rice meal and fishmeal?

Data Supplied

Concentrate, C = 45% CP and 2900kCal kg^{-1}

Feedstuffs = Rice meal (RM) and fish meal (FM)

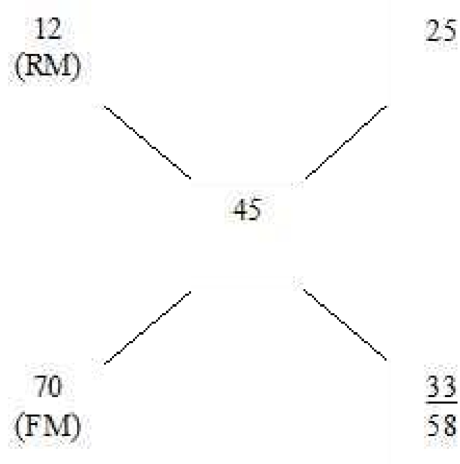
RM = 12% CP & 3200kCal kg^{-1}

FM = 70% CP & 2800kCal kg^{-1}

Solution

A. .Pearson's Square

CPrm = 12%, CPfm = 70%, CPc = 45%



% RM = 25/58 x 100% (of feed)

RM = 43.10345% ≈ 43.1%

%FM = 33/58 x 100% (of feed)

FM = 56.89655% ≈ 56.9%

So, 43.1kg RM & 56.9kg FM are required to produce 100kg of feed

To Cross Check

Feedstuff	**%**	**Content CP (%)**	**Contributed CP (%)**
RM	43.1	12	5.172
FM	56.9	70	39.830
Total	**100**		**45.002**

C.CP. = Contributed Crude Protein

Note: The difference of 0.002% CP is due to approximate values in the calculation.

B. Quadratic Equation

Let, a stand for the proportion of RM required in the feed

b stand for the proportion of FM required in the feed

CP = crude protein & ME = Metabolizable Energy

Contributed CP of RM in the feed = CPrm x a

Contributed CP of FM in the feed = CPfm x b

Therefore,

CPrm x a + CPfm x b = CPc (concentrate) ----- equation (i)

Likewise,

Contributed ME of RM in the feed = MErm x a

Contributed ME of FM in the feed = MEfm x b

Therefore,

(MErm x a) + (MEfm x b) = MEc---- equation (ii)

Substitute the values of CP and ME in equations (i) & (ii)

(For CP) 12a + 70b = 45----- (i)

(For ME) 3200 a + 2800b = 2900 ---- (ii)

To solve for variation a in equations (i) & (ii),

Multiply (i) by 4 and (ii) by 0.1

48a + 280b = 180 (multiply by -1)

<u>320a + 280b = 290</u>

<u>272a + ----- = 110</u>

a = 110 / 272

a = 0.4044118

% RM ≈ 0.404 x 100%

RM = 40.4%

Substitute the value of a in equation (i) to solve for b

12 a + 70b = 45 --- (i)

12 (0.4044118) + 70b = 45

70b = 45 – 4.8529416 = 40.147058

b = 40.147058 / 70

= 0.5735294

% FM ≈ 0.574 x 100%

= 57.4%

So, 40.4kg of RM should be mixed with 57.4kg of FM to produce 100kg of concentrate of 45% CP and 2900kCal kg^{-1}

To Cross Check

Feedstuff	**%**	**CP (%)**	**ME (kCalkg^{-1})**	**C.CP (%)**	**C.ME (kCalkg^{-1})**
RM	40.4	12	3200	4.848	1292.8
FM	57.4	70	2800	40.180	1607.2
Total	**97.8**			**45.028**	**2900.0**

C.CP = Contributed crude protein (%)

C.ME = Contributed Metabolizable Energy (kCal kg^{-1})

<u>Case 3.2</u>

A catfish farmer wants to formulate a 45% protein and 3 500kCal kg^{-1} concentrate for his adult fish, using corn meal, insect meal, hatcherybyproduct meal and fish meal. Assuming the insect meal, hatchery by-product meal and fish meal were to be included in the concentrate at a ratio of 1:1:2. Determine the percentage of each feedstuff in the concentrate.

Data Supplied

Concentrate: CP = 45%

ME = 3,500kCalkg^{-1}

Feed items: CM and IM:HBM:FM (= 1:1:2)

Solution

A. Pearson's Square

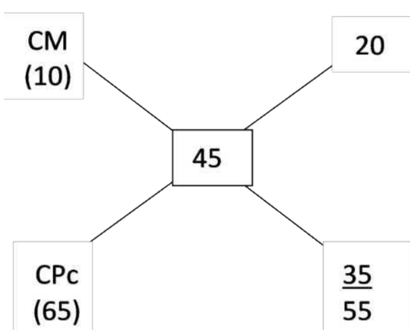
The collective protein content (CPc) of IM, HBM & FM = ?

IM = ¼ x 60 = 15.0

HBM = ¼ x 60 = 15.0

FM = 2/4 x 70 = 35.0

Collective CPc = 65.0



% CM = 20/55 x 100%

= 36.4%

% C = 35/55 x 100%

C = 63.6%

C = IM, HBM & FM

IM = ¼ x 63.6% = 15.9%

HBM = ¼ x 63.6% = 15.9%

FM = 2/4 x 63.6% = 31.8%

So,

Feedstuff	CM	IM	HBM	FM
% inclusion	36.4	15.9	15.9	31.8

To Cross Check

Feedstuffs	%	Content CP (%)	Contributed CP (%)
CM	36.4	10	3.64
IM	15.9	60	9.54
HEM	15.9	60	9.54
FM	31.8	70	22.26
Total	**100.0**		**44.98**

B. Quadratic Equation

The question may be solved using quadratic equation, as outlined below.

Collective CP (CPc) of C (IM, HBM & FM) = 65% (as above)

Collective ME (MEc) of IM, HBM & FM

IM = ¼ x 4,000 = 1,000kCal kg^{-1}

HBM = ¼ x 5,000 = 1,250kCal kg^{-1}

FM = 2/4 x 2,800 = 1,400kCal kg^{-1}

Total (MEc) = 3,650kCal kg^{-1}

If,

a represents the proportion of CM

b represent the proportion of C

(MEcm x a) + (MEc x b) = ME of (CM + C) …. equation (i)

(CPcm x a) + (CPc x b) = CP of (CM + C) ….. equation (ii)

(Note CM + C = concentrate)

Since,

MEcm = 3400 & CPcm = 10

MEc = 3650 & CPc = 65

ME (CM + C) = 3500 & CP (CM + C) = 45

Substitute the above values in equations (i) and (ii)

3400a + 3650b = 3500 ... (i)

10a + 65b = 45 ... (ii)

Using elimination method, multiply equation (i) by 1 and equation (ii) by 340, and subtract equation 1 from equation 2 to eliminate a.

3400a + 3650b = 3500 --- (i) (x -1)

3400a + 22100b = 15300 --- (ii)

- - - - + 18450b = 11800

b = 11800 / 18450

b ≈ 0.64 = proportion of C

Solve for a by substituting the value of b in equation (ii)

10a + 65b = 45 - - - (i)

10a + 65 (0.64) = 45

10a + 41.6 = 45

10a = 45 – 41.6 = 3.4

a = 0.34 = 34% (= proportion of CM)

Therefore, % proportion of IM, HBM & FM will be

IM = ¼ x 64% = 16%

HBM = ¼ x 64% = 16%

FM = 2/4 x 64% = 32%

So,

Ingredient	CM	IM	HBM	FM
Feed content	34%	16%	16%	32%

To Cross Check

Feedstuffs	**%**	**CP (%)**	**ME (kCal kg^{-1})**	**C.CP (%)**	**C.ME (kCal kg^{-1})**
CM	34	10	3400	3.4	1156
IM	16	60	4000	9.6	640
HEM	16	60	5000	9.6	800
FM	32	70	2800	22.4	896
Total	**98.0**			**45.0**	**3,492**

Case 3.3

A catfish farmer with access to cheap broken rice waste from a nearby rice mill industry and cultured duckweed, wishes to formulate a feed concentrate of 40% CP and 2900kCal kg^{-1} for his 4-month-old fish. If the feed materials to be used in the formulation are corn meal, fish meal, soybean meal (20%), rice (waste) meal and duckweed meal (10%), calculate the proportion of mixture of the feed ingredients, assuming corn meal and rice meal are to be included at a ratio of 1:1 in the diet.

Data Supplied

SM = 20%

DW = 10%

Other ingredients are CM: RM = 1:1, and FM

Concentrate (C) = 40% CP and 2900kCal kg^{-1}

Solution

A. Pearson's Square

20% SM will contribute 20/100 x 44% CP = 8.8% CP

10% DW will contribute 10/100 x 39% CP = 3.9% CP

= 12.7% CP

Thus,

CM, RM & FM will contribute (40 - 12.7) = 27.3% CP

% Content of CM, RM and FM in concentrate (C)

= 100 – (SM + DW)

= 100 – (20 + 10) = 70%

Thus,

CM, RM & FM = 70% feed content

= 27.3% CP

Upgrade the % of CM, RM & FM (=70%) to 100% to derive an equivalent %CP, for easy calculation.

Hence,

100% CP = 27.3 / 70%

= 39% CP

[Note that CM:RM = 1:1]

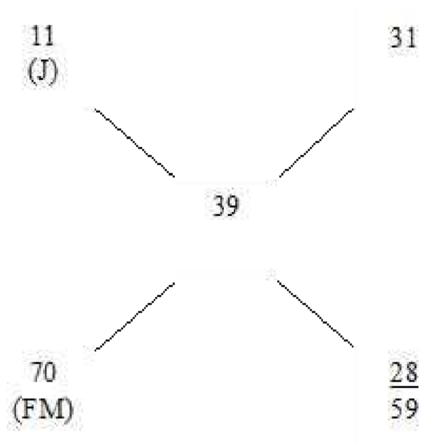
The joint (J) % CP contribution of each will be

CM = ½ x 10% = 5% CP

RM = ½ x 12% = 6% CP

J (CM + RM) = 11%CP

Apply the square,



J = 31/59 of (CM, RM & FM)

J = 31/59 x 70%

J = 36.8% (for CM + RM)

CM: RM = 1:1

CM = ½ x 36.8% =18.4%

RM = ½ x 36.8% = 18.4%

FM = 28/59 of (CM, RM & FM)

FM = 28/59 x 70% = 33.2%

OR

% FM = % (CM + RM + FM) - % (CM + RM)

= 70% - 36.8% = 33.2%

Thus, the concentrate formulation should contain:

CM	RM	DW	SM	FM
18.4%	18.4%	10%	20%	33.2%

To Cross Check

Feedstuff	CM	RM	DW	SM	FM	**Total**
% Content	18.4	18.4	10	20	33.2	**100.0**
CP (%)	10	12	39	44	70	
C.CP	1.840	2.208	3.900	8.800	23. 240	**39.988**

B. Quadratic Equation

20% SM will contribute 8.8% CP (as previously shown).

MEsm = 20/100 x 2700

= 540kCal kg^{-1}

10% DW will contribute 3.9% CP (as previously shown)

MEdw = 10/100 x 2450

= 245kCal kg^{-1}

CM, RM and FM will contribute,

CP (CM, RM, FM) = 40 – (8.8 + 3.9)

CP (CM, RM, FM) = 27.3% CP (as previously shown)

ME (CM, RM, FM) = 2900 – (540 + 245)

= 2900 – 785

= 2115kCal kg^{-1}

% Content of CM, RM & FM = 100 – (20 + 10)

CM, RM & FM = 70% content

To upgrade the variables to 100%,

CP (CM, RM, FM) = 27.3 / 70%

= 27.3 / 0.7

= 39% CP

ME (CM, RM, FM) = 2115 / 70%

= 2115 / 0.7

≈ 3020 kCal kg^{-1}

[Note that CM: RM = 1:1]

The joint (J) CP and ME contribution of CM and RM will be:

CPj = CPcm + CPrm

= (½ x 10%) + (½ x 12%)

CPj = (5 + 6)%

CPj = 11% CP

MEj = MEcm + MErm

= (½ x 3400) + (½ x 3200)

MEj = 1700 + 1600

= 3300kCal kg^{-1}

ME_{FM} = 2800kCal kg^{-1} and CPfm = 70% CP (given)

If,

a represents the proportion of J (i.e. CM + RM)

b represents the proportion of FM

(CP_J x a) + (CP_{FM} x b) = CP (J + FM) [= CP (CM, RM, FM)] . . . (i)

(ME_J x a) + (ME_{FM} x b) = ME (J + FM) [= ME (CM, RM, FM)] . . (ii)

Substitute the values in both equations (i) and (ii),

11a + 70b = 39 - - - (i)

3300a + 2800b = 3020 - - - (ii)

To eliminate a,

multiply equation (i) by 300 and equation (ii) by 1, and subtract

3300a + 21000b = 11700 . . . . (i)

(-) 3300a + 2800b = 3020 . . . . (ii)

- - - - + 18200b = 8680

b =8680 / 18200

≈ 0.477

Substitute the value of b in equation (i) to solve for a

11a + 70 (0.477) = 39

11a = 39 – 33.39 = 5.61

a = 5.61 / 11 = 0.51

a is the proportion of J = 0.51

b is the proportion of FM = 0.477

Since J + FM = 70% of 100% concentrate formulation

J = 0.51 x 70% = 35.7%

FM = 0.477 x 70%

= 33.39% (≈ 33.4%)

J = CM + RM = 35.7%

(Remember, CM: RM = 1:1)

CM = ½ x 35.7% = 17.85%

RM = ½ x 35.7% = 17.85%

Thus, the concentrate formulation should contain:

CM	RM	DW	SM	FM
17.85%	17.85%	10%	20%	33.4%

To Cross Check

Feedstuff	CM	RM	DW	SM	FM	**Total**
% Content	17.85	17.85	10	20	33.4	**99.1**
CP (%)	10	12	39	44	70	
ME	3400	3200	2450	2700	2800	
C.CP	1.785	2.142	3.900	8.800	23.380	**45.000**
C ME	606.9	571.2	245.0	540.0	935.2	**2,898.3**

Harder Mensuration

Harder mensuration is a complex but simple algebra. An easy example involving the use of harder mensuration will be given for better understanding.

Assumptions

Feedstuff	**Corn meal (CM)**	**Blood meal (BM)**	**Fish meal (FM)**
Protein, CP (%)	10	70	70
Energy, ME (kCal kg^{-1})	3400	3000	2800
Ether Extract, E (%)	4.0	4.5	1.0

Case 3.4

A farmer wishes to formulate a concentrate for his 3 weeks old catfish, using corn meal, fish meal and an easy accessed, cheap blood meal.

What proportion of each feed item will be required in making 100kg of concentrate of 50% CP, 3000kCal kg^{-1} and 4% ether extract (oil)?

Data Supplied

CP_{CM} = 10%; ME_{CM} = 3400 $kCalkg^{-1}$; E_{CM} = 4%

CP_{FM} = 70%; ME_{FM} = 2800 $kCalkg^{-1}$; E_{FM} = 4.5%

CP_{BM} = 70%; ME_{BM} = 3000 $kCalkg^{-1}$; E_{BM} = 1%

CP_{C} = 50%; ME_{C} = 3000 $kCalkg^{-1}$; E_{C} = 4%

(Note: C = concentrate)

Solution

If, a represents the proportion of CM in C

b represents the proportion of FM in C

d represents the proportion of BM in C

Then,

(CPcm x a) + (CPfm x b) + (CPbm x d) = CPc … equation (i)

(Ecm x a) + (Efm x b) + (Ebm x d) = Ec… equation (ii)

(MEcm x a) + (MEfm x b) + (MEbm x d) = MEc…equation (iii)

Introduce given data into the equations.

10a + 70b + 70d = 50 --- (i)

4a + 4.5b + 1d = 4 --- (ii)

3400a + 2800b + 3000d = 3000 --- (iii)

(Divide each equation by its highest common factor to limit the figures that we will be working with)

Divide equations (i) by 10, (ii) by 0.5 & (iii) by 200

a + 7b + 7d = 5 …. (i)

8a + 9b + 2d = 8 …(ii)

17a + 14b + 15d = 15 ….(iii)

Pair 2 sets of equations to eliminate a – (i) & (ii); (i) & (iii)

[Equations (i) & (ii)]

(x8) a + 7b + 7d = 5…….(i)

(1x) 8a + 9b + 2d = 8 …..(ii)

8a + 56b + 56d = 40

8a + 9b + 2d = 8 (x -1)

- - - + 47b + 54d = 32.…. (iv)

[Equations (i) & (iii)]

(x17) a + 7b + 7d = 5 ..…. (i)

(x1) 17a + 14b + 15d = 15 …… iii)

17a + 119b + 119d = 85

17a + 14b + 15d = 15

- - - + 105b + 104d = 70 …… v)

Pair equations (iv) and (v), and eliminate d

(x104) 47b + 54d = 32 …. (iv)

(x54) 105b + 104d = 70 …. (v)

4888b + 5616d = 3328 (x -1)

5670b + 5616d = 3780

782b + - - - - - = 452

b = 452 / 782 = 0.578

Substitute the value of b in equation (v)

105b + 104d = 70

105 (0.578) + 104d = 70

60.69 + 104d = 70

104d = 70 – 60.69

104d = 9.31

d = 9.31 / 104

= 0.0895

Substitute both b and d in equation (i) to solve for a

a + 7b + 7d = 5 …… (i)

a + 7 (0.578) + 7 (0.0895) = 5

a + 4.046 + 0.6265 = 5

a = 5 – (4.046 + 0.6265)

a = 5 – 4.6725

a = 0.3275

So, the proportion of CM = a x 100%

= 0.3275 x 100%

= 32.75%

FM = b x 100%

= 0.578 x 100% = 57.8%

BM = d x 100%

= 0.895 x 100% = 8.95%

So,

CM	FM	BM
32.8%	57.8%	9.0%

To Cross Check

Feedstuff	CM	BM	FM	Total
% Content	32.8	9.0	57.8	**99.6**
CP (%)	10	70	70	
ME	3400	3000	2800	
E (%)	4.0	1.0	4.5	
C.CP	3.28	6.30	40.46	**50.04**
C ME	1,115.2	270.0	1,618.4	**3,003.6**
C.E	1.312	0.090	2.601	**4.003**

C.E = Contributed Ether (%)

Finished Feed Economics

Cultured fish may be economically raised on finished feed that is well formulated from a combination of some conventional and unconventional feedstuffs. Unconventional feedstuffs to be considered must be locally available, easily produced or accessible in commercial quantities, relatively cheap, and is digestible and palatable to cultured fish. Such processed feedstuffs may then be used to replace the expensive (or scarce) conventional feed items e.g. fishmeal, soybean meal and cornmeal. The production / purchasing cost per kilogramme of the substituent should be cheaper than that of the material to be substituted for, bearing in mind the nutrient values of the two feedstuff s. If the nutrient disparity is wide, then the overall production cost per kilogramme of the resultant finished feed (of similar quality) should be cheaper than what previously obtained before the replacement.

A partial or complete replacement of these expensive feed items with cheaper, viable products / by -products of similar nutrient quality should bring some relief to farmers. Some of such viable substitutes for fishmeal are insect meal, tadpole meal, gluten meal, algae and worm meal, while groundnut cake, duckweed, brewery's yeast and canola meal may possibly replace soybean meal. Insects (e.g. housefly, blackfly and reproductive termites) may be cropped with insect harvester and processed into insect meal, while groundnut cake and brewery's yeast may be obtained from relevant local processing factories. Taking advantage of such unconventional feed materials will, in addition to the financial reward, encourage more agro -investors, invariably promote food animal security and empower more people.

For better understanding, some case studies will be addressed, assuming the quality of these feedstuffs is up to standard.

<u>Case 3.5</u>

An aquafeed producer, with a farm capacity of about 20 metric tonnes (20,000kg) of fish biomass per production cycle, had an average feed conversion rate (FCR) of 1.3 when using a feed formulation with 30% soybean meal (SM) and 15% fishmeal (FM).If he desires to replace 40% of FM with insect meal (IM) and 30% of SM substituted with duckweed (DW), then the economic value of the substitution is as shown below.

Assumption

The nutrient quality of the new and substituted finished feedsis similar.

Data Supplied

Total production = 20,000kg of fish / production cycle

FCR = 1.3:1

FM = 15% (40% to be replaced with IM)

SM = 30% (30% to be replaced with DW)

Solution

IM in feed = 40% of fishmeal content

= 40% of 15%

= 6% of feed

DW in feed = 30% of soybean meal content

= 30% of 30%

= 9% of feed

Feedstuff	% Replaced (N)	Unit Price (N)	Cost
FM	6	1,200	7,200
SM	9	240	2,160
	15%		**N9,360**

Amount of feed required for production = Fish biomass x FCR

= 20,000 x 1.3

= 26,000kg of feed

Amount of feed replaced = 15% of feed

= 0.15 x 26,000

= 3,900kg of feed

If N9,360 worth of feed is replaced in 100kg of feed

(assuming a worth of feed is replaced in 3,900kg of feed)

a = (9,360 x 3,900) / 100

= N365,040

Thus, a total of N365,040 worth of FM & SM is replaced.

<u>Cost of Production per Cycle</u>

Let us assume that:

- the harvesting cum processing of IM & DW is carried out by two of the regular workers twice weekly, at an extra cost of N10,000 per month per worker.
- the fish were produced within 5 months from fingerlings.
- the fish sales from the pond is used in its maintenance.

Workers earning per production = N10,000 x 2 x 5 months

= N100,000

Items	Cost
Insect harvester	30,000
Labour (2)	100,000
Feed analysis	20,000
Sub-Total	150,000
Miscellaneous(10%)	15,000
Total	**N165,000**

Saved cost = difference between cost of feed materials substituted and cost of producing feed replacement

= N (365,040 – 165,000)

= N200,040:00

The amount of money save per production i s estimated at N200,040 (from every N365,040 worth of soybean meal and fishmeal replaced).

Case 3.6

A toll-milling fish farmer located close to a groundnut processing plant and an abattoir, intends to increase his profit margin by utilizing some of the pr ocessed by-products (wastes) within his reach. If he intends substituting 50% of soybean meal (SM) and 25% of fishmeal (FM) content in his fish feed with groundnut cake (GNC) and blood meal (BM) respectively, how much will he be saving if his production pe r annual is 60 tonnes of fish, and a formulated feed of 1.3 FCR is used, of which SM content is 50% and fishmeal is 20%?

Let's assume that the same FCR is achieved and the prices of feed materials given below are true.

Feed Item	SM	FM	GNC	BM
Unit cost (N/kg)	380	1,860	300	400

Data Supplied

Total production / year = 60 tonnes (i.e. 60,000kg) of fish

FCR = 1.3:1

Initial SM content = 50%

50% of SM content is replaced with GNC

GNC = 50% of 50% (SM)

[50% = 50 / 100 = 0.5]

= 0.5 x 50% = 25% of feed

New SM content in feed = (50 – 25)%

= 25% of feed

Initial FM content = 20%

25% of FM content is replaced with BM

BM = 25% of 20 (FM) = 5% of feed

New FM content in feed = (20– 5)% = 15% of feed

Solution

Feedstuff	**% Replaced**	**Unit Price/kg**	**Cost**	**Cost Variance**
SM	25	380	9,500	
GNC	25	300	7,500	2,000
FM	5	1,860	9,300	
BM	5	400	2,000	7,300
Total	(30% substituted)			**9,300**

Cost difference = N9,300 for 30% feed constituent replacement

Amount of feed required per annum = 60,000 x 1.3

= 78,000kg of feed

Amount of feed replaced = 30% replacement x quantity of feed

= 30% x 78,000kg

= 0.3 x 78,000kg

= 23,400kg of feed

If N9,300 profit is made in every 100kg of feed

a profit will be made in 23,400kg of feed

a = (23,400 x 9,300) / 100

= N2,176,200:00

Thus, a profit of **N2,176,200 per annum** is made by replacing 25% SM & 5% FM

<u>*Note*</u>

- *This is only true if the nutrient and quality of the finished feeds (i.e. the prior and substituted feeds) are similar. Deficiencies in such substitute feed must be added as additives, thus incurring additional cost.*
- *The palatability of the resultant feed must be encouraging, otherwise the rate of feed consumption might be reduced (whether richer in nutrient or not), thus being anti-productive.*

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Chapter Four

Feed Processing and Production

Processing of Feedstuffs / Feeds

The drive to intensively produce large quantity of fish at an affordable rate and within a short period, to economically meet both local and global animal protein demand, has led to the use of various modified structures, hi -tech breeding and management, and the use of diverse feed materials to manage such productions. The continuous use of some cheap organic products and wastes (now termed by-products) such as poultry and hatchery by-products in fish management (without adequate processing) may produce some deleterious effects on cultured fish and occasionally on the end consumer (man). The stress induced on farmed fish, as a result of the high intensity of farming, may be worsened by the unmonitored, indiscriminate use of such unprocessed or poorly processed materials for pond fertilization and or as fish food. The final result is the horrible sight of various kinds of ailments that could have been prevented. Adequate processing of feed materials and the formulated finished feed are thus considered a **must** to maintain minimal level of water pollution and potential pathogens, and to increase nutrient availability. Such processing is expected to enhance fish health, minimizes loss of nutrient to immune building and promotes productivity.

Feed processing is the modifying of the nature of feedstuff / feed via physical or chemical means, in other to enhance feed quality, stability, durability and or utilization. It is us ually recommended for the under listed reasons.

- To improve nutrient availability, feed conversion rate and fish performance.
- To improve palatability and or presentation of the feed.
- To remove or minimize the risk of having pathogenic contaminants.
- To ensure feed stability in water, thus minimizing water pollution and feed loss.
- To make the incorporation of some unconventional feed materials into formulated fish diets feasible and healthy. This may include detoxifying anti-nutrient factors in such feedstuffs.
- To promote the shell-life of feed materials / finished feed.

Feed ingredients may be solitarily processed and stored for future / commercial use, or are collectively processed during feed production. Processing such feedstuffs may involve the use of modern machines and techniques. These techniques explore the use of heat-treatment ("dry" and "wet" heat application) and chemical application. Other considerations include functional feed additives and feed irradiation (yet to be explored in aquafeed production). These means of processing are often combined in such a way that healthy, quality aquafeed product ensues.

Heat-Treatment

This principle is currently being applied in aquafeed processing worldwide. It involves the use of heat to improve the quality of fee dstuffs / feed. The treatment may be in the form of "dry" and "wet" heat application, or a combination. The desired effects of heat treatment is further enhanced with pressure application ÷ to destroy feed pathogens, improve the availability of some bound nutrients, feed palatability, feed stability in water and to denature anti-nutrients. However, the technique is not without few set-backs – denaturing thermo-labile feed constituents (thermo-labile vitamins) and producing non-digestible elements, though its benefits outweigh the defects. The "cooking" under high pressure (baro-thermal conditioning) is effectively utilized in the operation of Universal Pellet Cookers, Steam Pelletizers and Extruders — see pressure pelleting and extrusion.

Chemical Application

Some chemicals with food digestive properties may be applied to increase feed digestibility / nutrient availability. An example is the use of potash, sulphide or pepsin in processing feather meal. Some bio-chemical processing may be achieved by incorporating useful bacteria / yeasts (probiotics) or digestive enzymes. Fish larval diet is often formulated with the addition of such digestive enzymes (e.g. protease enriched diet) to aid feed digestibility and utilization – refer to chapter 2 on fish fry nutrition.

Irradiation

Another feed processing method is the irradiation technique. The technique, although yet to be explored in aquafeed processing, is effective in feed (and feed material) heating, sterilization and shelf-life prolongation.

Functional Feed Additives

Feed additives, as earlier discussed in chapter 4, are substances that are included in finished feed, in minute quantity, to improve the quality of the feed, fish health and or minimize the resultant waste impact on their environment. Thus, with reference to feed processing, certainfeed additives – digestive enzymes (e.g. amylase, protease, lipase and xylanase), chemicals and pre- / probiotics – may be incorporated into fish diets in other to aid feed digestion and utilization, thereby promoting fish growth.

Examples of functional feed additives include probiotics, prebiotics, bacteria compounds, herbal extracts / products (e.g. ginger and garlic – acting as immune boosters) , animal extracts, some polysaccharides and attractants.

Processing of Some Unconventional Feed Items

Some cheaply sourced, unconventional feed items may be gainfullyenlisted and utilized in quality fish diet production. However, such feed materials must be adequately processed and kept until the needed quantity is realized for production. Where feasible, they should be extruded. In the absence of such modern processing technolog y, the suggested methods may be considered in processing the designated feedstuffs.

Hatchery / poultry by-products or wastes

(Unhatched eggs / Dead chicks / Poultry bird guts / offal)

- Where necessary, chop sizeable meat into bits.
- Rinse in changes of clean water to reduce dirt.
- Boil in salted water or steam the feedstuff for about 20 to 30 minutes.

- Drain off excess fluid.
- Properly dry up the stuff using a low heat feed drier (e.g. solar, electric or fuelled feed driers) to at least 10% moisture content – for proper storage. Where such a drier is unavailable or unaffordable, the farmer may hygienically sundry the material. It should be done in a dust free, netted site to prevent contamination.
- Mill into powdered form.
- Determine the nutrient content, package and store in cool dry place until it is needed for production.

Note

The calcium content of hatchery egg may be regulated by removing the shell or the calcium content considered when formulating the feed).

Bred earthworms / tadpoles / insects

- Harvest the animal, chop into bits (where feasible) and rinse
- Immerse into hot, salted (high concentration) water for about 20-30 minutes – to minimize microbial load
- Rinse in a clean change of water
- Drain off excess fluid
- Properly dry the feedstuff under low (uniform) heat in a feed drier or (alternatively) sundry under hygienic condition.
- Mill into powdered form.
- Package and store for future production.

Note

- *Flying insects, such as flying reproductive termites and farm flies, may be harvested in substantial quantity with "**insect-harvester**" overnight (plate 4.1).*

- *Fish attractant(s) may be added to increase palatability.*
- *Spices such as salt, ginger, garlic and turmeric may be added to the final package to increase the shelf-life and or enhance palatability.*

Plate 4.1. Insect-Harvester

Plate 4.2. Cultured Mosquito Larvae

Plate 4.3. Fish Drier

Just before production, the required quantities of the selected fe ed ingredients should be assembled, and the following certified.

- All incoming feed items should be assessed and the right quality and quantity ensured. Sub-standard feedstuffs should be rejected, even if cheap.
- Factory workers' and production hygiene should be ensured.

Modern Fish Diet Production

An agro-investor with interest in aquafeed production may tactically approach the business by considering some essential logistics that should ensure the viability of the project. This becomes more relevant when the produced feed is solely for commercial purpose. Factors to consider are:

1. Site logistics

- The best suited location for the project should be considered with factors such as easy accessibility to feed material suppliers, targeted markets, transport logistics (materials, finished feed, workers…), equipment maintenance, ease and cost of securing viable workers … and competitors,.

2. Raw materials

- Which feed materials are available locally? What is the comparative value (especially the quality, price and availability) of each of suc h items in with imported ones?
- Is it cheaper / worthwhile buying the feed materials or should an important / expensive, scarce feed material (e.g. soybean meal and corn gluten) be produced for easy accessibility and cost-effectiveness?

3. Production details

- What type / group of fish are the feed for?
- What feed formulation to use – considering feed economics, quality and palatability?
- What quality and quantity of feed to produce?
- What feed additives (such as attractants) should b e included to boost product marketability?

- What list of production equipment is needed?
- What number of experienced and casual workers should be sourced for?

Once the above has been taken care of and the feed well formulated, the selected quality feed ingredients should then be assembled for production.

In producing a well-formulated fish diet, other factors such as fish species, age group / size, feeding habit (herbivore / carnivore / omnivore) and environment must be put into consideration. Commercially pr oduced fish concentrates are commonly sold as granulated, flaked or capsulated feeds that may be sinking, slow-sinking or floating in water. The feeds come in various sizes, as cultured fish are best fed on feeds of about 20% of their mouth size.

Commercial aquafeed production is basically by extrusion or pressure pelleting. The feedstuffs are pre -milled with a milling machine into fine particles, and thoroughly mixed in a homogenizer (mixer). Homogenized fluid or semi-solid feedstuffs such as milk, egg and tomato puree may be added to the mixture in the homogenizer to produce a mash. The thoroughly mixed mash may then be fed to a conditioner, or directlytransferred into an extruder / pelletizer, depending on the moisture content.

Feed Extrusion

Present day extruders may be classified as either single-screw extruders or twin-screw extruders. Extruders are basically screw pumps within which feed ingredients are subjected to thorough "cooking" under high temperature and pressure in an extruder barrel, to prod uce the sheared end product (finished feed) from the die. This method of feed processing, using an extruder, is termed feed extrusion. The process may or may not require that the mixed feed / mash be pre-conditioned in a conditioner before it enters the extruder barrel i.e. ‘wet’ or ‘dry’ extrusion.

Basically, an extruder barrel consists of the barrel heads, screws, shearlocks (flow restrictors) and a die. The barrel heads may be jacketed for steam or cooling water to manage the cooking process in the barrel. Its wall is designed to maintain the generated pressure and resist the dough-like feed from sticking to the screws as they rotate.

The rotating screws generate the heat (mechanical energy) used in the cooking process, help in pressure building and distribution, and mixing of the mash into dough form. Shearlocks control the feed retention time, thus managing the pressure, the period of cooking within the barrel and the final product quality. The die aperture design controls the shape and size of the final product.

The extruder barrel may be sectioned into the feed zone, transition zone and metering (final cooking) zone. Each section is furnished with a set of screws, with or without shearlocks, for proper functioning. The feed zone serves as the entry point for feed mash into the extruder barrel. With the aid of the screws and shearlocks of the barrel transition and metering zones, the received mash is compressed, expanded, degassed and cooked (under high temperature and pressure) into amorphous, continuous dough. The cooking is facilitated by the pressured steam from the steam injector and the mechanical heat generated by the screws, with the continuous mixing of the mixture. The highest degree of cooking takes place in the final cooking zone. Moisture regulator may be installed in the barrel to control the moisture level.

This cooking under great pressure and temperature is of enormous importance in improving feed gelatinization for proper binding (feed stability) and floating feed production. It also enhances nutrient digestibility, feed palatability, denatures anti-nutritional factors such as trypsin inhibitors and gossypol, and inactivates most microbial agents.

As the dough is forced out through the extruder die, it assumes a shape and size similar to the design of the die aperture. The length of the final product is regulated by the die shear rate. The feed is then heat dried and cooled with a cooling drier or simply dried with a dry-low-heat blowing device to the desired moisture content (preferably less than 10%). Heat sensitive amino acids, lipo-soluble vitamins, phytase, enzymes and other additives are often applied using liquid fat that is sprayed as feed coating, after extrusion. The obtained dried, hydrophobic feed strands may then be crushed by crumble rollers and sieved through screens to produce the desired particulate size for fish seedlings. Samples of the final product should be tested for feed quality to ascertain the final nutrient quality, microbial titre and moisture content. The feed is then bagged in a well labelled, ideal packaging material and stored in a dried, cool place till needed.
(See feed production chart after pressure pelleting).

The resultant feed is well bound and water stable (i.e. floats on water). Floating feed is often preferred to other feed types (sinking and slow-sinking feeds) because it enables farmers observe the rigour at which their fish feeds ("feeding frenzy"), and so determines when the fish are satisfied, as well as their growth performance. However, it is not suitable for bottom feeders such as prawns.

Pressure Pelleting

This was initially achieved by forcing moist feed mash through the barrel of a meat mincer or a manual / motor driven screw pump, and out through the apertures of its die. The screw of the barrel is either manually or mechanically driven to mix and move the mash towards the die. The pressure generated by the screw forces the mash through the die apertures to produce compressed feed strands that are sheared and dried to form feed pellets. There is no significant feed "cooking".

Later on, a series of steam pelletizers were manufactured to produce feed pellets under pressure and heat. The homogenized feed is fed into the barrel of the pelletizer and cooked by mechanically generated heat and injected steam to a temperature of about 70 to 85°C. Pellets produced are fairly stable (in water) and pathogen-free.

This method of feed processing has further been improved on lately. The mash is cooked under slightly elevated steam pressure at a temperature of about 100°c (or more) in the barrel of the pelletizer. The formed dough is forced through the apertures of a die to produce pellets from the sheared noodle-like output. The pellets are then dried, cooled and bagged for future use. This type of feed may float for a while and later slowly sinks in water, especially when the feed materials are carefully selected.

Today, virtually all the available feed processing machines employed in aquafeed industry function by means of heat treatment (wet and dry heating) under high pressure — extruders, pelletizers, universal pellet cookers, expanders, feed driers and so on — to produce wholesome feed for fish consumption. However, the extrusion technique may be preferred in handling highly contaminated materials that are b eing considered as feed ingredients e.g. hatchery by-products and abattoir by-products, because of the high processing temperature and pressure.

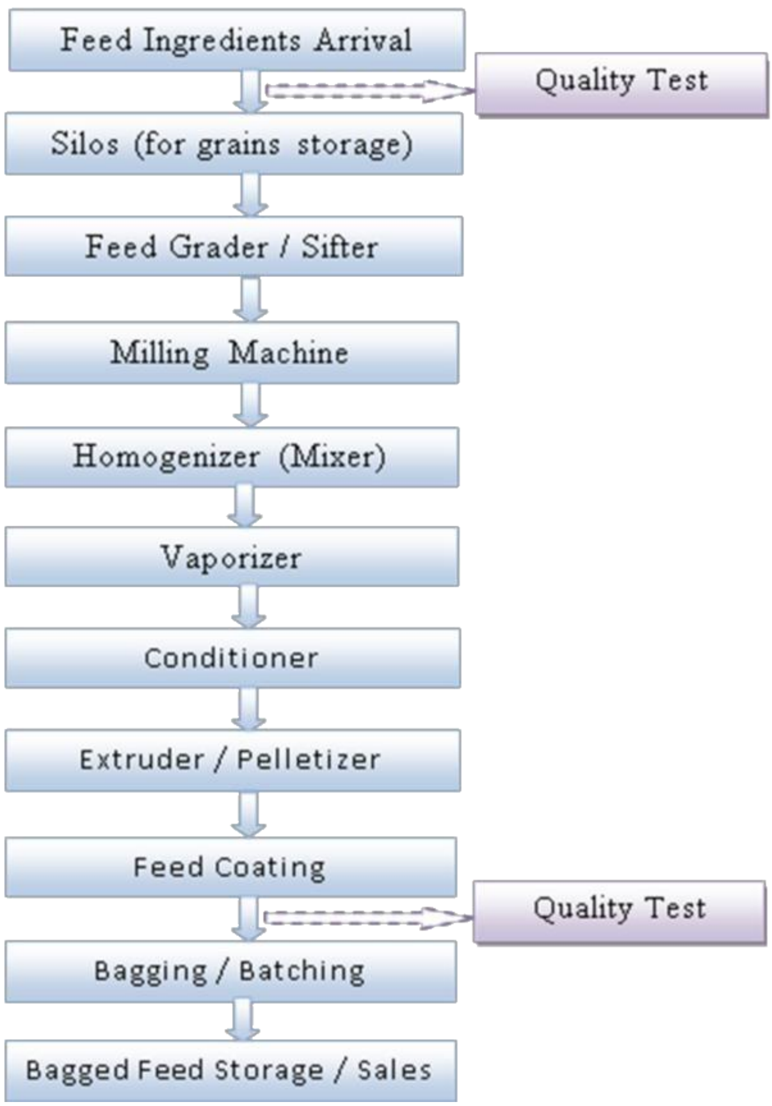

Figure 4.1. Feed Production Chart

Plate 4.4. Poorly pelletized feed

Plate 4.5. Extruded feed

__Plate 4.6. Product packaging__

__Plate 4.7. Product packaging__

Once the feed product is produced, the following details should be made.

1. Detailed record of each production should be kept – feed formula, time of production, batch data and distribution zones. T his is helpful in product traceability.
2. Laboratory test of each batch to certify its wholesomeness. This should include microbial details and feed values.

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Chapter Five

Fish Feed Quality Control

Introduction to Quality Control

Once the diet formulation has been determined, the next step is to find a good feed miller that will assemble all the necessary feed materials (including the required additives) to produce the expected quality feed bargained for.

Ideally, it is expected that aquafeed millers should ensure that quality feedstuffs are used in their industry to produce quality feeds, the opposite is sometimes encountered. In some sighted cases, poor quality corn was more than 20% of the corn supplied – containing crushed corn cobs, weevils, dirt and other wastes. This may arise due to factors such as:

- Miller's inability to distinguish between good and poor quality feed materials.
- Desire to increase their net profit by buying cheap products / poor graded feedstuffs.

- In an attempt to sell or produce fish feed at similar price to other buoyant competitors.

Feed quality control is thus aimed at ensuring that feed purchasers obtain the required feed quality bargained for i.e. free of toxins and other feed adulterations often seen in feedstuffs (for millers) or finished feeds (feed purchasers). To ensure that quality finished feed ensues, quality feed inspection should start from the very beginning of feed production- quality of the selected feed items.

Quality of Feed Items

The grade or quality of feed materials used in feed production is a major determinant of the final feed quality. Incoming grains and other feedstuffs brought into a feed-mill by dealers are expected to be physically examined for purity, texture and density by the quality control manager or trained management personnel, in order to maintain good standard of operation. The supplied bagged ingredients should be randomly sampled using an appropriate probe (e.g. spear probe for grains). The obtained s amples of each ingredient should be thoroughly mixed, the volume reduced and the residual examined for normal colouration, moisture, odour (for freshness), mouldy growth, weevils and impurities, with or without the aid of a hand lens. Where fine granules a nd powdered materials are involved (e.g. fish meal and lysine), feed microscope may be required to physically examine the quality of such items. Part of the mixed sample should be submitted for chemical quality control analysis, especially when in doubt ofthe examined feed quality. Parameters to be determined in the quality control laboratory should include moisture content, amino-acid profile / protein content, utilizable energy, lipid content, calcium, phosphorus, lysine and methionine contents. Feed ingredients that are predisposed to high levels of certain anti-nutrients need to be tested prior to use. Likewise, the digestibility of the selected feedstuffs (especially when using unconventional feed materials) is essential in ensuring the quality of the finished feed.

Poor quality feedstuffs may, in addition to not providing the expected nutrients, serve as possible carriers of harmful microbes / chemical's e.g. salmonella and mycotoxin contaminants. The sight of broken grains, dull looking or mouldy feedstuffs, rat faeces and the likes in bagged feed materials, is an indicator to the poor quality of feed materials supplied (see plate 5.1). In countries where there is no serious standard regulatory control unit (or its efficiency is limited), the quality of some finished fish feeds may be compromised through the use of such supplied inferior quality feed materials by unguarded feed millers.

Feed producers may checkmate this act by randomly obtaining samples from bagged feedstuffs (using appropriate feed probes) and examining them physically using "sensual tests" (sight, touch and smell senses), feed microscopy and carrying out laboratory feed quality tests. Some notable feed millers would actually pass supplied feedstuffs (e.g. grains) through series of purifying processes (such as sifting, blowing and de-stoning) and extrude to get quality end-products.

Table 5.1. Some impurities often found in adulterated feed items

Feed Items	Impurities
Corn	Chopped cobs, chaffs & stones
Soybean	Sand, stones & millet
Full-fat soy	Ground yellow corn
Groundnut cake	Cottonseed cake
Brewers dried grain	Sand & stones
Lysine	. Yam flour
Methionine	Cassava flour
Bone meal	Charcoal
Milled oyster shell	Beach sand

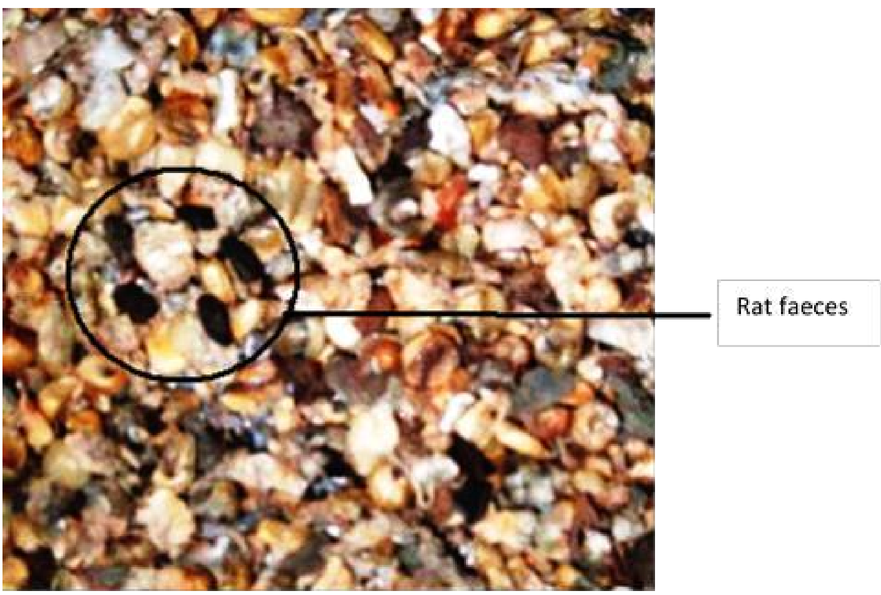

Plate 5.1. Impurities found in sampled corn

Feed Processing

Aquafeeds are often processed into pellets, flakes… or capsulated feeds for various reasons. The degree and method of "cooking" in a feed processor goes a long way in determining the final feed quality — nutrient content and availability, digestibility, feed stability, floatability, palatability, pathogen obliteration, anti-nutrient denaturing and so on. The heating effect of feed extrusion, for instance, is significant on some amino acids (e.g. lysine) and vitamins availability, although it ensures anti-nutrient denaturing, adequate feed binding and stability in water, feed floatability and feed sterility. For bottom feeders however, sinking feeds may be preferred.

Where the quality of the finished feed cannot be guaranteed due to lack of an appropriate processing equipment, it is safer and better to maintain your fish on an expensive, sustainable, commercial feed of high nutrient quality than to produce a cheaper feed of poor quality. The better the quality, the healthier the fish and the shorter the time of production. The method of feed processing is important, especially when producing fish diets from animal protein or other easily contaminated materials. To prevent the ugly site of (feed transmitted pathogenic) diseases, formulated feeds should be hygienically handed, and preferably extruded with an extruder (or steam pelletizer) under high temperature and pressure, or the finished feed irradiated.

Feed Presentation

Feed millers are expected to produce well blended, thoroughly mixed, quality fish diets. The quality of finished feed produced from a feedmill or those obtained from feed -sales outlets may be assessed by the manager / farmer by considering its physical appearance and odour, before sending the sample to a feed laboratory for further analysis.

Physical Appearance

Quality finished feeds may be ascertained by ensuring that the ingredients are well blended, thoroughly homogenized and hygienically pelletized or extruded. Samples of such finished diet (or feedstuff) should be taken, crushed, examined and the following questions answered.

- Is the feed dull looking or fresh in appearance?
- Are the feed crumbs similar and well homogenized?
- Is the feed stable in water?
- For how long can the feeds (if expanded) float in water?

The obtained respons e to these questions may give a lead to the type of quality feed expected.

Taking a critical look at some identified feed particles (e.g. corn and soy particles) with the aid of a feed microscope may be helpful — provided the feed is simply pelletized and not thoroughly " cooked" to gel. The personnel's eyes should be trained to identify feed particles of specific ingredient and compare them with known quality feedstuff particles. When suspecting that the feed is pirated, the quality of the sampled crumble (under microscope) may be compared to those obtained from the factory?

Odour

In a similar way, the freshness and scent of the feed may be used in quality assessment, based on experience. At times the scent of a particular feedstuff (e.g. fish meal) in a formulated diet or the peculiar scent of a finished feed may be picked on for the assessment. Fresh smelling feeds are often better fed on and of higher quality than their stale scented brand.

A combination of the visual and scent assessment should be the first-line feed assessment protocol before further laboratory assessment i.e. identifying the freshness of the feed.

Feed Storage

Feed materials / finished feeds are expected to be stored under cool hygienic conditions. The method and period of storage of feed materials and finished feed have a significant role to play in feed quality control. Feed items / products are expected to be stored at low moisture content in dry, cool sites. Such materials should preferably be lifted off the ground to avoid moisture absorption. Generally, the longer the length of time of storage of either the feedstuffs used or the produced concentrate, the lower the expected quality. Concentrates produced from quality feedstuffs are thus expected to be consumed within 1 to 3 months from the time of production. However, some hygienically processed and preserved diets do last much longer than the stipulated period, especially when extruded, properly stored and a moisture content of less than 10% is maintained. So, farmers should always endeavour to check for the date of manufacture of purchased finished feeds, expiration date and moisture content.

Microbes and Pests

The qualities of selected feedstuffs and the resulting finished feed are greatly affected by microbes and pests.For instance, the presence of weevils and moulds in a sampled bag of feedstuff (especially grains) is an indicator to the expected poor quality of such feedstuff, much more when such material is slowly consumed in production. Some ill-health feed contaminants, such as salmonella, E. coli, aspergillus and mycotoxins, have been periodically isolated from such poorly managed ingredients and finished feeds.

Microbial contaminants may affect the quality of feed ingredients / finished feed in diverse ways. Microbes may affect the odour and taste (palatability) of the feed, cause ca king, promote feed degradation – reduce the nutrient content, spoilage and produce harmful toxins, hence the need for feed producers to conduct regular feed laboratory analysis on supplied feedstuffs and their finished feed. For effectiveness, a functional feed laboratory unit is thus suggested for standard feedmills.

To avert such ugly scenario and ascertain the quality of feed product bargained for, farmers should periodically conduct comprehensive feed analysis, especially when changing to new feeds, in addition to thevital feed (production) details – manufacture date, batch details / expiration date.

A handy field technique is the "sensual tests". This techni que utilizes the sensory organs, using visual and olfactory senses, in analysing feed quality. The smell of the feed (for freshness), dusty nature, feed consistency, manufacture date, expiration date, storage condition (where purchased) and diminished feed acceptability to cultured fish are indicators to probable feed quality. Suspicious feeds, based on sensual tests, may then be transferred to a standard feed laboratory for confirmation. As a matter of fact, millers that use low graded feedstuffs and those with sub-standard quality fish diets should be avoided, even when offering relatively low prices.

With the current advancement in feed technology, bagged aquafeed may last up to a year without any significant decrease in quality. This is achievable by:

- Sampling incoming feed raw materials for quality control.
- The ingredients should be well pulverized and thoroughly mixed before extrusion. This ensures that the resulting feed is homogenous.
- Extruding finished feeds at high temperature and pressure to achieve feed stability and sterility.
- Lowering the moisture content of finished feed to less than 10% – to deactivate microbial and enzymatic activities.
- Hygienically handling and packaging finished feeds.
- Randomized feed quality control test on finished feed products.

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Chapter Six

Aquafeed Marketing and Traceability

Feed Product Marketing

Production of quality (feed)product without proper plansfor viable disposal strategies could be frustrating and sheer waste of time and resources. At times, rather than equipping the pocket with financial strength, it may result in huge debt. Thus, a wise agro-investor in commercial feed should plan to succeed by strategizing and installing needful machineries for viable feed product (and probable by-product) marketing, even before the commencement of production. He must be able to:

- Identify the target clients / market zones and the market size.
- Identify the feeds and feeding practice commonly adopted by (targeted) farmers, the practice defect(s) and how to take advantage of the situation.
- Understudy the existing aquafeeds within the target zones to improve on, thus enhancing the product market strength i.e. price-wise, quality-wise, presentation and fish response (using attractant and improving palatability).
- Identify and consider the strength of his would be competitors.

- Consider some marketing psychology that may be employed in pushing the commodity – this includes using the flagged benefits attached to the product (and packaging technique) in attracting would-be clients.
- Formulate a laudable marketing strategy – this may be achieved via the use of:
  - Sales agents – training and using vibrant marketers to encircle major marketers / players in the field.
  - Establish business relationship with organized fish farmers' communities.
  - Adverts – having an active website for regular update on the product; exploring viable livestock-based e-sites and social platforms; quality radio / TV jingles, and the likes.
  - Open a good customer-relation office or distribution outlet in each of the target locations for sales promotion and feedback on the product(s).
  - Organize free (online and on -site) seminars and farm services for notable clients.
  - Ensure product availability
  - Have wider product size range and "sister" feed product for larger catchment area e.g. protease enriched feed, medicated feed, probiotic fortified feed, and cheaper but good quality feed.

A comparative comprehensive analysis (and price list) of existing feed products, in addition to suggesting what the target farmers / clients want from a feed brand, should be prepared to address or give insight to the underlisted questions.

- Which fish feed brands are the first three (or five) preferred brands in my catchment areas and why?
- Can a similar quality feed product be produced at an affordable price?
- In what capacities can these branded fish feeds be improved i.e. what do they lack? Can I handle the challenge?
- Do I have the capital / facilities / technology to produce such quality feed? Am I able to employ capable hands that can producesuch branded quality feed?
- If I do not have the full requirements, what other means can be used in competing favourably with the leading brands OR at least have credible sales?
- At what price should I sell the feed? Is the tagged price competitive and sustainable? What is the marginal difference? Can the difference be justified?
- If already on sale, you may like to verify why some potential clients are not picking the feed product? What can be done to entice them?
- Can I recruit sales representatives to incre ase my coverage zone? Are there trustworthy independent marketers that will be willing to have such products? What other channels do l have as options?
- Is the time ripe for project expansion? In what capacity may I expand? Will I be able to manage the logistics if l expands?

Answers to these questions and more should go a long way in ensuring product continuity and outstanding business viability. So, a feed miller may decide to set -up a concise questioner, and with the aid of some young dedicated guys, obtain valuable information that should guide in his product marketing.

Feed Traceability System

Feed traceability will be limited to animal / fish feed in this content. As the word suggests, it is the ability to trace and harness pertinent information on processes associated with a feed product, starting from procurement of its raw materials to production, distribution and disposal i.e. obtaining needful information on a feed product for its tracking along its life cycle. Consequently, feed traceability helps in tracking specific feed product (or feed production batch) upstream or downstream the flow of production, processing and distribution phases to the precise location along its supply chain, which supports the feed product recall where need beIt thus involves all supply chain sectors of a branded feed such as feedstuff suppliers, feed producers, wholesalers, distributors and retailers.

For its successive implementation along the chain, feed traceability is often guided by regulations:

- Feed products / brands should be well-labelled and tagged to enhance its traceability.
- Each of the sector / player in the feed chain must keep traceable information of their direct business suppliers and customers i.e. traceable record of a step backward and that of a step forward in the feed chain.
- Feed retailers should keep traceable information of their suppliers, but not that of the end-consumers, except they re-supply the feed product.
- Such traceable record must be well harnessed and stored in worthwhile storage system(s) for safety and quick accessibility when the need arises.

Recommended best practices for individual company in the feed chain are:

- Ensure that your suppliers have good traceability systems installed.

- Ensure that your company has good traceability system that makes all transactions visible and traceable.
- Your company traceability system should be reviewed periodically.
- The time interval in keeping traceability information.

It is interesting to know that feed traceability provides some notable opportunities for producers and consumers alike.

Producers

- permits feed product / production batch recall, thus ensuring the maintenance of quality feed
- enhances operational competence
- improves value chain efficiency
- strengthens brand name and costumers' trust, thus promoting feed sales
- minimizes litigation cost / compensations
- saves time and money

End Users

- verify production date and details
- promotes the safety of feed product
- ensures animal health
- improves customer service / relations
- determine the source of a feed product when tracing upstream in the supply chain

Traceability Procedure

- The System – being able to trace feedstuffs and feed from the supplier to the supplied outlet (except the end-consumers).
- Tagging Feed Batches – this helps in ensuring good traceability and minimizing the amount of feed to be recalled if warranted.
- Traceability information – this includes
  - The business name of supplier and supplied feed outlet
  - Traceable address of the business
  - Description of transaction i.e. feed brand, type and size
  - Quantity bought and sold
  - Transaction date
- Record keeping — the above information must be well kept in an easily retrievable system on demand

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Chapter Seven

Aquafeed Production and Utilization Analysis

The fish feed industry is the integral component of aquaculture that is aimed at increasing productivity via the provision of acceptable quality fish diet, in other to meet the growing fish needs of mankind. Since a figure of 60 to 80% of the re-current production expenditure is assumed for feeding fish, in addition to the significant role of aquafeed in health related issues, it is expected that aquafeed related issues be taken serious. This involves sourcing for quality feed materials at reasonable prices; transporting the materials to the milling site; storing such materials under good condition; assembling them for production in the right proportion (based on formulation requirement) for healthy product manufacture, proper product assessment… and storage.

A standard fish feed industry is thus expected to have (at least) the following components installed.

Structural component

- Warehouse with adequate space for equipment and ease traffic flow; silos and or large space segments (or rooms) for feed materials and finished feed storage, and operations.
- Offices for personnel – factory manager, accountant and other administrative staffs.
- A waiting room

Equipment

- Milling machine (e.g. hammer -mill and vaporizer) with motor, and feed conveyor
- Homogenizer with motor and feed conveyor
- Conditioner
- Extruder or pelletizer machine
- Scales
- Feed quality assessment & microbiology equipment
- Equipment installation

Man-power

- Production manager
- Accountant
- Store record keeper
- Factory workers
- Sales representatives (optional)

Feed materials

This may be a combination of the common animal feedmill ingredients, locally available feedstuffs and necessary feed additives, depending on the fish need / specification. Such products may include cereal products / by-products e.g. cornmeal, corn-gluten meal, ricemeal, wheatmeal and soybean products (full -fat soy, soybean meal and soybean oil); cottonseed cake; sunflower meal; brewer yeast; groundnut cake; blood meal and fishmeal. Feed additives include di -calcium phosphate, bone meal, feed binder, salt, vitamins-electrolytes premixes, vitamin C, mycotoxin binder, liver tonic, digestibility enhancer, prebiotics, probiotics and clinoptiles. Other locally available, economic agro - products and industrial wastes of relevance such as broken rice (rice meal), biscuit waste , wheat noodles waste and poultry by -products / hatchery by-products, may be analysed and utilized in production.

Power and back-up device

- Electricity and power installation
- Power back-up (e.g. high voltage generator) and installation. Th is is optional, depending on the country's power stability.

Miscellaneous spending

- Materials transportation
- Power maintenance
- Equipment maintenance
- General (factory) maintenance
- Stationeries
- Other factory running cost etc.

Being able to attach a price tag to each of the above items (where possible) or rent value should help in drawing up a good feasibility plan on establishing a standard feed industry.

The laboratory section of a standard feed-mill unit, though often neglected, is of paramount importance in ensuring that the finished product (fish feed) is biologically safe and fit for consumption. The sector helps in identifying when and where a challenge ensues, the particular feed production batch affected, and in determining the necessary amendment befo re dispatching the product. This saves the feed producers a lot of fortune and protects the company's trade name / business.

For a self-producing fish company, the laboratory helps in ascertaining the quality of produced feed, as well as disease prevention / management in cultured fish. It is also helpful in determining the quality of supplied feed ingredients. With proper microbial sampling and quality assessment of finished feed, prevention of feed related diseases is made easy. It should be noted that what you feed your fish with will, to a large extent, determine the outcome of you produce. This means that healthy fish often ensues from a combination of sound fish seedling, quality (disease agent free) feed, good water management and facilities.

To start an aquafeed producing mill, certain question must be answered carefully.

- Why do I need a feedmill? Is it for commercial purpose or to minimize expenses incurred on finished feed? Is it economically reasonable to venture into such project at that moment?
- How long do l intend to run the business? Is there a future for it?

- What quality and sizes of fish feed am l planning to produce?
- How and where do I source the various raw and processed feed materials required for production?
- What is the financial implication of setting-up my dream feedmill? Can l afford it? What other sources of funds are available to be exploited? Can l manage the rate of returns?
- Who are my target clients – is it for personal farm use, large commercial farms, peasant farmers or all?
- What production capacity am I starting with? Can l expand if need be?
- Which locations can l successfully cover if l want to distribute my feed far and near?
- What marketing strategies are my contemporaries using? Can l do the same? Do l have a better marketing strategy to push the product(s) at reasonable price?

To address some of these issues, a few cases will be considered.

Case Study

Case 7.1

A fish farmer is considering investing the sum of ninety million naira in setting up a feedmill industry for his fishfarm. He desires to produce 80 tons of fish from purchased quality fingerlings every 4 months, using a high quality, self-produced fish feed B. If feed B is of similar quality to a previously used finished feed A, and a sum of N1,000,000 per production cycle (4 months) is projected as feedmill maintenance expenses.

a) How much will he be able to save per production cycle?

b) How long will it take to break-even on his dream investment?

c) Will you term such investment as being worthwhile if an annual interest rate of 10% is paid to the funding bank?

Finished Feed	**FCR**	**Weight (feed bag)**	**Price (N)**	**Production Frequency**
A	1.25	15kg	4,200	3
B	1.25	20kg	4,400	3

Data Supplied

Amount invested = N90 million

Quantity of fish / production cycle = 80 tons = 80,000 fish

Fish production frequency = every 4 months

= 3 batches per year

Feedmill maintenance bill / fish production batch = N1,000,000

Feed A: Unit price = 4,200 / 15

= N280 per kg of feed

Feed B: Unit price = 4,400 / 20

= N220 per kg of feed

Solution

a) Amount saved per batch production?

Cost of feed/ batch = FCR x change in fish biomass x unit cost of feed

Cost of feed A = 1.25 x 80,000 x 280

= N28,000,000

Cost of feed B = 1.25 x 80,000 x 220

= N22,000,000

Difference in cost of feed / production batch

= N (28,000,000 – 22,000,000)

= N6,000,000

Amount saved per production = gross savings per production – feedmill maintenance

= N (6,000,000 – 1,000,000)

= N5,000,000:00.

b) Time taken to recuperate invested money in feedmill?

No of production to cover mill cost

= 90,000,000 / 5,000,000 = 18

Since there are 3 production cycles in a year,

No of years required to recuperate investment on feedmill

= No of production / production frequency

= 18 ÷ 3 = 6 years

i.e. 6 years of investment

c) Assuming bank lending rate is 10%

Annual interest = 10% of capital

= 10% of 90,000,000

= N9,000,000

Annual gross profit = 3 x unit production profit

= 3 x 5,000,000 = N15,000,000

Profit (after Interest) = N (15,000,000 – 9,000,000)

Annual profit on feedmill = N6,000,000

Expected period to break-even = capital / profit

= 90,000,000 / 6,000,000

= 15 years

It shows that the farmer will need about 15 years to make up for the investment, outside the profit made when using finished feed A. The project may be worthwhile if he has a si gned contract that assures a regular supply for such a period of years; his product (fish) is in high demand and has a good future, or he goes commercial to increase his gain. It will be a long term investment.

Case 7.2

An investor in the aquafeed industry seeks to commercially produce a branded fish feed and make an annual return of 20% on his one hundred million naira bank assisted project that is expected to be paid back in 4 years with an interest rate of 10% per annum. If a running cost of seven hundred thousand naira is budgeted per month and his 20 staff workers that earn an average salary offorty thousand naira per month are saddled with the responsibility of running a 2-tonnes per hour production plant at 80% production capacity for 5 hours per day and 20 days in a month, at what:

a). selling price can he achieve the desired 20% profit target?

b). rate should he payback in other to clear his debt within the shortest possible period, assuming his product is sold at N7,000 per bag of feed?

Assumptions

- Each bag of feed is 20kg in weight
- An average of N300,000 is required per tonnage of feed ingredients purchased for feed production.

Data Supplied / Deduced

Feed = 20kg per bag

1 ton of feed ingredients = N300,000

Bank loan = N100,000,000

Loan payment plan = N100,000,000 capital to be paid back in 4 years

i.e. N100,000,000 / 4 = N25,000,000 to be paid yearly

Bank interest rate per annum = 10% of N100 million

= (10 x 100,000,000) / 100

= N10,000,000

Anticipated annual profit = 20% of N100 million

= (20 x 100,000,000) / 100

= N20,000,000

Machine production = 2 tonnes per hour

Production efficiency = 80%

Production period = 5 hours per day x 20 days per month x 12 months

= (5 x 20 x 12) hours per year

= 1,200 production hours per year

Factory running cost = N700,000 per month

= N (700,000 x 12) per year

= N8,400,000 per year

Workers' salary = average of N40,000 per month

= N40,000 x 12 months x 20 workers

= N9,600,000 per year

Solution

a). Feed price @ 20% profit margin = ?

Annual production = production efficiency (80%) x rate of production (2 tonnes per hour) x production hours

= 80% x 2,000kg per hour x 1,200 hours per year

= 1,920,000kg of aquafeed per year

No of bagged feed = 1,920,000kg / 20kg

= 96,000 bags of feed per annum

Assuming there is no loss of ingredients,

Annual cost on ingredients' purchase = quantity of feed produced (in tonnes) x average cost per tonnage

= 1,920,000kg of aquafeed per year (÷ 1,000) x N300,000

= N576,000,000 per annum

If the N100 million invested should be paid back in 4 years and the only source of income is from the feed sales, then:

Annual sales return = No of feed bags x price tag per bag, y - - - (i)

Annual sales = 20% (envisaged gain) + 10% (bank interest) + cost of ingredients + salary + loan payback + expenses - - - (ii)

Merge equations (i) & (ii),

No of feed bags x price tag per bag, y = 20% (gain) + 10% (interest) + cost of ingredients + salary + loan payback + expenses

96,000 x y = 20,000,000 + 10,000,000 + 576,000,000 + 9,600,000 + 25,000,000 + 8,400,000

96,000 y = 649,000,000

y = 649,000,000 / 96,000

y ≈ N6,760:42k

So, a 20% profit may be made if the feed is sold at an average price of N6,760:42k per bag of feed.

b). Loan payback rate within the shortest probable time = ?

Annual sales = No of feed bags x price tag per bag = 10% (bank interest) + cost of ingredients + salary + loan payback (z) + expenses

[Note: no 20% profit expected here – so excluded]

Substitute the values,

96,000 x 7,000 = 10,000,000 + 576,000,000 + 9,600,000 + z + 8,400,000

672,000,000 = 604,000,000 + z

z = 672,000,000 - 604,000,000

z = N68,000,000 (annually)

[This means that the investor may decide to payback (but not more than) N68,000,000 yearly, in addition to the 10% interest rate]

If he is paying quarterly (i.e. every 3 months),

= 68,000,000 / 4

= N17,000,000 quarterly loan servicing

Since N100,000,000 is the actual bank loan (outside the interest rate), Period of payment = N100,000,000 / N17,000,000

≈ 6 times

This implies that he will be paying the sum of N17,000,000 for six quarters (1½ y ears) in other to service the N100,000,000 bank loan, apart from the 10% interest rate.

Choice of Feed

Another issue plaguing farmers is that of being able to decide wisely on the choice of feed. They believe that using a particular brand of feed or feed formula a senior practising friend (or supposed successful farmer) is using on his farm should give about the best result. Actually, determining the choice of feed to adopt on one's farm should be based on parameters such as:

- Feed conversion rate (FCR) – the quantity of feed required to produce a kilogramme of fish.
- The number of (fish) production cycle obtainable with each feed brand.
- The moisture content.
- Feed palatability to the fish.
- Unit cost of the feed i.e. cost of 1kg of the feed.
- Stability in water – that is the rate at which the feed dissociation in water.

Case 7.3

A fish farmer was able to record an average profit of N250,000 per production cycle with feed A, but on trying another aquafeed B obtained a batch profit of N200,000. Assuming each batc h of fish production lasted 6 months when using feed A, and 4 months with feed B. Which of the feed is more economical?

Data Supplied

Annual Production Data

Feed	Batch Profit	Batch Period	Production Frequency
A	250,000	6 months	2
B	200,000	4 months	3

Solution

To resolve this challenge, the annual profit made when using each feed should be compared.

Annual profit on feed A = production batch p rofit x production frequency

Annual profit on feed A = N (250,000 x 2)

= N500,000:00

Annual profit on feed B = N (200,000 x 3)

= N600,000:00

Difference = N (600,000 – 500,000)

= N100,000:00

This suggests that feed B is more rewarding than feed A.

<u>Case 7.4</u>

A fish farmer, who has just identified three quality fish feeds within his farm locality, is faced with the ch allenge of determining the most cost-effective feed. Assuming he is planning on producing 10 tons of fish, which of the feeds (20kg per bag) will be advisable to use for production, if the parameters below are true of the enlisted feeds.

Feeds	**A**	**B**	**C**
Prices (N/20kg)	5,000	4,500	4,000
FCR	1.1	1.3	1.5

Solution

To resolve this challenge, the cost of feed input (on each branded feed) should be determined and compared to ascertain which feed will be most economical.

Formulae

Cost of producing feed = FCR x fish biomass x unit price

Feed A

Cost of feed production = 1.1 x 10,000 x 5,000 / 20

= N2,750,000

Feed B

Cost of feed production = 1.3 x 10,000 x 4,500 / 20

= 2,925,000

Feed C

Cost of feed production = 1.5 x 10,000 x 4,000 / 20

= N3,000,000

Conclusion

Feed A, although the most expensive, is the most cost -effective of the three feeds, since it has the least feed cost requirement– as shown in the workings. The low feed conversion rate will likewise support short production period, thus favouring more meat production per unit time and increased production frequency (production cycle per year) than others. This also favours good fish health and presentation (bigger fish size than others).

Case 7.5

Three quality fish feeds were identified within a farm locality . Assuming they have similar feed conversion ratio (FCR) but attracts different prices and moisture contents i.e. feeds A, B & C cost N4,000, N4,100 & N4,150 per 15kg of feed, and contain 12%, 10% & 8% moisture content respectively. How do l determine which of the feeds to choose?

Data Supplied

Feeds	**A**	**B**	**C**
Prices (N/15kg)	4,000	4,100	4,150
Moisture Content (%)	12	10	8

Solution

The percentage of feed moisture suggests the percentage of dried feed paid for i.e. (100 - moisture content) %. We will determine the cost of moisture included in the feed and the actual cost of the (dried) feed paid.

<u>Price paid for moisture content</u>

A = 12% of 4,000

= N480

B = 10% of 4,100

= N410

C = 8% of 4,200

= N336

<u>Actual cost of the (dried) feed</u>

Actual Feed Cost (A) = N4,000 / (100 - 12) %

= N 4,545:45

Actual Feed Cost (B) = N4,100 / (100 - 10) %

= N4,555:56

Actual Feed Cost (C) = N4,150 / (100 - 8) %

= N4,510:87

The determined actual cost showed that feed C is the most cost effective of the three feeds.

Also, the level of feed dryness would help in minimizing microbial load, thus promoting feed durability and fish health.

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Chapter Eight

Feeding Your Fish

Quantity of Concentrate to Feed

The aim of most farmers has always been to maximize their gains and break even within the shortest possible period. However, no healthy animal can develop optimally without being adequately well fed. Farmed fish are normally fed collectively without special monitoring of individual fish feeding behavi our or agility. Thus, it must be ensured that an adequate quantity of feed is logically served to meet their (individual and collective) needs without wastage.

Feed may be served based on an estimated fish biomass (total body weight) or to satiation to ensure adequate growth and minimal / possibly no wastage. Feeding of fish based on biomass is achieved by having a random sampling of a representative number of the cultured fish. The total fish weight (biomass) is then determined, and a set percentage of theestimated biomass is then served as the daily feed intake, based on the a ge, size and management. This is regularly carried out at intervals – preferably weekly, to account for fish growth.

Case Study

Case 8.1

Assuming a farmer has just stocked each of h   is 10 tanks with 2,000 juvenile fish weighing an average of 15g. What quantity of feed will be needed to feed all the fish the following day, if they are to be fed at 8% body weight?

Solution

Fish biomass = 2,000 x 15g x 10 (no of fish tanks) = 300,000g

= 300kg of juvenile fish

Quantity of feed to serve = 8% of 300kg

(Note: 8% = 0.08)

= 0.08x 300

= 24kg of fish feed / day

Case 8.2

Suppose a farmer test cropped 50 fish out of his stock of 5,000 catfish. Assuming the total weight of the 50 randomly picked fsh is 45kg. What quantity of feed needs be served at each feeding period, if they are to be fed thrice a day, at a feeding rate of 4% body weight?

Solution

50 fish = 45kg

1 fish= 45/50 = 0.9 kg

Therefore,

5,000 fish = (0.9 x 5,000) kg

Estimated fish biomass = 4,500 kg

Quantity of daily feed = 4% of 4500

= 180 kg of feed

Quantity to feed at once = ⅓ x 180

= 60 kg of feed

So, 60kg of feed has to be fed to the fish in the morning, afternoon and evening i.e. 3 times a day.

The quantity of concentrate required to feed one's fish may also be determined by observing the feeding activities of the fish that are being fed, to know when they are satisfied i.e. feeding to satiation. Normally, healthy fish are expected to rush at served feed, creating a splashing sight that is termed "feeding frenzy". As the feeding progresses, the splashing movement wanes gradually (figure 8.1) until they are all satisfied. As the struggle for feed diminishes, the quantity of feed dispersed should be reduced and the rate of feeding slowed down. Once some feed are sighted uneaten (when feeding with floating feed) or just a few number of fish are sighted, the feeding should be stopped. It means they are satisfied.

Feeding to satiation is considered to be the best form of feeding for intensively raised fish that are manually fed, and are expected to be cropped within the shortest possible period. It eliminates the usual challenge of poor fish sampling – when determining fish biomass, and bulling of small sized fish. Fish sampling is often a big task, especially with "new comers" into fish farming. Poor sampling may bring about feed wastage / water pollution – if over-sized fish were picked, while selection of under-sized fish will encourage under-feeding. Newly introduced / stressed fish may sometimes go "off feed" , just as would those fed on less scented / palatable feed. With this feeding technique, the challenge of poor feeding is easily detected at an early stage as the quantity of feed consumed drops.

Plate 8.1. Feeding frenzy in fish

Fish may likewise be fed based on previous feeding records. Preferably, a two to three standard production records should at least be carefully studied and adjusted to suit the desired goal. The fish are expected to be produced under similar conditions, from the same strain of parent stock (preferably obtained from the same farm) and fed similar diets. However, the fish performance should be monitored regularly to verify if there is any significant deviation from the recorded norms for necessary adjustments.

Frequency of Feeding

Feeds are better utilized when served in bits over a period of time than bulk feeding. Thus, the calculated quantity of feed required for each day's feeding should be divided into parts that are then served, based on the frequency of feeding.

Feeding frequency is important in intensive fish management because of the bulk feed served, in relation to the biomass, as daily meal. Consequently, the higher the proportion of feed to body weight fed, the higher the frequency of feeding. This means that fry being fed on a 12% body weight daily feed intake are expected to be fed more frequently on a proportion of the daily feed, each time they are to be fed. Increased frequency of fish feeding on the expected daily ration is expected to assist in:

- Minimizing feed wastages.
- Reducing water pollution.
- Increasing feed nutrient assimilation than in bulk feeding, thus enhancing feed conversion to flesh.
- Optimizing the rate of fish development.
- Managing possible nutritional abnormalities that may likely arise from "overfeeding".

Bearing this in mind, fish fry should be fed ad -libitum (recommended) or manually fed every 1 to 2 hours interval, while adult fish are fed 2 to 3 times per day (see table 8.1). A proportion of about 1.0 to 1.5% of the biomass is thus recommended to be served at each feeding hour, under normal rearing condition. However, the quantity of feed served early in the morning and late in the night is expected to be slightly higher than others, when not using auto-feeders. The frequency of feeding depends on:

- the fish age / size
- how intensive and fast the production is expected to be
- the temperature of the culture system

A table of suggested feeding rates, frequencies and likely feed size ranges that may be considered for each age group feeding is given below.

Table 8.1. A guide to manual feeding of warmwater fishes

Age group	**Estimated weight (g)**	**Feed size (mm)**	**Feeding rate (%bwt/dy)**	**Feeding frequency (x/dy)**
Fry	< 0.05 0.05 – 0.1	0.1 – 0.3 0.2 – 0.3	≥ 15	12
Advanced Fry	0.1 – 0.5 0.5 – 1.0	0.3 – 0.5 0.5 – 0.8	12 – 15	8 – 12
Fingerling	1 – 5	0.8 – 1.2	10 – 12	8
Post fingerling	5 – 10	1.2 – 1.5	10	6 – 8
Juvenile	10 – 20	2.0	8 – 10	6
Post juvenile	20 – 50	2.0 – 3.0	8	6
Grower	50 – 100	3.0	6 – 8	4 – 6
	100 – 200	4.0	5 – 6	4

Adult	200 – 500	4.0 – 6.0	5	3 – 4
	500 – 1000	6.0 – 9.0	3 – 4	3
	≥ 1000	≥ 6.0	2 – 3	2 – 3

Note

- *The suggested feeding table above is just a feeding guide. Field experience may warrant some necessary alterations.*
- *Few days old larvae (swim-up fry) should be fed on hourly basis for better performance. They may be fed with a combination of concentrate and zooplankton.*
- *Suggested feeding data are meant for active, fast result yielding fish production.*
- *This data may only be considered for controlled, intensive / super-intensive fish farming that employs the right feed and management*

Quantity of Feed Required for Production

The total amount of feed required in feeding a group of cultured fish to a desired stage / pre-determined weight can be estimated. The knowledge of such an estimate is of immense importance in making adequate plan for a successful fish business. Since the cost of feeding often carries about 60 - 80% of the running cost of operating an intensive fish farm, determining the required amount of feed needed in feeding a desired number of fish to a pre-determined weight is considered a wise step towards being a successful businessman.

The advantages of having such a fore-knowledge include:

- It is needed in determining the quantity of feed / number of bagged feed to use for production, thus giving an insight into what should be reserved for feeding the fish to the target weight. This helps in making adequate plan / preparation towards a successful production.

- It is essential in relating the quantity of feed required to feed a set of fish to a particular fish size, to that actually used in feeding, for prompt assessment of the fish's performance.
- It is necessary in writing a good feasibility.

The pre-determined quantity of feed needed for production is easy to calculate once the farmer can provide the following data.

- What quantity of fish will be produced?
- The pre-determined fish weight i.e. the average fish weight desired by the farmer.
- The conversion ratio (FCR) of the feed – can be obtained from the feed producer or sales agents.

Note: Good fish breed and quality culture water are vital production parameters.

Case 8.3

Assuming a farmer wishes to raise 2,000 fish fingerlings to an average weight of 1.2kg, using a standard f eed with a feed conversion rate of 1.1. What number of 15kg bag of the feed will be needed for production?

Data Supplied

Quantity to produce = 2,000 fingerlings

Estimated (average) fish weight = 1.2kg

Feed conversion rate (FCR) = 1.1

Solution

Estimated fish biomass = no of fish x av. weight

= 2000 x 1.2

= 2,400kg of fish

Quantity of feed required for production

= fish biomass x FCR

= 2400 x 1.1

= 2640kg of the feed

No of feed bags = 2640 / 15

= 176 bags of the feed

So, about 176 bags of feed will be required for production.

How to Feed Fish

There are basically two ways by which fish may be fed— using supportive appliances (feed dispensers) or being hand -fed (manual). Feed dispensers may be grouped as feed -demand-driven feeders (demand feeders) or automated feeders (auto -feeders). Feed dispensers (feeders) are often installed to stimulate continuous fish feeding to satiation, for optimal performance. Some feeders are made handy with simple designs, while some others are large and computerized. Auto -feeders operations require (mechanical or electrical) energy input, while demand feeders are touch / weight sensitive tools. Examples of feed dispensers are: belt-timed feeders, rotating feeders and pendulum-type (demand) feeders.

A proportionate number of feeders are fed with the estimated quantity of feed required or simply filled and hung over / installed beside the water body. The feeders are auto-regulated to release feed at specific periods or when stimulated by the fish. Thus, fish appetite is always satisfied, as they are provided unlimited access to feed round the clock with minimal stress.

This feeding method encourages farmers to produce up to three (or sometimes four) sets of marketable fish of 500 grams to 1 kilogram per year from viable fingerlings / juveniles that are fed on high quality protein and energy diets. Some farm-related challenges that are associated with poor farm attendants' operations are limited with its use. A continuous, gradual feeding pattern is ensured, which minimizes feed wastage, energy wastage, water pollution and bullying to the barest minimum. It enhances good record keeping in that the quantity of feed consumed can easily be determined where such appliances are calibrated. Thus, the method ensures good feed management, cropping weight, health status (because of reduced water pollution and bullying) and profitability.

However, it is somewhat difficult trying to observe the physical fitness of satisfied fish since they won't rush for food or surface when someone is around. They also have to learn to adjust to the machine's mode of operation. In cases of reduced feed intake due to poor water quality, a drastic change in weather condition, certain disease conditions or body irritation, feed wastage may be inevitable with timed feed dispensers. Infestation with external irritants such as "ich", high ammonia titre or bullying may result in a continuous accidental bumping into feeder pendulum or scale.

In the absence of such feeders, fish feed should be manually dispersed over the surface of a culture water in such a way that virtually all the fish within would have access to the feed (at the same time) and are adequately fed. In a moderately large water bodies, the fish should be first enticed by making a peculiar sound that they are trained with when feeding to draw their attention. This is almost immediately followed by attracting with some quantity of feed, which gradually ushers in the real feeding. However, it worth noting that these two pre -ambles may not be necessary in small culture tanks because the cultured fish will normally pick the attendant's moving sound and easily sight the feeding bag or bucket, apart from identifying his person.

Once the feeding commences, the rate of dispersing the feed should be promptly adjusted in response to the rate of dispersed feed disappearance (if using floating feed) and the dispersal surface increased to accommodate the growing cluster size. Later, when the rush for feed begins to subside, the rate of feed dispersal and dispersal area are gr adually reduced in response to the fish demand for feed to spot (or point) feeding. This helps in preventing feed wastage. Weak and relatively small fish often join in to feed when the rush has abated. As such, feeding should continue (though at low rate and quantity in a spot) till virtually all ofhem are well-fed. This feeding pattern encourages even fish growth i.e. with less wide size / weight disparity and runts.

In large ponds however, feeding zones (not spots) may be randomly sited over each pond s urface, where feeding should take place simultaneously. The feed is then divided equally and dispersed over the surface of each feeding zone until the rush wanes, and their feeding is gradually localized to feeding points.

It is a good practice to maintain specific, regular periods of feeding. With constant feeding at such periods, the fish population becomes accustomed to the timing, thus they are expectant and well positioned to receive the feed when served. At the slightest sound or movement, they often would rush, creating splashing sounds and sights similar to what obtains when being fed. Thus, less feed wastage and better feed conversion is ensured.

Fishes, just like other animals, perform optimally within certain temperature ranges. As water temperatu re increases and decreases within the tolerable range, so do the feeding and enzymatic activities of fish i.e. high water temperature (within the tolerable range) is expected to promote fast fish growth. However, microbial growth is likewise enhanced by su ch increase in temperature at exponential rates in systems with organic load. When properly harnessed, fish feeds and grows well, and the increased microbial digestive ability may be channelled towards waste management in re-circulating aquaculture systems. If poorly managed however, the enhanced microbial activities may increase the system oxygen demand and ammonia generation / sensitivity that may result in fish stress / system collapse, and invariably may precipitate a disease condition or fish kill. Con sequently, feeding in uncontrolled aquaculture systems should preferably be done when the sun is not high i.e. early (6 - 10 a.m.) and late (3 - 7 p.m.) in the day.

To ensure optimal feeding / performance, cultured fish should be raised in controlled systems. In the absence of such facility and a cold weather results, slow-sinking feeds should be provided and the quantity of served feed reduced.

Observations to Note When Feeding Your Fish

Fish behaviour should regularly be observed and their performance assessed while being fed. The questions that need be answered are:

- How vibrant are they?
- Are they brilliant looking?
- Do they respond well to feeding?
- Do they look well fed? Is the growth rate (visual assessment) appreciable?
- Is there a little or wide size disparity?
- What quantity of the feed was consumed before the rush for feed subsided? Is the observation similar to previous ones?
- Is there any sign of sickness or body lesion?
- Do you notice the presence of any pest or predator within or close to the water body?
- Is there any need to adjust the water quality?
- Is the weather warmer or cooler than what it used to be?

The answer to some of these questions may suggest the next step to take in ensuring proper management and good fish health. A prompt response may make a difference between success and loss.For instance, assuming the fish were looking healthy and ready to feed, but the expected rush for feed wanes faster than expected. The first thing to suspect should be the quality of feed, if the fish population is intact. Has the formula been changed? Was one of the flavoured ingredients (e.g. fish meal or attractants) reduced or replaced with another of lower grade or scent? Once observed and a prompt solution found, probable negative sequel would have been prevented, and a steady fish growth assured.

In conclusion, fish diets may be economically computed and produced from a careful selection of fairly cost-effective, adequately processed unconventional and conventional feedstuffs, without compromising the quality. Fish that are intensively farmed should be fed on well-processed, complete diet to satiation. The right quantity of feed required per day may be calculated based on selected fish biomass, divided based on the frequency of feeding and served as at when due. They may also be fed to satiation without feed wastage by monitoring their response to served feed. The smaller the fish size, the more frequent the feeding should be. The quantity of feed to be served per meal should be dispersed over the tank surface or feeding zones in sizeable ponds rather than having a feeding point or spots.

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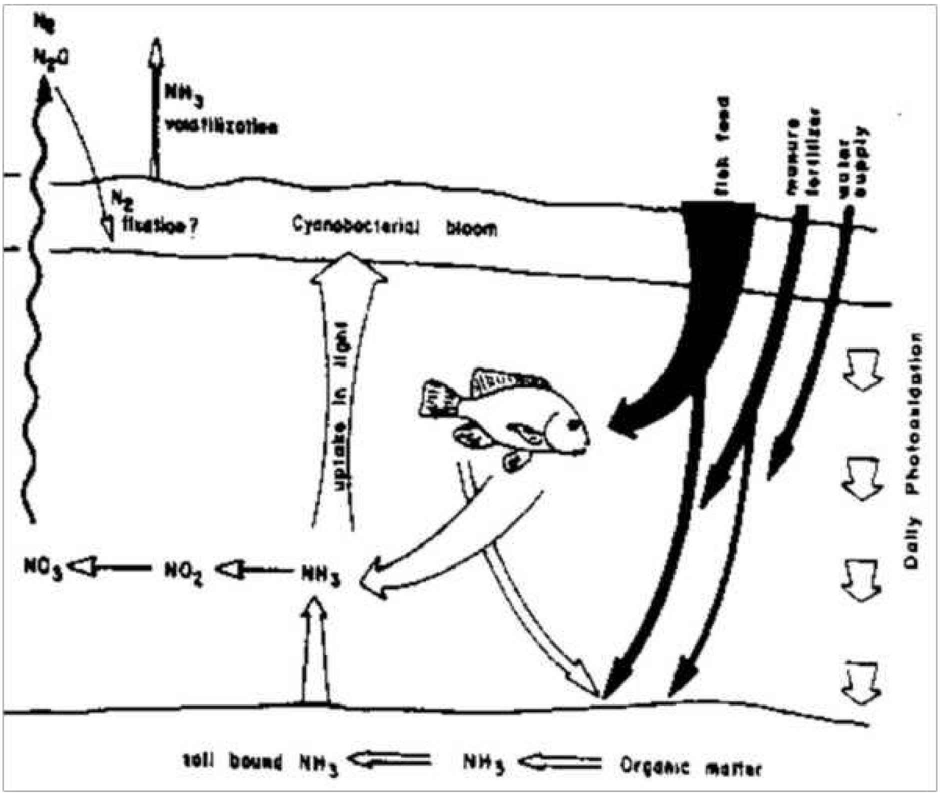
Chapter Nine

Aquafeed and Fish Waste Management

Aquafeed in Fish Waste Management

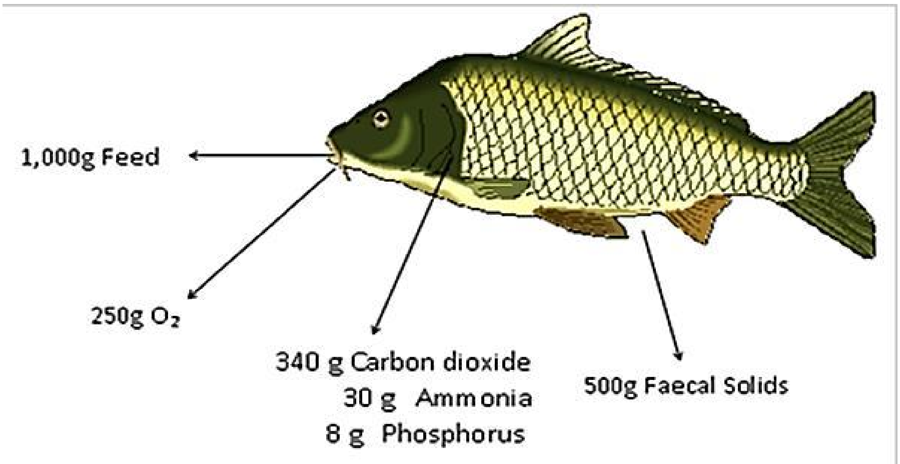
All aquatic animals eat to survive. A portion of the consumed feed is excreted as organic wastes – mainly faeces and ammonia. In earthen water bodies, fish wastes and other organic wastes such as uneaten feed, dead fish and plants are decomposed mainly by microbial agents, especially bacteria. Ammonia, a toxic by-product of such decomposition, is further converted by nitrifying bacteria to nitrite and thereafter nitrate. Nitrate and other by-products are utilized by algae and water plants that may be consumed by fish, in a process referred to as nitrogen cycle (see figures 3a&b). Denitrifying bacteria may also reduce some of the toxic wastes (NH_3, NO_2 & NO_3) to gaseous nitrogen (N_2) in the absence of air.



Shilo and Rimon (1982)

Figure 9.1. Nitrogen transformation

In an intensive aquaculture system, the quantity of feed fed to cultured fish is the major determinant in defining the quantity of faecal waste and ammonia produced. A 1kg feed is expected to produce about 0.5kg of solid waste and 0.03kg of ammonia, according to Timmons *et al* (2002). The quantity of ammonia generated is referred to as the total ammonia nitrogen (TAN), which consists of the ionized ammonia (NH_4^+-N) and the un-ionized ammonia (NH_3-N, the more toxic form). Since the quantity of TAN (and NH_3-N) produced affects fish health, and is directly related to the quantity of feed fed to cultured fish, then it implies that the carrying capacity (and stocking density) of a system may be determined from the quantity of feed served, and how fast such generated wastes (organic wastes and TAN) can be removed, assuming the source of culture water is ideal.



(Timmons et al, 2002)

Figure 9.2. Nitrogen transformation

In a situation where sinking pellets are over-fed and sediments are formed in a system with poor drain design, the total solid wastes (i.e. waste feed and faeces) increase. Some of these wastes later dissolve in the water (dissolved solids), are suspended (suspended solids) or remain as sediments (settleable solids). Such solid wastes, especially the "suspended solids", may result in fish gill clogging and subsequent ill-health. Heterotrophic bacteria may also act on the organic solids to produce additional ammonia and nitrite that further reduces the carrying capacity of the system. Thus, the feed quantity, quality and feeding technique are important factors to be considered in aqua-farm management, as they affect quite a lot of farm activities and parameters – water quality / management, system carrying capacity, microbial boom, fish health and business profitability.

The main production-limiting environmental factors in intensive, controlled aquaculture systems are oxygen, ammonia and nitrite (the toxic oxidative by-product of ammonia), more so other factors such as pH, temperature fluctuation and possibly salinity are easily managed in such systems. When the cultured fish (e.g. the African catfish, *Clarias gariepinus*) can utilize atmospheric air and air diffusers / oxygenators (e.g. aerators, oxygen generators and liquid oxygen) are provided, the main environmental challenge to contend with would be ammonia. Thus, managing ammonia is of great consequence in determining the level of aquaculture intensification.

However, the level of tolerance to these toxic wastes differs from one type of fish to the other. Below is a table of the lethal dose of ammonia (NH_3-N) to some fishes, as researched by some authors, and the related references.

Table 9.1. Lethal dose of NH_3-N for some aquaculture species

Species	**(mg l^{-1})**	**Reference**
Catfish	3.10	Summerfelt et al., 2004
Catfish (C. batrachus)	3.42	Duangsawasdi & Sripoomun, 1981
Common carp	2.2	Summerfelt et al., 2004
Arctic charr	0.03	Summerfelt *et al*., 2004
Rainbow trout	0.32	Timmons *et al*., 2002

<u>Case Study</u>

<u>Case 9.1</u>

In a controlled intensive system with one tonne of fish, what quantity of wastes is expected to be removed per day if a daily feeding rate of 5% body weight is served?

Data Supplied

Fish biomass = 1 tonne = 1,000kg

Daily ration = 5% body weight

Solution

Daily served feed = 5% of 1,000kg of fish = 50kg.

Assuming 1kg of fish feed will produce 0.5kg of faecal waste and 0.03kg of ammonia – according to Timmons *et al*, 2002.

Then,

50kg of feed = 25kg (i.e. 0.5 x 50) of faecal waste

(and) 50kg of feed = 1.5kg (i.e. 0.03 x 50) of ammonia

This suggests that such a system must be designedto effectively manage that (25kg of faecal solids and 1.5kg of ammonia) quantity of wastes on daily basis – assuming no increment in biomass / other contributing factors.

Case 9.2

Assuming one tonne of fish is fed at a daily rate of 3% body weight in a $10m^3$ controlled culture tank; what is the expected TAN concentration in the culture tank at the end of each day if 30g TAN/kg of feed consumed holds.

Solution

Daily quantity of feed = fish biomass x feeding rate

= 1 tonne x 3%

= 1,000kg x 0.03

= 30kg of feed

TAN production/day = 30kg of feed x 30g TAN/kg of feed

= 900g TAN / day

TAN concentration in $10m^3$ = 900g TAN per day / $10m^3$

(Note: 1g = 1,000mg & $1m^3$ = 1,000 litres)

= 900 x 1,000mg TAN per day / 10 x 1,000 litres

= 90mg TAN per litre per day

(90mg of TAN per litre is produced per day, provided the waste solids are promptly removed).

<u>Case 9.3</u>

A farmer with a ton of fish per culture tank is raising his fish on a 40% protein feed at 5% body weight.

a) What will be the TAN production rate per day?

b) At what exchange rate of water will the fish be comfortable if NH_3-N tolerance level for the farmed fish is 0.1ppm at pH 7.0 and 25 °c temperature?

Assumptions

- Protein is 16% nitrogen (= 0.16)
- 80% nitrogen is assimilated (= 0.8)
- 80% assimilated nitrogen is excreted (= 0.8)
- All TAN is excreted in time, t
- Non-assimilated faecal nitrogen is quickly removed from the system (=1.0)

Note

- *TAN equation constant, c = 0.16 x 0.8 x 0.8 x 1.0 ≈ 0.102*
- *Ammonia is assumed to be produced only by cultured fish via feed metabolism*
- *Ammonia is assumed to be the main limiting factor in fish production.*

Data Supplied

Fish biomass = 1 tonne = 1,000kg per culture tank

Feed Protein, Fp = 40% (= 0.4)

Feeding rate = 5% body weight

So,

Feed consumed per day, Fr = 0.05 x 1,000

Fr = 50kg

Water parameters:

TANm = 0.1ppm; pH = 7.0; Water Temp. = 25^{o}c

Solution

a). TAN production from feed, TANp = c x Fp x Fr / t

TANp = 0.102 x 0.4 x 50 / 1

= 2.04kg TAN is produced per day

b). @ PH 7.0 & 25^{o}c,

%NH_3-N (from table 6) = 0.566%

TANc = NH_3-N tolerance level / %NH_3-N

= 0.1ppm / 0.566%

TANc ≈ 17.7ppm

(Note: ppm ≡ mg/l)

The minimum water flow rate, FR = TANp / TANc

= 2.04kg TAN/day / 17.7ppm

(Note: 1kg = 1,000,000mg & 1day = 24 x 60 = 1440 minutes).

= 2.04 x 10^6 mg / 1440 mins / 17.7mg l^{-1}

≈ 80 litres min^{-1} OR $4.8m^3$ hr^{-1}.

Since NH_3 is the main determinant, the flow rate of water required to keep the farmed fish healthy is 80 litres min^{-1} OR $4.8m^3$ hr^{-1}.

Ammonia – Its Effect and Determination

Ammonia is a colourless, pungent gas that reacts with water to form a weak base. It is produced as a by-product of protein or nitrogenous metabolism which is principally excreted through gill membranes, and to a less significant extent in faeces. Though produced as a toxic metabolic waste of fishes, it is well utilized by bacteria and water plants. A relatively significant level of ammonia is sometimes noticed in natural water bodies with high microbial activities cum large quantities of organic load, and occasionally in underground water sited over a dumpsite with high activities of aerobic microbial decomposition.

Ammonia occurs in two forms in water – the ionized ammonia-nitrogen (NH_4^+-N) and the un-ionized ammonia-nitrogen (NH_3-N, the more toxic form), which together form the total ammonia-nitrogen, TAN. A reversible change exists between the two forms of ammonia, with the balance being determined by water pH and temperature. The measure of ammonia (especially the un-ionized form) within an aquaculture system is a major environmental determinant that influences the performance and survival of aquatic anim als. Ammonia has been reported as being toxic at 0.53 to 22.8mg/l to freshwater fishes. The severity of its effect is influenced by factors such as the fish species, size and tolerance, and waterchemistry (i.e. water pH, temperature and salinity). Calcium chloride and common salt (NaCl) have been demonstrated to reduce ammonia (and nitrite) toxicity in fish. Within the tolerable range for each aqua -animal, it is safe to keep the level low to maximize fish yield. A safe level of 0.02mg/l has been suggested by Meade (1989) for fish culture.

Ammonia toxicity is often associated with the following signs and side effects:

At high but non-toxic level:

- Reduced growth rate and performance, though the fish may be feeding well and appears normal
- Increased respiratory activity and heart rate
- Elevated blood pH

At mild toxic level

Affected fish may experience

- Poor growth rate
- High disease susceptibility due to immune suppression
- Stressful breathing and abnormal swimming
- Congregation around water inlet or shallow edges.
- Effect is prominent during the day, though affected fish may recover at night due to reduction in water temperature.

At high ammonia toxicity

The affected fish may experience the following:

- Gill damage or rot
- Internal bleeding – seen as dark skin colouration
- Tissue and internal organ damage
- Loss of equilibrium and lethargy
- Convulsion, coma and death

The measure of TAN obtainable within a given culture system can be determined with the use of water quality test kits. Most commercial ammonia test kits measure the total ammonia nitrogen (TAN), not the un-ionized ammonia, though the un-ionized ammonia value may be extrapolated from the measured TAN value. Once the TAN value is measured alongside with the prevailing water temperature and pH, the next step is to deduce the percentage constant (c %) of TAN in the un-ionized form. This constant is obtained by matching the water temperature and pH on the ammonia-nitrogen proportion chart (table 9.2). Thereafter, the value of NH_3-N in the measured TAN is determined and the obtained value compared with the tolerable NH_3-N level for the given fish. This is illustrated in case 9.4.

Similarly, the tolerability of a measured TAN level may be determined by comparing the measured TAN with the tolerable TAN level. With the given pH and temperature values, the tolerable TAN level may be calculated, using a formula, as illustrated in the case study below (case 9.5).

Table 9.2. Percent of total ammonia nitrogen in the un-ionized form at various temperatures and pH							
Temp (°c)	**pH 6.5**	**pH 7.0**	**pH 7.5**	**pH 8.0**	**pH 8.5**	**pH 9.0**	**pH 9.5**
0	0.026	0.083	0.261	0.820	2.55	7.64	20.7
5	0.039	0.125	0.394	1.23	3.80	11.1	28.3
10	0.059	0.186	0.586	1.83	5.56	15.7	37.1
15	0.086	0.273	0.859	2.67	7.97	21.5	46.4
20	0.125	0.396	1.24	3.82	11.2	28.4	55.7
25	0.180	0.566	1.77	5.38	15.3	36.3	64.3
30	0.254	0.799	2.48	7.46	20.3	44.6	71.8

The table signifies the relationship between TAN (total ammonia-nitrogen), the un-ionized form of ammonia, water temperature (t^O) and pH. The table gives the percentage of un -ionized ammonia-nitrogen in TAN at specified water temperature and pH.

Case 9.4

In a RAS, it was observed that the NH_3 reading measured 0.7 mg/l at a water temperature of 25°c and pH of 7.0.

a) What is your judgment about the suitability of the cultured medium?

b) Assuming the temperature and pH changes to 30 °c and 8.0 respectively, what is your opinion?

c) If the temperature and pH are maintained but the TAN reading is 7.0 mg/l. What is your judgment?

Assumptions

$[NH_3T]$ = total ammonia-nitrogen

$[NH_3U]$ = un-ionized ammonia nitrogen

c = proportional constant

Solution

a). $[NH_3U]$ = c% of $[NH_3T]$

c value at temp 25°C & pH 7.0 on table 9.2 = 0.566%

$[NH_3U]$ = 0.566% of $[NH_3T]$

= 0.566% x 0.7

$[NH_3U]$ = 0.003962 mg/l

Match calculated $[NH_3U]$ with that permitted for your fish

(let us assume that the fish can tolerate $[NH_3U]$ at values < 0.025 mg/l)

The obtained value (0.003962 mg/l) is less than 0.025 mg/l.

Thus, the cultured medium is healthy for aquaculture.

b). $[NH_3U]$ = c% of $[NH_3T]$

c value at temp 30°c & pH 8.0 on the table = 7.46%

= 7.46% of $[NH_3T]$

= 7.46% x 0.7

$[NH_3U]$ = 0.05222 mg/l

Match calculated $[NH_3U]$ with that permitted for your fish. The obtained value (0.05222 mg/l) is more than 0.025mg/l. Fish in such a medium may be stressed and signs of toxicity observed – depending on the fish species' ammonia tolerance level.

c). $[NH_3U]$ = c% of $[NH_3T]$

c value at temp 25°C & pH 7.0 on table 6 = 0.566%

$[NH_3U]$ = 0.566% of $[NH_3T]$

$= 0.566\% \times 7.0$

$[NH_3U] = 0.03962$ mg/l

Match calculated $[NH_3U]$ with that permitted for your fish. The obtained value (0.03962 mg/l) is more than 0.025mg/l. Fish in such a medium may be stressed and signs of toxicity may begin to manifest – depending on the fish species' ammonia tolerance level.

Case 9.5

An aquaculturist, when in doubt of his pond water quality, measured and recorded a TAN reading of 2.5 mg/l at a temperature of 26°c and pH of 6.8.

a) Will you say the water condition is tolerable for the cultured fish, assuming the tolerable ammonia-nitrogen level is 0.02mg/l?
b) What is your opinion if the temperature and pH are 27°c and 7.2 respectively?

Data Supplied

Tolerable ammonia-nitrogen, Tn = 0.02mg/l

Tolerable TAN concentration, TANc = ?

Solution

a). $TANc = Tn \times [1 + 10^{\{0.09018 + (2729.92 / (273 + T)\} - pH}]$

$= 0.02mg/l \times [1 + 10^{\{0.09018 + (2729.92 / (273 + 26)\} - 6.8}]$

$= 0.02mg/l \times [1 + 10^{\{0.09018 + (2729.92 / (273 + 26)\} - 6.8}]$

$= 0.02mg/l \times 264.237176621$

TANc ≈ 5.285 mg TAN/l

The tolerable TAN level (5.285mg TAN/l) at 26ºc and pH 6.8 is higher than the measured TAN value (2.5mg/l), thus suggesting that theculture water is tolerable to the fish.

b). $TANc = Tn \times [1 + 10^{\{0.09018 + (2729.92 / (273 + T)\} - pH}]$

$= 0.02mg/l \times [1 + 10^{\{0.09018 + (2729.92 / (273 + 27)\} - 7.2}]$

$= 0.02mg/l \times [1 + 10^{\{0.09018 + (2729.92 / 300\} - 7.2}]$

$\approx 0.02mg/l \times 98.7042225518548$

TANc ≈ 1.974 mg TAN/l

The tolerable TAN level (1.974 mg TAN/l) at 27 ºc and pH 7.2 is less than the measured TAN value (2.5mg/l), thus suggesting that the culture water is intolerable to the fish.

Nitrite, the intermediate product in the process of nitrification of ammonia to nitrate, is toxic to fish by affecting the blood haemoglobin's oxygen transport ability. The characteristic brown coloured haemoglobin (termed met-haemoglobin) is synonymous with nitrite poisoning, hence the common name "brown colour disease". It results from the oxidation of iron in the haemoglobin molecule from the ferrous state to ferric state. Though toxic to freshwater fish, nitrite is often not considered to be a problem in most flow -through systems as water retention time is usually not enough to allow significant nitrification. Its toxicity is significantly reduced by chlorine salts ($CaCl_2$ and NaCl). Culture water of less than 1.0mg/l NO_2-N content is recommended.

Waste Management in Intensive Aquaculture

Aquaculture wastes removal often requires a great deal of water to flush the system clean. Even in situations where the 'waste water' is re-used, at least about 5-10% of the water is discharged. Such accumulated wastes often constitute health problem and the waste water discharged a nuisance.

The effects of aquaculture wastes are often managed in diverse ways. Some of the techniques commonly employed include:

- Flushing out solid wastes with good quality water.
- Incorporating filters to minimize water requirement.
- Agitating culture water surface for gaseous exchange / system aeration.
- Minimizing feed intake in areas with poor water supply. In such an instance, the feed quality is increased and appropriate feeding technique employed to ensure that individual fish are fed on basic daily feed requirement, not to satiation.
- Reducing the stocking density.
- Reducing the water pH and temperature.

Solid wastes, as earlier said, comprise of the dissolved, suspended and settleable solid wastes. Suspended and settleable wastes are easier managed than dissolved wastes. They are removed through sedimentation, swirling movement and mechanical filtration. On the other hand, dissolved wastes are largely removed using biological filters (biofilters). The use of biofilters in dissolve waste management is of great importance in intensive and 'super'-intensive aquaculture. Such use requires the knowledge of how to estimate the quantity of dissolved waste to manage, the selection of an appropriate biofilter, determination of the filter size and volume, proper installation and so on. Below are illustrations that may serve as a guide in such decision making.

Case 9.5

A catfish farm, with five 20m ^{3} water capacity tanks, was stocked at 80kgm^{-3} and the feeding at 3% body weight. At what performance rate must a 50m^3 bio-sump with about 240m^2/m^3 specific surface area work in other to effectively manage the generated wastes?

Assumptions

* 1kg of fish feed will produce 0.5kg of faecal waste and 0.03kg of ammonia – according to Timmons *et al*, 2002.

* There is no other source of ammonia generation, and TAN production per day is adequately managed by the bio-sump

Given

Culture tank = 20m^3 x 5 tanks

Stocking density = 80kgm^{-3}

Specific surface area, SSA = 240m^2/m^3

Bio-sump volume, BV = 50m^3

TAN removal rate (i.e. biofilter performance rate), TRR =?

Solution

Capacity of each tank = volume of tank x stocking density

= 20m^3 x 80kgm^{-3}

= 1,600kg of fish

Total stocking capacity of tanks = 5 x 1,600kg

= 8,000kg of fish

Feeding rate = 3%

Quantity of feed taken per day = 3% of 8,000kg

= 240kg of feed

Quantity of TAN produced per day, TANp

= 30g/kg of feed x 240kg of feed

TANp = 7,200g of TAN per day

Total surface area of biofilter, BA = BV x SSA

= 50 x 240 = 12,000m^2

TAN removal rate, TRR = ?

If TAN produced (TANp) = TAN consumed (TANc) by bio-sump

TANc = TRR x BA

So,

TANc = TANp = TRR x BA

7,200g of TAN = TRR x 12,000m^2

TRR = 7,200 / 12,000

TRR = 0. 6g of TAN per m^2 per day

This suggests that the biofilter system must be able to remove not less than 0.6g of TAN per m^2 per day in order to operate at 100% efficiency.

<u>Case 9.6</u>

A fish farmer has just installed a 20m^3 bio-sump media with specific surface area of 500m^2/m^3 to run an intensive system. Assuming the TAN removal rate is 0.5g of TAN/ m^2/day, and the bio -media efficiency is

40% capacity; what quantity of fish (in kg) can the system effectively support if the fish were fed at 5% bo   dy weight, and TAN production rate of 30g/kg of feed consumed applies?

Given

Feeding rate, FR = 5% body weight

TAN production rate, TPR = 30g/kg of feed consumed

Specific surface area, SSA = $500m^2/m^3$

Bio-sump volume, BV = $20m^3$

TAN removal rate, TRR = 0.5g of TAN/ m^2/day

Biofilter efficiency = 40%

Maximum quantity of fish to stock = ?

Solution

Quantity of TAN that bio-media can manage, TANc

TANc = BA x TRR

(where BA is the biofilter area)

BA = SSA x BV

So,

TANc= SSA x BV x TRR

= $500m^2/m^3$ x $20m^3$ x 0.5g of TAN/m^2/day

= 5,000g of TAN/day

At 40% efficiency,

TANc = 40% x 5,000

TANc = 0.4 x 5,000

= 2,000g of TAN/day

Feed consumed by fish biomass, FC

FC = fish biomass (t) x daily feeding rate (FR)

= t x 5% = t x 0.05

FC = 0.05t

TAN production/day, TANp = FC x TPR

TANp = 0.05t x 30 = 1.5t

In an effective system,

TAN production/day (TANp) $\leq$ TAN consumed/day (TANc)

1.5t = 2,000

t = 2,000/1.5

t $\approx$ 1,333kg of fish

This suggests that the system may not support more than 1,333kg of the farmed fish under the presented condition.

<u>Case 9.7</u>

A fish farmer, with a production capacity of about 10 tonnes of fish from his five culture tanks per harvest, is planning to feed his fish with a 40% crude protein floating diet at 3% body weight.

a) What will be the TAN production per culture tank?

b) If all the culture tanks are to be connected to a centrally operated trickling filter with a specific surface area of $250m^2/m^3$ and TAN removal rate of $0.55gTAN/m^2/day$, what will be the required bio-filter area and volume?

Assumptions

* 16% of feed protein is nitrogen (FPN).

* 80% of the protein nitrogen is assimilated (PNA).

* Non–assimilated nitrogen in faecal matter is removed rapidly.

* 80% of assimilated nitrogen is excreted (PNE).

* The excreted nitrogen is 90% TAN (PNETAN) and 10% urea

* All of the TAN is excreted in t hours.

Given

Production capacity = 10 tonnes from 5 culture tanks

i.e. 10 tonnes / 5 = 2 tonnes of fish per culture tank

Daily feeding rate = 3%

CP = Protein content of the feed = 40%

Time = 1 day

TAN removal rate, TRR = 0.55gTAN/m^2/day

= 5.5×10^{-4} kgTAN/m^2/day

Specific Surface Area, SSA = 250 m^2/m^3

Solution

a). To determine TAN production (TANp) per tank?

Feed consumed by fish biomass, FC

FC = fish biomass x daily feeding rate

= 2 tonnes x 3%

= 2,000 x 0.03

= 60kg of feed is consumed everyday

TANp = (FC x CP x FPN x PNA x PNE x PNETAN)/t

TANp = (60 x 40% x 16% x 8% x 8% x 90%)/1

TANp = (60 x 0.4 x 0.16 x 0.8 x 0.8 x 0.9)/1

≈ 2.2kg of TAN/day/culture tank

b). Bio-filter area, BA = ?

Bio-filter volume, BV = ?

Total TANp from the 5 tanks = 5 x 2.2

= 11kg of TAN/day

Assuming the bio-filter will detoxify all produced TAN

Total TANp = BA x TRR

$11 = BA \times 5.5 \times 10^{-4}$

$BA = 11 / 5.5 \times 10^{-4}$

$= 20{,}000 m^2$

Bio-filter volume, BV = BA / SSA

= 20,000 / 250

$BV = 80m^2$

Some Useful Ways of Managing Aquaculture Wastes

Aquaculture, as summarized in figure 4, utilizes quite a number of factors to produce the expected fish biomass and a quantum of w astes — uneaten feed, faecal waste and waste -bearing water. Naturally, these wastes are processed by soil particles (mechanical filters) and soil microbes (bio filters) for plant use, and the water purified. However, with large volume of waste generation, solid wastes may be concentrated and recycled into useful products such as animal (e.g. ruminant) feed / feed ingredients and fertilizers (for arable farming) , or used for biogas production. The "waste water" may be utilized for "micro-hydro" power generation and plant irrigation (see figure 6). This makes fish farming more interesting, more profitable, a means to power generation, poverty alleviation through employment, and a lot more.

Assuming an intensive backyard aquaculture project is practiced within a fenced residential quarter with vacant space of at least half / one plot of land, the ‘wastes’ may be converted into useful by-products without necessarily constituting environmental nuisance. These wastes (including processed fish offal) may be gainfully processed into home pets’ food / animal feedstuff, or combined with home (faecal) wastes and channelled into bio-gas production chamber for home use. Resultant sludge from the chamber may be used for periodic mini-orchard or garden fertilization. Wastewater may be directly used for home power generation (mini-hydro generator) and plant / garden irrigation. Solid waste is removed by soil particles, while dissolved waste is managed by a possible combination of plants, bacteria and algae. Not too far from the garden should be a well (or two) that will serve as nature-processed-water receptacle. Water from this receptacle is then re-used for aquaculture purpose, farm irrigation and or lavatory use, as illustrated in figure 4. The gainful utilization of generated wastes obtained from a multi-culture system – an aquaculture system, poultry and horticulture – is presented in figure 5.

Generally, in as much as cultured aqua-animals are expected to be fed to satiation for optimal growth and performance, a sound production environment (culture water) must be maintained through proper wastes monitoring and management. An estimate of the maximum daily solid waste and TAN generation a system can successfully accommodate, based on the daily feed intake and system performance, may be helpful in determining the likely stocking density an intensive culture system can effectively support (i.e. the system carrying capacity) for optimal production. Such wastes may be gainfully employed for home, farm and commercial use when pro perly designed, rather than being an environmental nuisance.

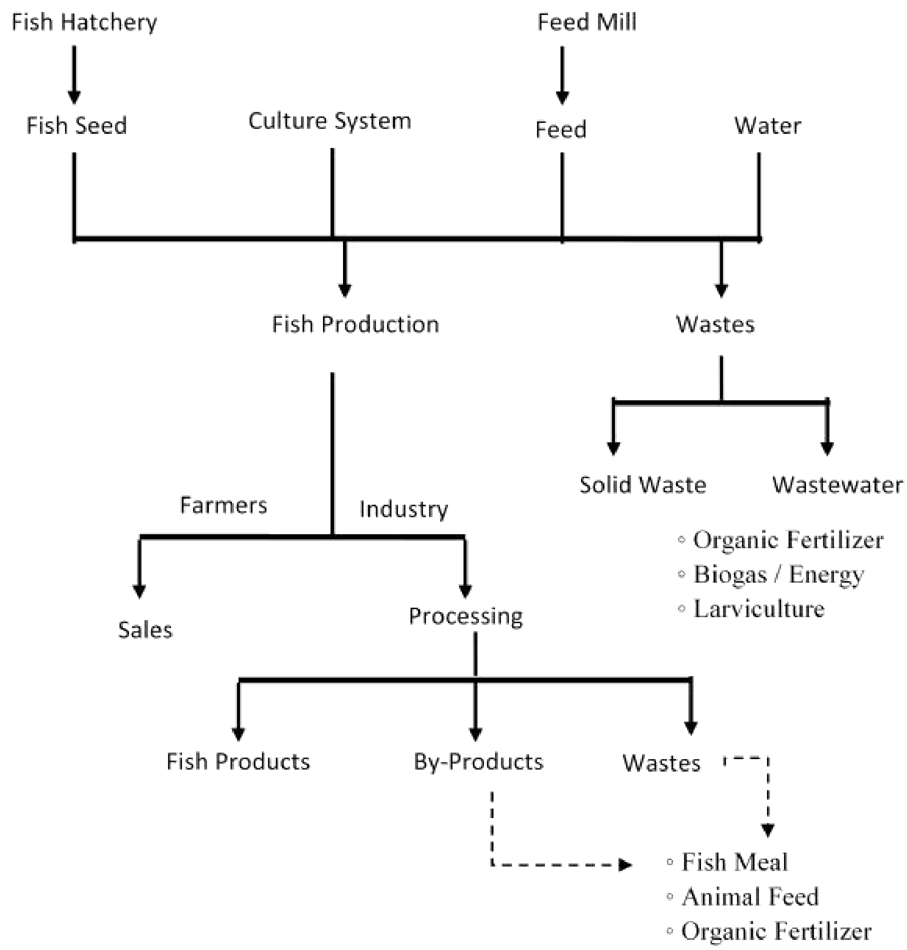


Figure 9.3. Fish Production & Products Chart

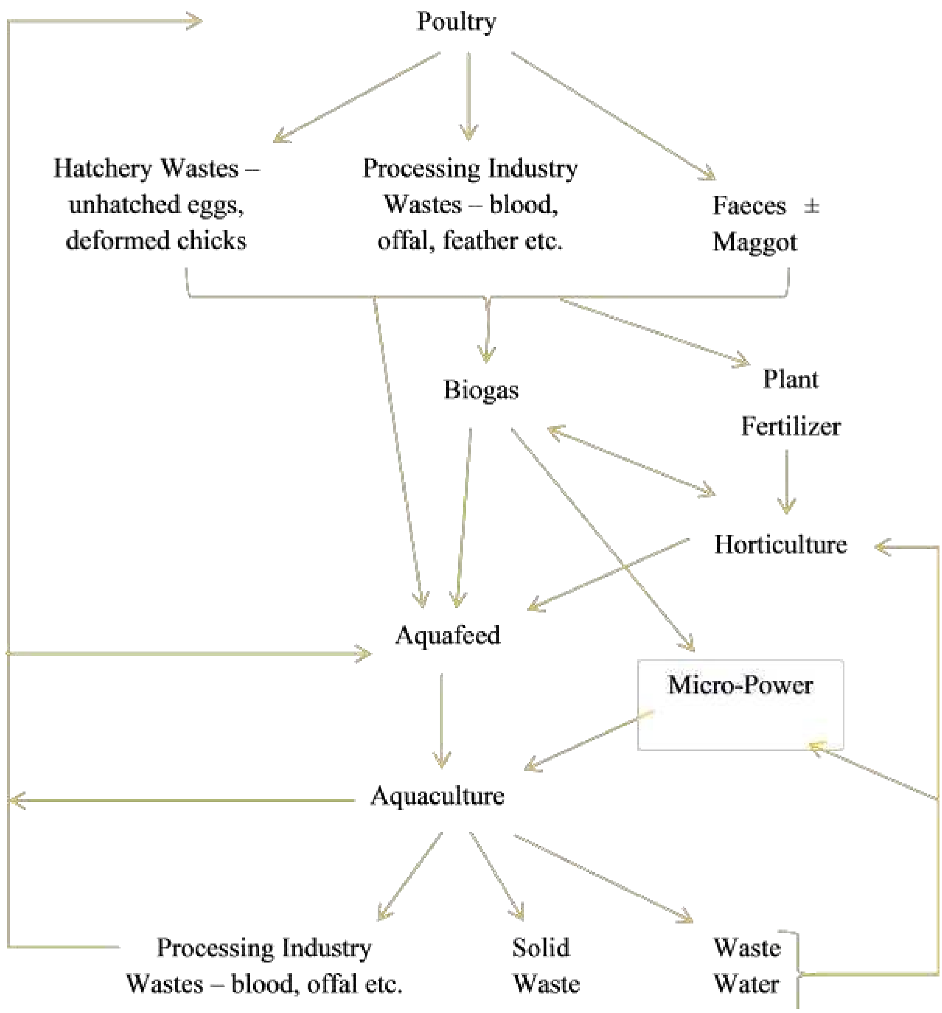


Figure 9.4. Waste management in a multi-culture system

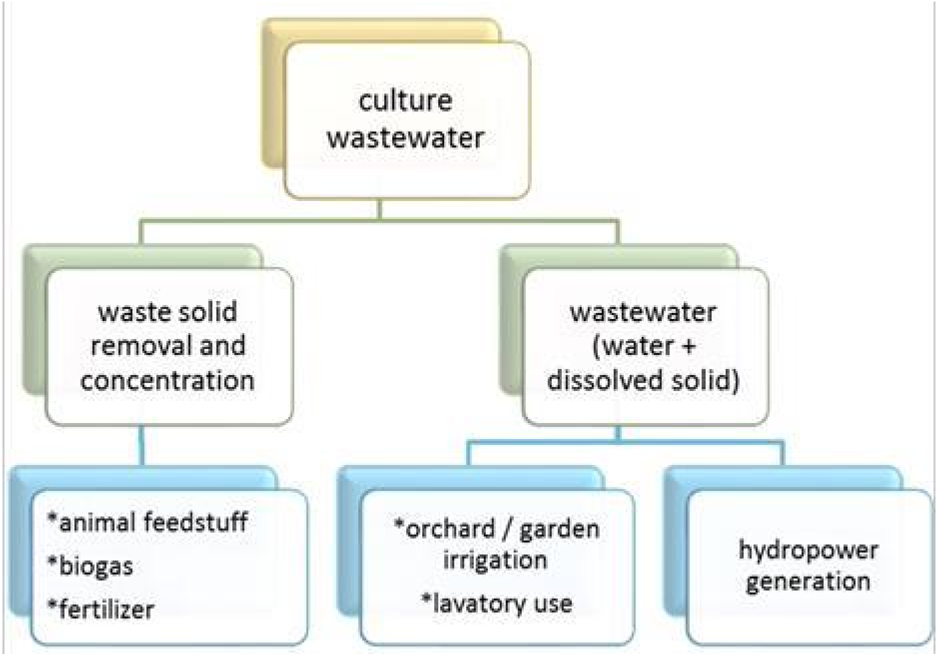


Figure 9.5. Aquaculture wastewater management

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Chapter Ten

Nutritional Diseases / Challenges

Introduction to Nutritional Challenges

Diseases are not limited to pathogen based diseases. There are four basic types of diseases – pathogenic (microbial), nutritional, environmental and miscellaneous (of unknown origin) diseases i.e. they can originate from biotic (life) or abiotic (non-living) substances. Also, there are four routes through which pathogens come in contact with their aquatic host(s) i.e. vertically from parent stock, through the feed, culture water and or facilities used, as outlined in the 'fish health' schematic diagram (figure 10.1). The figure (10.1) suggests that a fish (or school of fish) stays healthy when healthy fish are raised in an ideal environment and condition, being maintained on adequate quality feed. For instance, a healthy fish population may become sickly when they are fed on poor quality feed or contaminated quality feed. Some common microbial contaminants isolated from feed ingredients and finished feeds include *Escherichia coli*, *Salmonella species, Enterobacter species, Klebsiella oxytoca, Vibrio species* and Aspergillus.

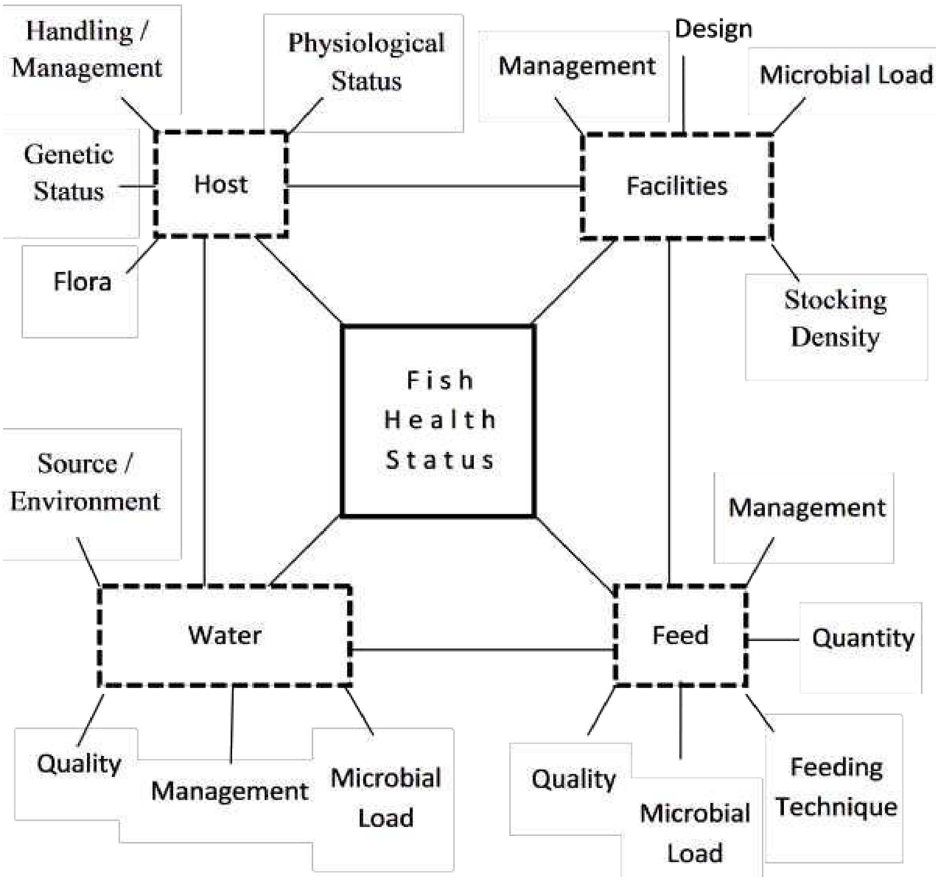

Figure 10.1. OAK fish production and health chart

Nutritional diseases (or abnormalities) are often problems resulting from poor feed nutrient and nutrient availability, lack of some essential nutrients required for normal body functions, excessive consumption of anti-nutrient factors and feed-associated toxins. It is quite different from diseases caused by pathogens or environmental factors, although they are inter-related.

Nutritional disease may result from a sudden change in diet – as often experienced when introducing fish larval first feed and when changing from zooplankton to concentrate, poor nutrition, poor feed storage, prolonged period of f eed storage, poor ingredient / feed quality, poor feed quality resulting from the processing method, anti -nutritional factors, use of unpalatable feeds and a host of other associated factors.

Nutrient Deficiencies in Cultured Fish

Table 10.1. Nutrient deficiencies in fish

S/N	Deficient Nutrient	Diseases / Disorders	Clinical Signs / Comments
1	Vitamin A	Keratomalacia, exophthalmos & ascites	Poor vision, poor growth
2.	Vitamin B		
a)	Folic acid	Nutritional anaemia	Anaemia + poor growth
b)	Pantothenic acid	Nutritional gill disease	Fusion of primary lamellae of affected gills results in respiratory & excretory problems
c)	Thiamine	Neurologic disorders	Acute disease – convulsion & death. Chronic form — oedema, loss of balance & poor growth
d)	Riboflavin	Ocular defects	Defects of the eyes e.g. cloudy lens & blindness
e)	Niacin, biotin & pyridoxine	Neurologic disorders	Spasms & convulsions (Niacin helps to prevent sunburn)

3.	Vitamin C	Broken back disease (Ascorbic acid)	Cartilage abnormalities, impaired wound healing & immune function, Vertebral column may collapse. (Use phosphorylated Vit C + proper feed storage)
4.	Vitamin E (Selenium)	Myopathy	Muscular deformities
5.	Choline, Biotin, Inositol & Vit. E	Fatty liver disease	Poor growth due to poor fat / oil metabolism
6.	Calcium & Phosphorus	Broken head disease	Weakened, cracked or broken skull
7.	Iodine	Goitre	Also caused by goitrogenic substances
8.	Fat / oil (excess) & Rancid fats	Fatty liver, Anaemia & Obesity	High dietary fat / oil Yellow to pale orange coloured, swollen, greasy liver
9.	Aflatoxins (in feed)	Aflatoxicosis (Hepatomas)	Liver tumour & emaciation Avoid mouldy feeds

Table 10.2. Some anti-nutrients found in feedstuffs that may cause physiological abnormalities or impair the growth of aqua-animals	
Anti-Nutrients	**Feed items**
Cyclopropenoid fatty acids	Cottonseed oil and meal
Glucosinolates	Rapeseed meal
Glycosides	Grass and leaves
Gossypol	Cottonseed meal
Haemoglutinins	Soyabean meal
Histamine and putrescine	Fish meal, primarily tuna
Mimosine	Leucaena leaf meal
Mycotoxins (aflatoxin)	Not naturally occurring but produced by microorganisms in cereal-based meals
Nitrosamines	Fish meal
Oxidized and polymerized lipids	Fish meal; poultry by-products, krill meal
Phytates	Plant feedstuffs
Plant phenolics	Plants
Tannins	Rapeseed meal
Trypsin inhibitors	Soybean and rapeseed meal

Management of Nutritional Challenges / Diseases

Prevention of Nutritional Challenges

1. Aquafeed producers

- Live food (plankton) culture should be hygienically handled to prevent transmission of possible pathogens.
- Ensure that the right feed formulation (with essential additives) is used to satisfy specific fish need.
- High quality ingredients should be used in feed production. Sifting out impurities from feedstuffs is important in quality feed production.
- Selected feed ingredients should be properly processed to manage anti-nutrients (e.g. thiaminase). Anti-nutrients may cause vitamin deficiencies.
- Fish feed / ingredients should preferably be stored for not more than a month (before use) to prevent degradation of sensitive nutrients.
- Maximum storage time should preferably not exceed 90 days, except when properly extruded and well packaged.
- Heat-sensitive nutrients (some amino-acids, lipids and vitamins additives) should be added in the right proportion, after extrusion.
- The feed should be well bound (and dried) to keep the particles / water-stable-additives intact.
- Feed additives such as anti-mycotoxins (or toxin binders), probiotics, essential plant oils and or growth promoters, may be incorporated in endemic locations.
- Protect feedstuffs and finished feed from moisture, pests and rodents to avoid contamination and wastage.

- Feeds, in which easily contaminated materials are incorporated as ingredients, should be adequately processed and stored to check microbial contamination and feed degradation.
- Finished feeds should be batched, labelled and samples analysed to ensure the quality of produced feed. Any batch defect should be identified and corrected.

2. Aquafeed purchasers

- Always examine feed label to avoid expired feeds.
- Smell and visually assess the quality of the purchased finished feed or the miller's feed ingredients when toll milling your animal's feed.
- Feed samples obtained from your regular (feed) pur chase outlet should periodically be analysed in a standard laboratory to ensure quality maintenance.
- The adopted feeding pattern should ensure that each cultured fish is adequately fed, and that each served feed is picked almost immediately to ensure minimal feed-coating additive dissociation and water pollution.
- Fish fry first food / feed should be gradually introduced, similar to when changing their feed (that is from zooplankton to concentrate). This should preferably be done with the use of gut stabiliz ing agents e.g. probiotics and natural oils.
- Feeds should be stored dry and kept in a dry, cool place to prevent being mouldy, rancid, and getting degraded.
- Avoid using stale or mouldy feed.

Control Measures

Diseases are better handled in a holistic mat ter wherein thorough investigation is made in ensuring that the root cause of such disease is identified and treated. In handling a suspected nutritional disease case, efforts must be made in ensuring that other similar diseases of pathological, environmental or miscellaneous disease origin have been eliminated, based on proper diagnosis. It should be noted that a disease may be multi-factorial, which may result in a complicated case if not well managed. For example, a case of poor nutrition may lower the fish immune status and precipitate a pathogenic disease condition. Environmental pollution may result from uneaten (excess) feed, which may encourage hypoxia (low oxygen in the tissues) and or ammonia toxicity. It is thus advised that a fish health expert (veterinarian) should be called to manage disease cases.

Some useful tips in nutritional disease management should include:

- Avoid handling stressed / unhealthy fish, unless necessary.
- Take history / clinical signs of ailment.
- Assess and possibly rule-out diseases conditions / abnormalities – based on the noticed fish activities / signs / post-mortem findings.
- Check the feed formulation and quality, including microbial load. Sensual assessment (sight, touch and smell) may be helpful here.
- Administer the required nutrient / therapy (only) based on diagnosis.
- In a complicated pat hogenic disease case, identify , treat and trace the disease to the source of infection to prevent a re-occurrence. For instance, if the disease agent is transmitted through served feed, treating the fish without changing the feed may result in disease re -occurrence and increase drug resistance.

- Feed fed to stressed / unhealthy fish should be reduced to what they will consume, the quality improved and essential vitamins, minerals and fatty acids included to satisfy their daily needs.

Case Study

Case 10.1

Assuming the rate of mortality of newly hatched catfish (*Clarias gariepinus*) larvae suddenly increased from about 3% to over 30% within the first two days of (artemia) feed introduction, what could be the probable cause(s) and preventive measures?

Probable sources of the case

It should be noted that African catfish larvae usually receive their first meal from the 3rd day of life. The presented case thus suggests that:

- the mortality case experienced is most likely linked with the larvae feed since it started after administering the feed.
- 30% mortality within two days suggests an acute disease case.

The likely causes, based on the "OAK Fish Production & Health chart", are:

(Water quality)

- Pathogens could build-up within the culture water and cause disease. In such a case, the resulting disease pattern is usually gradual and most likely from day 1.
- Poor water quality could also result in larval mortality. Though the effect may be severe, mortality pattern would be slightly different. In

such a scenario, the reaction should have been noticed from the onset, not from the three day.

(Host)

- The larvae could have been poorly produced, have defects or be infected vertically (via broodfish). Where the death is associated with larvae defect or vertically transmitted disease, mortality often result from day 1, apart from obvious deformities / symptoms.

(Feed)

- Introducing a "strange feed" – newly introduced (strange) feeds are often seen as "foreign" proteins. The elicited immune reaction could cause such a tragedy (Gisbert *et. al*., 2004; Akintomide *et. al*., 2017). Such cases are commonly seen when farmers introduce their first fish feed and when there is a drastic change in feed type to a new one e.g. from artemia (live food) to formulated diets.
- Feed contamination is another probable cause , although some pathological lesions / obvious disease signs should ensue . Checking the feed expiry date, moisture content (< 10% moisture content is ideal), scent and consistency, and considering the handling and storage should help in eliminating / confirming the possibly of contamination.

(Facilities)

- Using contaminated materials / culture receptacles and oily / corroded appliances could cause mishaps. However, such mis haps are usually observed to be gradual, with signs being noticed (usually) before the third day i.e. before first feeding. Routine records and obvious clues may indicate such conditions.

Probable solutions to the case

- A careful investigation should be co nducted to ensure that the situation is not due to (or complicated with) disease outbreak or environmental abnormality.
- New feed(s) should first be sparingly introduced to cultured fish, and subsequently the quantity served should be gradually increased, with or without the inclusion of digestive enhancers and gut stabilizers such as probiotics a nd some natural plant oils. These are useful in maintaining good gut flora, which improves feed utilization and enhances good fish health.

<u>Case 10.2</u>

A fish producer noticed that his fish seems to be okay i.e. feeding well (with normal swimming), but are not growing up to the required size / weight, unlike what is seen on his friend's farm where he got them. What could be wrong with the fish?

Probable Sources of the Case

The presented case suggests that:

- the fish breed is relatively good, since its source is the same with his friend's stock.
- the probability of having a pathogenic disease outbreak is slim, since they are feeding and moving normally.

In line with the "OAK Fish Health chart", likely causes are:

(Water quality)

- Poor water quality may retard fish growth without obvious signs of stress, if the level of water factor (e.g. ammonia and nitrite) is fairly high but within tolerable range. The picking of a pungent (ammonia) smell from the culture tank may be indicative.
- The quality of the water source and the efficiency of the waste water treatment unit (filters) and oxygenator are probable factors thatshould be ascertained.

(Host)

- Though the fish in question seems healthy, the possibility of having mild parasitic infestation may be responsible. The infestation may be low where irritating parasites are involved (since the fish is said to be "calm"), or it may be high if parasites (e.g. intestinal worms) with mild effects are involved.
- The possibility of having a sub-clinical infection, though less likely since the fish are active, cannot be totally ruled out.

(Feed)

- The use of poor or less quality feed is a likely cause. The higher the protein and energy content, in most cases, the faster the expected growth rate. So, the feed quality label may be compared with that of his friend's fish feed. If the same feed (or another of similar quality / FCR) is used, a sensual quality feed test should be performed, and where need be a laboratory analysis to ruled out feed degradation.

- Less attractive / palatable feeds, though of similar quality, may encourage poor feeding that often results in reduced growth – conduct the sensual test for feed scent, consistency and dryness.
- Biodegradation of poorly stored feed (or expired feed) may bring about such. Presence of biotoxin in sub-lethal dose may precipitate the condition.

(Facility)

- Check and compare the stocking densities of both systems in comparison with the system carrying capacity.
- Check the filters and aerating systems for efficiency. A slight malfunction in any of these may result in retarded growth / disease condition, depending on the severity.

Probable solutions to the case

- Culture systems should be stocked based on the system carrying capacity.
- Monitor the quality of both in-coming and culture water to ensure sound environmental condition.
- Screen for intestinal and topical parasitic load, and health condition.
- Ensure that cultured fish are fed with high quality, well scented feed.

Finally, disease conditions should be thoroughly investigated, diagnosed, and the right treatment given based on the outcome and case prognosis. However, palliative treatment may first be administered to save the situation in an urgent case, after which proper treatment should be done i.e. treatment based on aetiological cause. The actual cause of the ailment should be known, extent of severity and organs / tissues affected determined in order to administer the right treatment / management.

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Appendices

Advice to Farmers

- Own and regularly visit your farm animals to learn from them.
- Learn about your farm animals' care and be kind to them. This is the best way to obtain the optimum result from them.
- Always have an up-to-date record.
- Do not hesitate to seek the assistance of a n animal health personnel / veterinarian when need be.

Fish Related Businesses

Fish Feed Related Businesses

1. (Conventional & unconventional) feed materials' production
2. Feed materials' supply
3. Feed additives' production & sales
4. Feed machine fabrication and sales
5. Aquafeed software programming
6. Aquafeed production / toll milling
7. Fish feed analysis cum laboratory
8. Finished fish feed marketing

Fish Production Related Businesses

9. Fish seed production

10. Table-size fish production
11. Fish products' marketing / disposal outlets
12. Fish production material / machine fabrication and sales
13. Aquaculture project consultation
14. Fish health and disease consultation
15. Fish disease diagnostic laboratory

Other Fish Related Businesses

16. Zooplankton production, packaging and sales
17. Water analysis laboratory
18. Fish processing factory
19. Fish by-products' marketing

OAK Ventures

Vision

To encourage most homes, schools and farms to be involved in active eco-friendly production of giant land snails, fish and other related activities, at least within their premises, to achieve global food security.

Mission

To develop African's potentials in the area of snail (African Giant Sn ails) and fish production; alleviating poverty and related disease / effects by encouraging sustainable (backyard) production through training and development, and provision of technical services.

Services

Snail and Fish Farm Consultancy & Health Management

Training (including online) on Snail and Fish Farming

Snail and Fish Feed Formulation and Sales

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Plus

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OAK Quotable Quotes

- To seek the LORD is wisdom; to live in HIS counsel is great gain.
- The wise trust in his wisdom; the strong in his strength, but the simple in the LORD.
- The fame of the rich is his hurt, but the wise lies low.
- A man is a " king" where he is wanted; the presence of his " subjects" brings him joy and courage.
- A loving home worth more than rubies, the joy therein is healing to the soul.
- A wise man makes his hands a subject to h is brain, and his brain an instrument of GOD.
- Success comes with patience; the hasty often outruns it.
- The heart that trusts in the LORD, and applies itself to sound teachings, lives forever in peace.
- He that has understanding shall strife for nothing, but the soul of the greedy shall be troubled.
- For fear of want, a man stores up treasure, but the wise disseminate it wisely for prosperity.
- He that is insensitive to mockery, but is focused on his goals, shall be called an achiever.
- The zeal of a determined man paves ways for his success, but he that faints in the days of trial shall prolong his woos.
- A man of valour is he that sees hardship as a challenge and calls innovation his friend, for in challenges come victory.

- He that is kind to his neighbour fortifies his soul, and he that shut not his heart to the needy shall have his name written in gold.
- The love shown to a dog makes it wag its tail and not bite.
- Intelligence is a privilege; use it for the good of mankind.
- Guide your mind, it is your " power house"; follow the vision, dare to make the good difference, and success will be yours.
- The profit of life is eternity; he that invests in it shall rejoice.
- Education is achieved by searching for the truth, while wisdom is in its application. So, live for the truth, be close to its source (your maker), and be a blessing to all.
- I love wisdom but for its price; I seek power but it's too demanding; I prefer wealth but for the troubles it brings; yet I want to live but for life's worries.
- Life is a privilege; treasure it while it's yours. Be a good influence, a gift of life for others to treasure while you're gone.
- Life is but a dream to one without hope; a taboo to him without focus; a routine phenomenon when there is no decisive destination, and a fairy tale to him without CHRIST.
- Life is a teacher, for those who care to learn; an indicator to the truth, for those that can see; a pointer to The Creator (GOD) and wisdom to the willing soul.

OAKman

Food for Thought

- Consider to learn from the goose and hen; sheep and goat. The one brags and fights for itself, yet it ends up being a victim of circumstance, while the other (gentle and humble) is always fought for By GOD.

- Though you may not comprehend, you have a divine calling which only you can unravel to fulfil. Apply your heart to it in determination, trusting GOD, and success will be yours.

- A slow-tongue with quick understanding, insult -ignoring heart and life - saving words, is an uncommon treasure from GOD.

- When tempted, strengthen self in Him, knowing that He won't leave nor forsake the faithful; when lost, signal for His help for He's the light to your path in life; when down, let His word & the faithful's testimonies uplift you. He cares!

- Behold, the same dark sky is made clear and bright by the appearance of the sun. Only CHRIST can give the right meaning to your life.

OAKman

Your Comments, Observations and Contributions are welcomed and appreciated

Be a Determined, Diligent, Disciplined Advocate of what is good and pleasing to GOD.

Thank you for reading my book.

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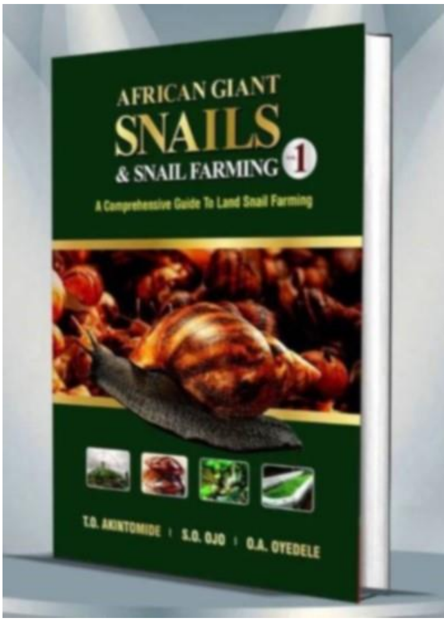

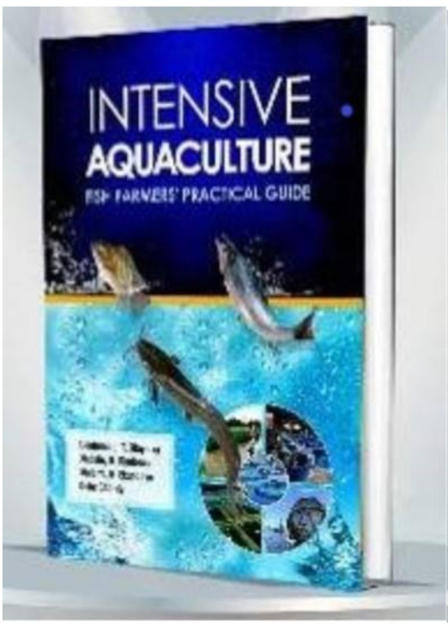

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