Best Management Practice guidelines (BMPs) for GIFT tilapia & Curriculum for the Promotion of Commercial Aquaculture in Nigeria

Report submitted to WorldFish Nigeria

Krishna R. Salin, PhD

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Contents

1. Introduction

CHAPTER 1

Introduction

Introduction to aquaculture

FAO defines aquaculture as farming aquatic organisms with some form of intervention by individuals or corporates who own the stock being cultivated in the rearing process to enhance production. Manipulations of spawning/ breeding and stocking density, provision of aeration to supply dissolved oxygen, feeding with formulated feeds, and protection from predators are the forms of intervention in aquaculture. This definition implies that humans modify the life cycle of cultured animals. The modification of the life cycle of Nile tilapia by humans for aquaculture purposes is depicted in Figure 1.

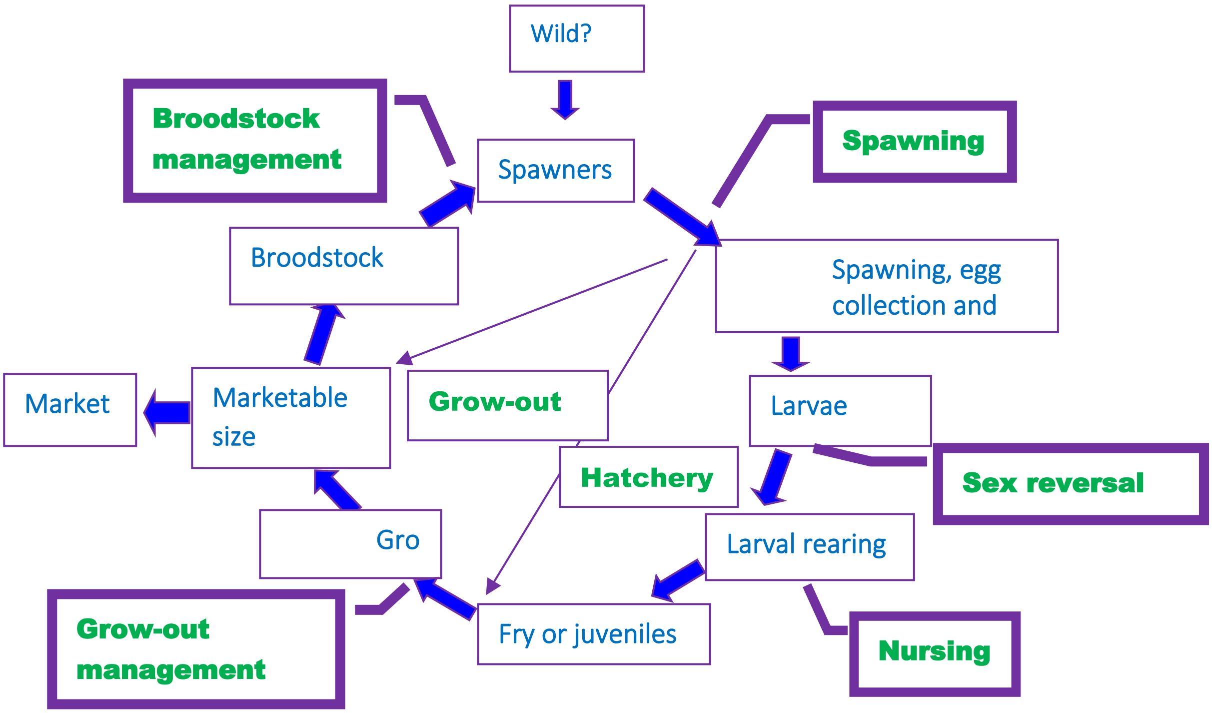


***Figure 1** Aquaculture production process of Nile tilapia*

For fish like Nile tilapia, the whole life cycle can be manipulated. However, in Africa, broodstock is still collected from the wild by many farmers. In commercial Nile tilapia culture, the sex of fish larvae is converted to males by hormonal manipulation. Larvae are then nursed using high-quality feeds to produce fish fry or juveniles for grow-out culture. There are two major types of grow-out systems in Africa – cage culture and pond culture – to rear fish up to marketable size. Some of the healthy fishes from the grow-out culture can be used as broodstock.

Introduction to the curriculum

There are two types of aquaculture: (1) non-commercial aquaculture; and (2) commercial aquaculture. Non-commercial aquaculture is mainly a small-scale family-business venture. It plays an extremely important role in contributing to food security and contributes to local aquaculture market chain. This curriculum is developed to assist in upgrading the aquaculture value chain and focuses mainly on commercial aquaculture. The major goal of commercial aquaculture is to maximize profits. Profit is one of the main performance indicators of the economic sustainability of commercial aquaculture.

Fixed cost of aquaculture operations arising from land, pond construction, cage frame and net-bags, equipment, fish seed, fingerling, feeds and feeding, oxygen supply, water pumping/ exchange, electricity, etc., account for the operation cost. Provided that the farm is already in operation (i.e. fixed cost has been fixed), the major cost for a practitioner is the operation cost. This curriculum is mainly developed to help farmers to improve the technical aspects of aquaculture with a session (or several sessions) dedicated to introducing the concepts of aquaculture business.

The aquaculture business should be economically viable or sustainable over time, which requires the business venture to be profitable and competitive to stay in the market. The latter requires the improvement of the production process as the market demand changes over time. Hence, the producers also should pay attention to the changing consumer demand and keep consumers satisfied with the product's quality as well as the way the product is produced. Therefore, producers must respect the legal, environmental and social sustainability of aquaculture while making profits.

Legal sustainability: As with any other industrial sector, commercial aquaculture industry is governed by the laws and regulations of the particular country. Industrial stability is one of the criteria potential investors look for, and the laws and regulations are designed to make the sector stable. Thus, legal and economic sustainability are linked as investment is a necessary component to stay competitive in the market.

Social sustainability: Aquaculture should be socially acceptable to the local community where the production facility is located, and the product should be acceptable to the market, consumers, and various interest groups in the society that have a stake in the process, e.g., environmental groups monitoring the pollution effects. Moreover, the production operations should benefit a broader proportion of society, including women, young people, and the poor.

Environmental sustainability: Aquaculture should produce aquatic animals in responsible and ethical ways by reducing/ eliminating environmental pollution. All negative impacts of aquaculture should be reduced/ mitigated to maintain the integrity of aquatic ecosystems that the production process is embedded, thereby enabling farmers to continue production at the same site over time.

This course takes a holistic view of designing and delivering a curriculum aimed at promoting a sustainable aquaculture production process considering the total sustainability (economic, legal, social and environmental sustainability) of the business to ensure the future prosperity of the sector. The course is also focusing on the need for injection of new investments to upgrade the current systems to improve both the product quality and the production process.

One of the most important aspects of aquaculture production planning process is to address the following questions on the product and market characteristics, access to resources and the operation model:

Product:

1. What species to produce? e.g., Nile tilapia (this curriculum focus on Nile tilapia)
2. How much (the producer wants) to produce? e.g., the target quantity per crop (tonnes/ crop)
3. What quality? e.g. size of fish, taste, food safety

Market:

4. For whom to produce: i.e., the target markets, e.g. local market, processors, export market
5. What quality is demanded by market? e.g., the quality expected by the market, such as non-contamination of antibiotic and chemical residuals
6. The nature of the product: e.g., live, frozen, processed, and the individual weight of fish at harvest
7. What is the capacity of market? e.g., what quantities the market can be absorbed without over supply (supply of fish more than the demand reduces farm-gate price)

Resources:

8. What resources are available? e.g., land, number of ponds, number of cages; feed; fish seed, labour, electricity, credits to cover operation costs etc.
9. What are costs per unit resource, e.g., price per tonne of feed, labour wages, electricity costs

Operation model:

10. How to produce? Define resources required for the production process, e.g., pond aquaculture, cage culture) and how to combine the resources (e.g., pond fertilization, feeding) for efficient production
11. How to make sure the system is bio-secured?
12. What are the by-products of the production process? e.g., effluents, sludge etc.
13. What is planned to do with by-products? e.g., waste treatment methods

These questions will be raised throughout the course in relevant sessions to emphasise the business side of the production process. The Best Management Practice guidelines (BMPs) on tilapia production are also discussed as detailed descriptions of the course content to make this report more compact.

Modular structure of the course

The course consists of two modules, covering the part of the life cycle of Nile tilapia shown below. Each module consists of 10 sessions, and one session would preferably take around 3 contact hours. All the sessions are followed up by either discussion or a laboratory/ practical session.

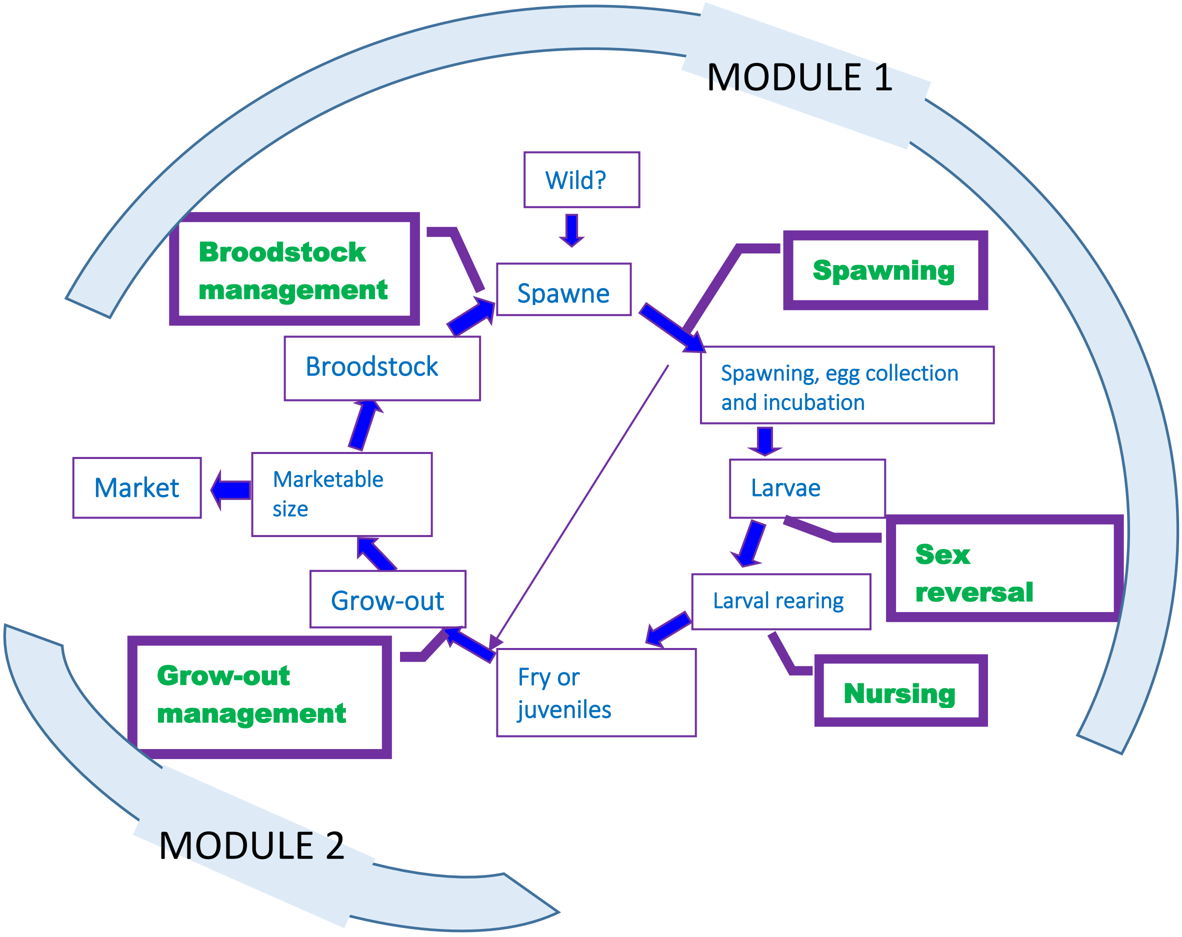


Figure 2 *Module 1 focuses on Nile tilapia seed production process. It begins with exploring the biology of Nile tilapia and then moves into discussing broodstock management, spawning, sex reversal, larval rearing, and nursing*

Table 1 *Module 1: Nile tilapia seed production - Objective: To provide high quality seeds for grow-out farmers*

Session	Lecture sessions	Practical sessions
Session 1.1	Biology of tilapias – general and reproductive biology	External characteristics; sex identification from external features; dissection of fish for internal organs
Session1.2	Reproductive physiology	Class discussion
Session 1.3.	Broodstock management and improvement	Class discussion; Short trial testing different sex ratios
Session 1.4	Nile tilapia breeding systems – pond, tank, and hapa based systems	Making hapa from blue nets; setting-up hapas in ponds and add broodstock
Session 1.5	Egg collection, transportation, incubation and hatching	Egg collection and incubation
Session 1.6	Sex reversal (preparation of MT feeds and feeding) and nursing	MT feed preparation and feeding Hatchery visit
Session 1.7	Sex determination	Aceto-carmine squash method of sexing fish fry)

Module 2 focuses on the grow-out process, both pond and cage culture. After introductory sessions, three sessions are dedicated to feed formulation, feed production and feeding and nutrition, as the unavailability of commercial feed is the most significant hindrance for commercial Nile tilapia culture ventures in Africa. Feeding and nutrition alone are insufficient – culture stock, water quality, and health management should go hand in hand. Harvesting methods are dependent on the marketing system – the linkage is highlighted. In the end, the fundamentals of aquaculture business management are discussed.

Table 2 *Module 2 – Nile tilapia grow-out process - Objective: To provide high quality fish to the supply chain*

Session	**Lecture session**	**Practical session**
Session 2.1	Principles of Nile tilapia grow-out culture	Class discussion
Session 2.2	Pond culture systems	Class discussion
Session 2.3	Cage culture systems	Class discussion
Session 2.4	Nutrition, feed and feeding	Nutritional calculations
Session 2.5	Feed formulation	Linear programming for Least Cost Feed Formulation
Session 2.6	Feed manufacture	Feed production and a short feeding trial
Session 2.7	Water quality management	Field exercise on water sampling and analyses
Session 2.8	Harvesting and marketing	Harvesting and ice storage
Session 2.9	Health management and biosecurity	Class discussion
Session 2.10	Aquaculture business management	SWOT analysis and Business Plan Development

The detailed session structures of the two modules are described in the following sections.

2. Module 1: Nile tilapia seed production

CHAPTER 2

Module 1: Nile tilapia seed production

Session 1.1: Biology of tilapias – general and reproductive biology

Session objectives:

To outline the reproductive biology of tilapia in relation to breeding and seed production

Learning outcomes:

At the end of this session the trainees will be able to understand the salient feature of tilapia reproduction

Session narrative:

Fish reproduction is an extremely complex process. Fish represent one of the most diverse groups of organisms among vertebrates in their patterns of reproduction. From an evolutionary point of view, fish are a versatile group with nearly every kind of adaptation for reproduction – structural, physiological, as well as behavioural. Most fish reproduce sexually, and fertilize their eggs externally. However, there are some fish with internal fertilization of eggs; for example, the live-bearing sharks, freshwater fish guppy, platy, molly, etc. that deliver the young ones. Most fish reproduce seasonally. The gonads in fish remain small during non-reproductive season, and in general, the gametes are produced only during spawning season.

Tilapia as a group plays a great role in tropical aquaculture with the Nile tilapia, *Oreochromis niloticus*, holds great economic promise in providing food and nutritional security and creating rural employment. As tilapia farming expands worldwide, the demand for its seed for stocking in production ponds also increases. Besides, the fish continues to be introduced in many regions outside its natural habitats. It is therefore important to understand the basic biology and ecology of tilapia, particularly in relation to its reproduction. This will help to improve the efficiency of intensive seed production and minimize the impacts of tilapia farming on the environment.

Figure 3 *Nile tilapia, Oreochromis niloticus broodstock*

Tilapia is a member of the family Cichlidae. Three genera are well-known, namely *Oreochromis*, *Tilapia* and *Sarotherodon*. Tilapia are endemic to Africa, Jordan, and Israel (more than 70 species), while only a few species are commercially important. Adult tilapia eat predominately vegetarian diets varying from macrophytes to phytoplankton, depending on species. Many structural features are related to the feeding habit, such as a terminal mouth, slender, notched teeth, long gill rakers, and long intestines (7 – 14 times the standard length) suitable for processing a plant diet.

This session outlines the reproductive biology of fish in general, and Nile tilapia in particular in relation to large-scale seed production of tilapia. Emphasis is given to the practical aspects of seed production and a short exercise to apply the skills learned by students from this session is included. A list of references for further reading are compiled at the end of this Module.

Reproductive cycle in fish

The reproductive cycle refers to the succession of processes in fish from immature germ cells to the production of mature gametes (eggs and sperm) that will finally unite and develop as the embryo. The process of formation, growth, and differentiation of gametes is called gametogenesis. This leads to the formation of female oocytes (oogenesis) and male spermatozoon (spermatogenesis). The reproductive cycle in both male and female involves two major phases – the 'growth phase' representing the phase of gonadal growth and development, and the 'maturation phase' leading to spermiation/ovulation and spawning. Spawning is the release of the mature gametes to the external environment, which is a highly synchronized event resulting in fertilization of the egg and embryo development. The successful progression of all these processes of the reproductive cycle resulting in production of good quality gametes is the basis of a successful event of reproduction in fish. The physiological aspects of the reproductive cycle are discussed in session 1.2.

Size at first maturity of Nile tilapia

The size and age at first maturity of tilapia varies with species and strains within the same species. Under natural conditions, Nile tilapia reaches sexual maturity at a size of 20–30 cm (150–250 g). However, in aquaculture ponds or under stressed environmental conditions Nile tilapia often reaches early maturity (30 – 50 g).

Identification of male and female tilapia

Water temperature has a significant effect on sex differentiation, sex ratio, and morphological development during early larval stages of tilapia, although at increased temperatures slow growth and body deformities may occur. Increased temperatures (34 – 36^{0}C) significantly increase the proportion of males (69 – 91%), while lower temperatures do not affect sex ratio.

Male and female fish can be identified by the shape and size of the genital papilla that is long and pointed in the case of male, and blunt in the case of females. Female body has three openings to the outside – the anus, urethra, and the opening of the oviduct in the form of a slit. Male is often larger than a female of the same age and has two openings to the outside – the anus, and the urinogenital aperture. These differences are easily distinguishable after the fish has grown to the size of 10 – 20 cm or 100 – 150 g, and are more pronounced during the breeding season when the male also develops a reddish colour around the jaws. Figure 2 highlights the differences between a male and a female tilapia during spawning season.

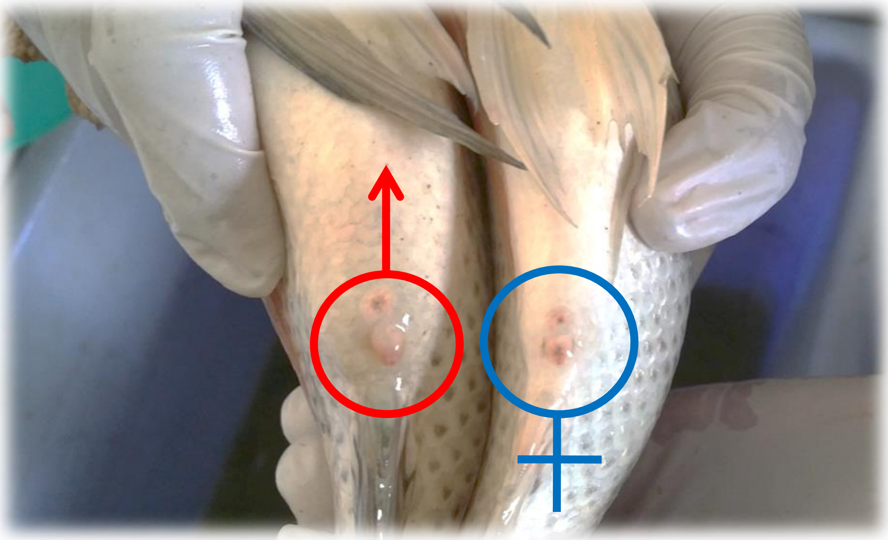


Figure 4 *Identification of male and female tilapia by external morphology*

Mode of reproduction of tilapia

Tilapias are nest builders and substrate spawners. *Tilapia* spp. guard the developing eggs and fry in the nests; *Oreochromis* spp. females incubate eggs and fry orally; and *Sarotherodon* spp. males and/or females incubate eggs and fry orally. Nile tilapia is a maternal mouthbrooder in which the fertilized eggs are incubated in the oral cavity of the female fish, similar to other species such as *O. mossambicus* and *O. aureus*.

The mode of reproduction in Nile tilapia is quite unique. The males build a spawning nest (Figure 3) by defending a breeding territory where only the visiting females ready for courtship will be allowed. The courtship lasts for a few hours followed by spawning by female repeatedly releasing a string of about 20 – 50 eggs followed by the male fertilizing the eggs by gently passing right over the eggs and releasing milt. Then the overturning female immediately captures all the eggs into her mouth for oral incubation (Figure 3). Often fertilization of tilapia eggs takes place inside the female's buccal cavity after the female sucks up the milt as well as the eggs into her mouth cavity for fertilization and incubation.

Figure 5 *Nesting and mouth incubation in Nile tilapia (Photo credits: www.sxlist.com; www.congo-pages.org; www.hawaii.edu)*

Temperature and photoperiod are the most important factors influencing spawning. The breeding behaviour of most species of tilapia begins when water temperature reaches 20^{0}C, and spawning starts at 22^{0}C. Optimum spawning temperature for Nile tilapia range from 25 to 30^{0}C. In tropical regions, spawning may continue year-round. Ripe females school in midwater with non-territorial males and egg-brooding females. 4 to 7 batches of eggs are spawned in one mating.

Photoperiod appears to have a significant role in reproductive performance of tilapia with the optimum reproductive performance taking place in normal daylength (12 h light : 12 h dark cycles). Other environmental factors that influence tilapia reproductive performance indicators such as size at first maturity and broodstock productivity include feeding and feed quality. Provision of good quality feed results in bigger size at first maturity and spawning.

Fecundity and egg size in tilapia

A characteristic feature of tilapia is low fecundity and relatively large egg size. Fecundity can be expressed as the number of mature ova in the ovary, the number of ovulated eggs, or the number of eggs deposited during spawning, all of which may vary for fish of equal size. Nile tilapia is reported to produce between <100 to >3000 eggs per spawn with the egg sizes ranging from <2.0 to >7.9 mm. Volume of eggs range from 2.8 to 11.1 mm^3, each weighing up to 3.7 mg mean weight. Approximately 100 – 500 eggs can be expected from every spawning batch. On a practical point of view, it is ideal to refer to the fecundity of tilapia as the 'number of fries produced per year' considering the environmental variables that can affect egg and fry production.

Table 3 *Optimum fecundity of Nile tilapia under different environments (El-Sayed, 2006)*

Culture systems	**Fish weight (g)**		**Sex ratio (♂:♀)**	**Stocking density/m³**	**Eggs/female (average)**	**Remarks**
	Male	Female				
Glass aquaria		42 – 75	1 : 3	28	305–753 (507)/spawn	Fed 40% cp in freshwater
Closed	162 – 211	112 – 177	1 : 3	4	3165/kg/month (678)	Fed 45% cp
Closed	117 – 177	92 – 160	1 : 3	20	50.9/kg/day	Photoperiod of 2500 lux, for 18 h
Concrete tanks	439	206	1 : 3	1.67	39.1/g (1328)	Fed 45% cp

cp = crude protein

During the initial period of maturity and growth the fecundity increases, which however, decreases as the fish grow very old. Optimum size of female breeder for tilapia seed production is 150 – 300 g, which produces about 200 – 500 fry per month. Smaller female produces many more eggs than larger fish with shorter spawning intervals of just over 100 days, while larger fish produce more eggs per clutch than smaller females. Larger eggs contain more yolk and result in larger, stronger, and fast-growing fry.

Egg incubation and larval development

Incubation time for tilapia is inversely and linearly related to temperature. Time to hatching of Nile tilapia eggs vary from 2-3 days at 34^0C to 8 days at 17^0C. The average duration of the incubation period and parental care is approximately 20 days. The number of days that the eggs take for hatching can be calculated by the following formula:

$$Hatching\ days = (12.8 - 0.32) \times temperature(\text{degree Celsius})$$

Temperature has an important effect on various biological relationships. Water temperature affects sex differentiation, sex ratio, and morphological development during early larval stages of tilapia, although at increased temperatures slow growth and body deformities are likely to occur. Temperature also affect the sex ratio in tilapia by increasing the proportion of males at higher incubation temperatures of 34 – 36^0C.

Tilapia eggs pass through four stages before getting transformed into the free-swimming fry (Figure 4). Stage I is characterized by light to dark yellow in colour; stage II with golden yellow colour; stage III with golden brown with dots on egg; and stage IV, which is the hatched yolk sac fry. The fry becomes free swimming when the yolk sac is absorbed.

Larval development involves the functional development of the mouth, 4-5 days after hatching (DAH) along with the absorption of yolk and development of swim bladder that aids in buoyancy control. Feeding begins between 8-10 DAH when the larva reaches a size of about 8 mm total length (TL). The females leave the brooding areas when the fry become 9-10 mm TL. The main food of the fry are diatoms and some amphipods, insects, and copepods.

In tilapia seed production there are mainly two types of systems for incubation of eggs and larval rearing. In the natural breeding system, the mouth-breeding females can be left to the pond to incubate the eggs and release the free-swimming fry to the pond from where they can be collected for further rearing to fingerlings. In the artificial incubation and hatching system, the eggs and yolk sac fry are collected from the mouth of incubating females and incubated separately in specialised hatchery systems. This system is most suited for large scale production of goof quality tilapia fry.

Figure 6 *Stages of egg development in Nile tilapia*

Exercises:

This exercise involves stocking breeders in hapa fixed in a pond, and examining the male and female broodstock of Nile tilapia maintained in breeding hapas for the following tasks:

- Identify the distinguishing features of male and female breeders and draw sketches in the record book
- Dissect the male and female fish and identify the internal organs
- Observe the mouth of female fish and collect the eggs or yolk sac fry after one week of stocking them
- Record the fecundity and different stages of eggs obtained

Module 1: Nile tilapia seed production

Session 1.2: Reproductive physiology of Nile tilapia

Session objectives:

To identify the complex interaction of environment (external) and hormonal (internal) factors that lead to successful reproduction and propagation of fish

Learning outcomes:

At the end of this session the trainees will be able to appreciate the role of the various factors that regulate the internal processes of reproduction in fish

Session narrative:

Reproductive physiology of fish refers to the overall progression of the physiological processes related to reproduction right from egg fertilization to embryo development, hatching, growth and puberty, male and female gonadal development and gametogenesis, sexual behaviour, timing of reproductive cycles, and endocrine and environmental control, all of which culminate in spawning. Internally, all these events associated with reproduction are regulated by the endocrine (hormonal) system in fish associated with the brain-pituitary-gonadal axis. These processes also interact with other important physiological functions in fish such as growth, nutrition, osmoregulation, and stress response. Many of the physiological attributes including tolerance to a wide range of environmental conditions such as dissolved oxygen, salinity, and high stocking densities contribute to the increasing popularity of tilapia in aquaculture. Environmental factors such as temperature, photoperiod, seasonal rainfall, water quality, and food availability are also known to significantly influence the physiological processes connected with fish reproduction.

Tilapias exhibit early maturity and relatively short reproductive cycles with prolific breeding under culture conditions. There are two phases in fish reproduction; the growth phase (gametogenesis), and maturation phase (Oocyte maturation in females and spermiation in males) both controlled by reproductive hormones of the brain, pituitary, and gonad. In most fishes, the growth phase can be achieved under captivity (controlled conditions), but the maturation phase require external hormone therapies. However, tilapia is an easy-to-breed fish that does not require any inducement for maturation and spawning as the reproductive processes are triggered naturally. This is one of the most significant advantages that propelled Nile tilapia aquaculture even in remote areas of their natural occurrence.

Environmental control of reproduction in fish

Reproduction in fishes is regulated by external environmental factors that trigger internal mechanisms into action. A constantly changing environment in which the fish live has a direct influence on the regulation of reproduction. Most important environmental factors that are known to affect reproduction in fish include photoperiod, water temperature, rainfall, stocking density, sex ratio, diet quality, presence of pheromones, substrates, water quality, diseases, parasites, etc.

Photoperiod appears to be one of the most important external impulses that influences fish reproduction by its well-known effect on the brain-pituitary-gonad axis. Temperature has its effect on its own and also in combination with photoperiod. Suboptimal temperatures inhibit the development of gonads. Nile tilapia produces sperm above a temperature of 24°C but spermatogenesis is arrested at 20°C. Besides its direct effect on gonadal development, temperature influences reproduction through the metabolic rate influencing the endocrine process. Generally high stocking densities retard the reproduction process in tilapia. Nile tilapia stocked in single compartments spawned more often than those which were stocked in groups. There has been some indication that the pheromones from female tilapia attract male towards increased courtship behaviour. Feeding tilapia with diet containing the optimum nutrients including protein and lipids has also been found to significantly influence reproduction in Nile tilapia. For example, tilapia females fed 20 and 35% protein diets had a higher output of eggs per spawn than those fed l0%. Major water quality parameters that have been found to influence reproduction in Nile tilapia include pH, hardness, dissolved oxygen, and salinity.

Endocrine control of reproduction

External factors controlling reproduction vary widely across fish species whereas the internal mechanisms that regulate spawning are similar in most fishes. The endocrine system is a collection of glands and organs that produce hormones, and regulate the secretion of hormones that control various body processes such as growth, metabolism, reproduction, etc. In fish the endocrine system regulating reproduction acts through a cascade of hormones along the brain-pituitary-gonad (BPG) axis (hypothalamo-hypophyseal-gonadal axis), also called the reproductive axis. The BPG axis sets the stage for the endocrine mechanism in fish regulating the entire process of reproduction in conjunction with various environmental and social signals. The sensory signals from the environment and other factors are transmitted to the part of the brain called the hypothalamus. The Gonadotropin-Releasing Hormone (GnRH) produced from the brain stimulates the secretion and supply of two pituitary gonadotropins (GTHs) namely Follicle-Stimulating Hormone (FSH) and Luteinizing-Hormone (LH) to control reproduction.

Pituitary gland, also known as hypophysis, is a small organ located on the floor of the brain in a cavity formed from the roof of the buccal cavity in fish. The anterior lobe (adenohypophysis), which regulates gonadal function in fish, and the posterior pituitary lobe (neurohypophysis) that serves as the major storage and transport region are the two major segments of pituitary responsible for the delivery of hypothalamic hormones. The pituitary gonadotropins initiate the growth phase (FSH) and maturation (LH) of gametes.

The hypothalamus in fish synthesizes products influencing reproduction (both stimulatory and inhibitory) that are transported to the pituitary by direct neuronal innervations. The neuronal processes, originated in the hypothalamus, penetrate into the pituitary and allow direct neural control of the pituitary function. The neuropeptide GnRH is the primary factor regulating reproduction, functioning to integrate the cues from the external environment and stimulating and sending neuroendocrine inputs for the regulation of the reproductive axis. The direct action of the GnRH stimulates the pituitary gland to secrete FSH and LH into the bloodstream that in turn acts on the gonads to synthesize steroid hormones leading to gonadal development. The smooth functioning of all components of the BPG axis throughout the reproductive cycle is vital for successful reproduction.

Dopamine is an inhibiting factor produced by hypothalamus to inhibit the production of GTHs in tilapia. The gonadal steroids can act either on the level of gonadotrophs from the pituitary or on the hypothalamus to increase dopamine levels in blood to either accelerate or inhibit the growth and maturation of gametes for reproduction. Depending on the reproductive phase of fish the gonadal steroids exert a positive or negative feedback control on the secretion of GTHs, particularly the LH that regulates the final maturation and release of gametes. The inhibition of dopamine secretion from the brain will stimulate GnRH secretion and thereby the secretion of GTHs. In sexually mature fish the gonadal steroids exert a negative feedback action on LH release, whereas in sexually immature fish the gonadal steroids exert positive feedback on LH secretion.

Gonadal development

Gonadal development in fish coincides with the different maturity stages and occurs during the onset of breeding season. While sexual differentiation of tilapia into male and female gonads occurs around 15 to 30 days after fertilization, the onset of sexual maturity varies from 2 – 3 months, influenced by environmental conditions. The development of ovary and ovulating mature eggs involve a series of processes mediated by hormonal and environmental factors.

The growth phase of ovaries in fish has six stages namely oogenesis, primary ooctyte growth, corticular alveolar stage, vitellogenesis (yolk deposition), maturation, and ovulation. Oogenesis is the process of creation of an egg in the female body and it starts with the differentiation of germ-line stem cells to generate a cyst of 16 cells that one of them will become the oocyte and the remaining 15 supply the oocyte with materials. The stem cells proliferate and undergo changes that turn them into oogonia which involves different stages and a complicated regulatory mechanism. The bulk of the mature (fully-grown) oocyte is due to yolk accumulation. The yolk precursor protein (vitellogenin) is synthesized in the liver and released into the bloodstream in response to the hormonal stimulation. Ovulation is the process of releasing mature oocytes aided by the rupture of follicular layer into the ovarian cavity. At this state the matured egg is ready for sperm binding and fertilization. The pituitary gonadotropins and gonadal steroids regulate the oocyte maturation process and vitellogenesis. Spawning is the release of mature oocytes from the ovary to the external environment.

Development of testes and spermatogenesis consists of three major stages; mitotic proliferation, meiosis and spermiogenesis. The spermatogonial stem cells are transformed into spermatogonia which produce four spermatids that finally transform into the flagellated spermatozoa. In the tropical conditions Nile tilapia is known to have a continuous sperm production throughout the year.

Exercises:

- Make two groups of students in the class
- Ask to draw a picture on the board highlighting the brain-pituitary-gonad axis controlling reproduction in tilapia, and discuss the various processes that underlie this regulation.
- Identify the different hormonal factors at each level and discuss their effects on regulating the reproduction in tilapia.

Session 1.3: Broodstock management and improvement

Session objectives:

To understand and apply the general principles of broodstock management of Nile tilapia for sustained hatchery production

Learning outcomes:

At the end of this session the trainees will be able to apply good broodstock management principles important for production of good quality tilapia fry

Session narrative:

Fish broodstock refers to the group of mature individuals maintained for breeding purpose either as a source of replacement or for enhanced fry production destined for grow-out. Good broodstock management involves the manipulation of environmental and genetic conditions around the broodstock to ensure maximum survival and enhanced reproductive performance including good gonadal development, high fecundity, and high fry survival. Obtaining good quality broodstock is the primary criterion that determines the success of a Nile tilapia hatchery.

Achieving sustainable production of Nile tilapia seed requires careful broodstock selection and management. Important information on broodstock include stocking density, nutritional management, fecundity, sex ratio, and environmental conditions in which the fish are maintained. Considering these factors will help ensure the maximum hatchery production efficiency. The following section highlights the major principles of broodstock maintenance of Nile tilapia for enhanced survival of its fry and sustained hatchery production.

Broodstock selection

The first step in broodstock management is stock selection. It is ideal that the farm establishes its own broodstock by selecting the best performing female and male fish of known genetic background. The broodstock have to be handled very delicately with the least stress to the fish during their segregation and selection for pairing in breeding ponds. While holding or carrying broodstock fish by hand, it is recommended to wear gloves and cover the eyes of fish with one hand so that the fish will remain calm. Slightly excess stock (25 – 50% extra) than the actual quantity planned to be bred every year should be maintained. This will facilitate meeting the seed production targets and ensure selection of the best pairs from the stock adapted to captivity for a reasonable period.

Important considerations in selection of tilapia broodstock include:

- Select genetically pure fish, avoiding individuals with unknown or doubtful origin
- Select fish with good shape and body form, and without any physical deformities or injuries, diseases, or parasites.
- Select reasonably big-sized fish avoiding the ones that are too small, as smaller fish may have a lower reproductive quality
- Maintain the broodstock belonging to different lines in separate holding facilities with no chance of mixing
- Avoid broodfish that are too old and have spawned several times, as fecundity may become lower in fish that are too old. It is recommended to cull broodstock that is older than 1.5 to 2 years
- Ensure that no fish from the previous breeding cycle remains in the pond while starting a new breeding cycle

- Take reasonable measures to avoid inbreeding (breeding closely related stocks) by maintaining a large founder population and ensuring that a large proportion of them have a chance to breed.
- Select juveniles for new broodstock from as many parents as possible while selecting for new broodstock
- Maintain proper record of all the stock held, and the breeding trials carried out, and
- Prevent the entry of any inferior quality stock (of the same or other inferior tilapia species) to the broodstock pond by filtering incoming water to the ponds efficiently.

Figure 7 *Egg collection from tilapia broodstock in hapas*

Rearing of broodstock from fingerlings

For rearing fish to the broodstock size, it is good to stock fingerlings in ponds at lower stocking densities of 1 – 2 fish/m^2. The breeding size is achieved in 5 – 6 months with the fish reaching 150 – 250 g. Proper fertilization of ponds using organic and inorganic manures will promote faster growth of fingerlings to broodstock size. Organic manures include chicken manure applied at a dose of 100 kg/ha/month. In addition, inorganic fertilizers like ammonium phosphate can be applied at 50 kg/h every month. Commercial pellet feeds containing about 30% crude protein has to be fed at the rate of 3 – 5% of body weight at least twice daily.

On attaining the breeding size, the male and female breeders should be segregated and held separately for conditioning. For breeding the females have to be carefully selected and introduced to the male in hapas. After conditioning, the readiness of female for spawning can be visually examined by the morphological changes, and are categorised into four maturity stages, viz., ready to spawn (RS), swollen (S), not ready to spawn (NRS), and already spawned (AS) as depicted in Table 4. The female breeder that falls under the category 'ready to spawn' should be selected for introducing to the hapa in company of the males for breeding. At least 10 – 15 spawning are achievable from each fish before they are culled.

For synchronous spawning, it is important to select males and females of almost the same size. If the males are significantly larger (30 – 40% larger than females) they will become very aggressive, frequently nipping on the females that may even lead to female mortality. Conditioning males and females separately before pairing, and selecting only the most 'ready to spawn' females are very important in attaining synchronous spawning. Synchronicity in spawning means that many females spawn at about the same time, which ensures that several batches of similar sized fingerlings are available for grow out.

Table 4 *Different maturity stages of Nile tilapia – adapted from Puttraksar (2004) and Nandlal and Pickering (2004)*

Category	Days to spawning	Description	Timing of fry collection from open ponds/hapas (days)
Ready to spawn (RS)	3 to 7	Pink to red and protruding genital papilla; fully opened genital pore; and distended abdomen	10 - 14
Swollen (S)	5 to 10	Pink to yellow genital papilla; slightly opened genital pore ; and slightly distended abdomen	12 - 16
Not ready to spawn (NRS)	21 to 30	White to clear and flat genital papilla; and normal to swollen abdomen	Further conditioning
Already spawned (AS)	15 to 30	Red genital papilla; shrunken to compressed abdomen	Further conditioning
Immature	No imminent spawning	Papilla very small with no sign of maturity	Further rearing required

Stocking density and sex ratio

It is important to maintain the correct stocking density and sex ratio of broodstock in ponds or hapas to facilitate an efficient hatchery production. High or low stocking densities would reduce seed production efficiency. Higher densities result in increased aggression and fighting behaviour among males, drastically reducing seed production by reduced courtship, egg fertilization, and incubation. Tilapia mucus has also been found to contain a substance that elicits autoallergic responses inhibiting reproduction at high stocking densities.

Several studies on the optimum stocking density of tilapia broodstock have reported different stocking densities depending on the culture system, broodstock size and condition, and water quality. These reports suggest that the optimum stocking density that gave better seed production and spawning synchrony falls within the range from 4 to 6 fish/m^2 compared to the higher densities tested (Figure 5).

Optimum sex ratio is another important consideration to maximize seed production (Figure 5). Different sex ratios of male and female have also been evaluated by many researchers. The male : female ratio tested range from 1 : 5 to 1 : 10, and it is found that the ratio of 1 : <3 is optimum for synchronous spawning. The optimum ratio was also reported as 1 : 2 compared to 1 : 3 (Hughes and Behrends, 1983). It is ideal that the hatchery operator makes an own assessment of the optimum sex ratio based on the farming systems (pond, hapa, etc.) and broodstock conditions (size and age).

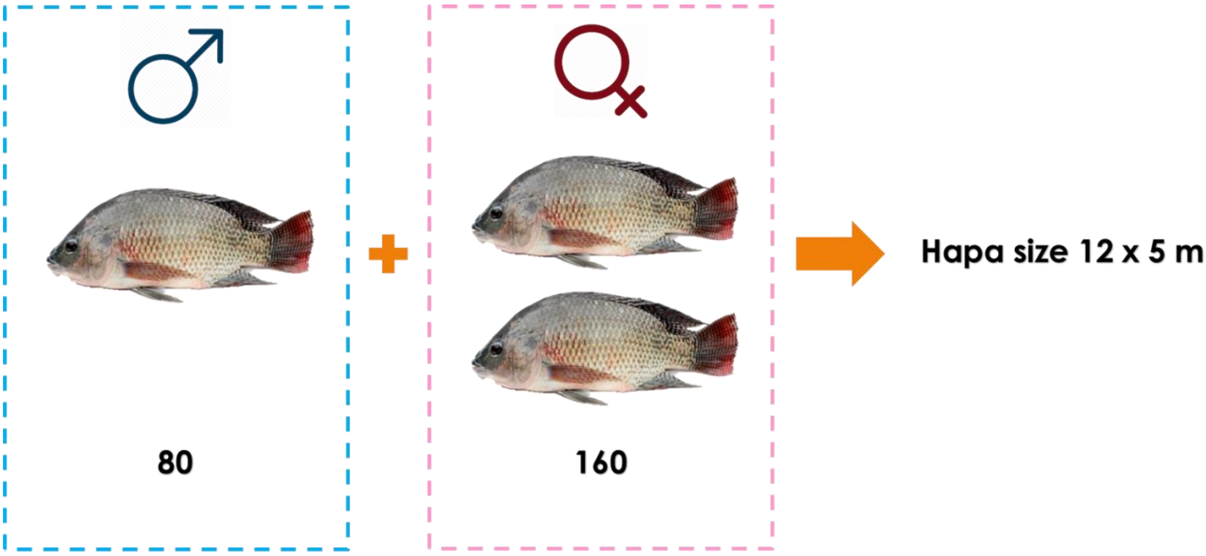


Figure 8 Recommended sex ratio for tilapia broodstock in breeder hapas

Spawning interval

One of the main characteristics of tilapia is their early maturity and asynchronous spawning. Tilapia can spawn several times a year if suitable environmental and culture conditions are attained. In these multiple spawning fishes, females' ovaries contain oocytes of different developmental stages at the same time. As a result of different gonadal developmental stages in tilapia, spawning intervals are expected to vary considerably among species, and even within the same species. These intervals are influenced by fish size and age, stocking density, sex ratio, nutrition status, culture conditions and environmental factors. For example, the first- and second-year classes of Nile tilapia spawned at short intervals (7 – 12 days) while the third year classes fish spawned at longer intervals (10 – 20 days) (Siraj et al., 1983).

The removal of eggs and fry from the female's mouth has been found to accelerate vitellogenesis, shortens the inter-spawning interval, and increases seed production. The spawning interval was shortened to 15 days when eggs were removed from the female's mouth compared to 27 days while they were left to be incubated by female in ponds (Baroiller et al., 1997). Removing eggs and fry at 5-day intervals is a common practice in Asia which has been found to increase seed production/kg/female/day compared to seeds produced from natural incubation (Macintosh and Little, 1995). Leaving females for undertaking parental care in ponds may significantly reduce their reproductive potential and increase the inter-spawning interval. This is more evident because of the non-feeding female fish during egg incubation, which prolongs the time for subsequent oogenesis in starving female.

Conditioning and broodstock exchange

Conditioning (resting) refers to the maintenance of Nile tilapia broodstock at moderate densities for a short period allowing them to prepare for breeding, or post-spawning to rest and recuperate from the stressful phase of breeding. Several studies have found that conditioning either male or female or both and fed with high quality diet have significant benefits in enhancing reproductive efficiency of broodstock. Exchanging male and female tilapia for spawning after some period of conditioning is a useful tool for improving seed production, spawning synchrony, and spawning frequency. Conditioned male and female have been reported to produce more eggs and fry, and result in more frequent spawning than non-conditioned broodstock.

However, prolonged conditioning may have some negative impacts as well. Longer durations of conditioning and more frequent disturbance might have an adverse effect on broodstock quality particularly in the case of male with lowered sperm quality. Resorption of ripe eggs may also occur if the female does not spawn in about a week. Therefore the recommended duration is of short intervals of 5 – 15 days of resting. Replacing old broodstock with one year class fish has also found to improve egg production and overall juvenile production in tilapia.

Broodstock Nutrition

The performance and reproductive efficiency of tilapia broodstock are greatly dependent on the quality of diet supplied to them. Although eggs can absorb some nutrients directly from water, the major source of nutrition for the developing embryo is the egg yolk. The exogenous nutrition from supplementary feed to broodfish provides the essential nutrients required for the gonadal development of females and the quality of the seed produced. Therefore, the supplementation of nutrition from a high quality diet for broodstock is essential for producing the best quality fingerlings for grow-out.

Protein requirements: Dietary protein content has been found to significantly affect the reproductive performance of tilapia broodstock, particularly reflected in their size at first spawning, fecundity, spawning frequency, and egg hatchability. Tilapia broodstock needs relatively higher protein levels in their diets. Generally, the Nile tilapia broodstock require a protein content of 30 – 45% in their diet.

Vitamin and mineral requirements: In many fish the requirement of vitamins and minerals for optimum reproductive performance has been clearly established, although such studies are scarce in Nile tilapia. Supplementation of ascorbic acid at 1250 mg/kg of dry diet significantly improved egg hatchability and fry quality in Mossambique tilapia, *O. mossambicus*. Some studies have also highlighted the requirement of Vitamin E for sexual colouration and reproductive activity in Nile tilapia.

Feeding management: Proper feeding management of tilapia broodstock is essential for improving its reproductive performance, hatchery efficiency and profitability. It may not be economical to abundantly feed tilapia during the period of their egg incubation, as the mouth breeding fish do not feed during that period. The recommended practice is to increase the feeding rate immediately after egg / fry harvesting, followed by a lower feeding rate or no feeding at all for fish raised in green water systems in pond.

A decrease in food ration has been found to stimulate reproduction in tilapia. In the case of the hybrid tilapia (*O. niloticus* x *O. aureus*) it was found that at lower feeding rates of 0.5 and 1% of body weight/day the fecundity/g of female was higher than at higher feeding rates (2 and 3%), although egg size, hatchability, fry length and weight were not affected by feeding levels. Restricting food to fish leads to growth retardation and reduction in total fecundity, but it tends to increase spawning frequency, the total number of eggs over a discrete period, and the amount of energy allocated to egg production.

Feeding frequency may also affect fish reproduction. It may be optimum to feed the broodstock twice a day, as a greater feeding frequency may not be cost-effective. Feeding tilapia broodstock with high-energy diets at low feeding rates might also be better than feeding larger amounts of a low-energy diet. The feed quality, feeding schedules and feed costs should be considered for achieving optimum reproductive performance. It also gives an option in the management of feeding their tilapia broodstock.

Environmental Factors in broodstock management

The environmental factors play a key role in enhancing the genetic and reproductive potential of Nile tilapia for improved seed production. It is important to maintain optimum water quality parameters in the broodstock ponds for successful reproduction. These include dissolved oxygen, temperature, salinity, photoperiod, light intensity, water level, water exchange, etc.

Dissolved oxygen: Nile tilapia has an inherent ability to survive in low dissolved oxygen (DO) conditions. However, oxygen levels as low as < 0.5 mg/l, often encountered in early morning hours in outdoor ponds may impact negatively on ovarian growth, courtship, seed production, and mouth breeding efficiency in females. Low DO also retards feed intake and induce behavioural and morphological changes such as concentration of melanin pigments in the skin. These stressful conditions have been reported to cause disease incidence, inhibit reproduction and spawning activities, cause oocyte atresia and decrease fecundity and hatchability.

Temperature: Tilapias are eurythermal fishes and can tolerate a wide range of temperatures, ranging from 8 to > 40°C. Most tilapia species can reproduce successfully at about 22°C. Tilapia reproduction generally slows at 21-24°C, while the optimum temperature for reproduction ranges from 25 to 30°C. At temperatures higher than 35°C, reproductive performance has been found to be very poor. Spawning units should therefore be designed and constructed in such a way as to protect the facility from severe weather changes. Use of greenhouse for tanks or ponds enables maintenance of uniform temperature and year-round production of fingerlings.

Salinity: Tilapias are generally salt-tolerant, and salinity is an important parameter for its reproduction, although Nile tilapia can tolerate only a narrow range of salinity. Tilapia has been tested for its farming in a wide range of salinities, in fresh, brackish water and seawater. The salinity-tolerant species of tilapia reproduce more efficiently at low and moderate salinities than at high salinities. At high salinities, resorption of eggs takes place in tilapia thereby reducing reproductive success. The aggressive behaviour of the dominant male tilapia has also been found to subside at high salinities. Maintenance of male broodfish in saline water at times of lower seed demand may be a good approach to overcome their aggression.

Photoperiod and light intensity: The effect of photoperiod and lunar periodicity in reproduction has been studied well in tilapia. Photoperiod has been found to play a significant role in fish growth, metabolism, and reproduction through secretion of melatonin, which is a key hormone engaged in regulating endogenous rhythms. The photreceptor cells in both the eye and pineal organ of fish appear to function in providing proper responses to the light signals, while this receptivity of fish to light depends on the species and developmental stage of fish.

Water level and exchange: Pond water depth (water level) appears to have a major effect in increasing the reproductive activity of tilapia females, resulting in smaller males being recruited into the breeding population. Partial water change at frequent intervals may also improve seed output and spawning synchrony. Some studies suggest that tilapia mucus contains a hormone-like substance that inhibits reproduction, especially at high densities. Regular exchange of pond water may remove this substance and improve reproduction efficiency. Water exchange also improves dissolved oxygen and flushes out harmful substances, such as undigested food, faeces and other metabolites, such as ammonia, nitrite and nitrates. Seed output from ponds filled with new water is higher than from ponds with water used for long periods. This suggests that pond water should be frequently changed, partially or completely; however, the exchange rate and frequency depend on water availability and cost, as well as the type of culture system.

Exercise:

- Discuss the important considerations for selecting Nile tilapia broodstock.
- Set up a short trial testing different sex ratios of fish in breeder hapas and record the behavioural pattern. Discuss the observations in the class.

Module 1: Nile tilapia seed production

Module 1.4: Nile tilapia breeding systems- pond, tank, and hapa based systems

Session objectives:

To provide technical information on the different breeding systems of Nile tilapia

Learning outcomes:

At the end of the session, the trainees will be able to identify the different breeding systems of Nile tilapia suitable for efficient seed production

Session narrative:

Recent interest in tilapia farming on a global scale and the rapid dissemination of hatchery technology have greatly helped the expansion of tilapia farming in many parts of Asia-Pacific region, Africa, and the Americas though in various scales. Tilapia seed production systems are fairly well established in many countries of Asia and are getting more popular in Africa. Intensities of production and the seed production methods vary among these regions, while the efficiency of production is gradually increasing. This section summarises the variety of breeding systems developed for Nile tilapia seed production.

Semi intensive and intensive systems of seed production

There are two types of seed production technology based on the intensity of operations – semi-intensive method and intensive method. The semi-intensive method of tilapia seed production is characterized by utilization of a medium level of technology using earthen ponds for breeding, fry production and fingerling production, and depending on natural food for early fry rearing, often producing mixed sex fingerlings. In this system, male and female broodstock are placed into a suitably prepared pond for breeding. The resulting fry are then transferred to fingerling rearing ponds, for growing to fingerling size. The broodstock are then removed from the breeding pond and returned to broodstock conditioning ponds.

The intensive method of tilapia seed production is characterized mainly by utilization of a high level of technology to produce both mixed sex and all male fingerlings with the operation carried out in a specially constructed hatchery for breeding, fry production and fingerling production. Concrete tanks are preferred due to space requirement and management considerations. Continuous aeration is required in ponds and tanks at intensive stocking densities.

Stocking densities are higher in the intensive systems compared to the semi-intensive system. Nutritionally complete feeds are required as there is very little or no dependence on natural fry for early fry rearing and fertilization of the tanks and ponds is usually absent. Frequent water exchange is also required. This system is usually utilized for the production of all male fry in commercial grow-out operations.

Semi intensive seed production in ponds

The easiest method to spawn tilapia is in the earthen ponds, and this method is widely used in many countries, including Africa. While tilapia can spawn in a wide range of environmental conditions, there are important parameters like pond size, shape, and depth that affect fry harvest. Rearing in earthen ponds is often suitable for producing mixed sex tilapia, monosex hybrids, or first-feeding of fry for sex reversal.

After stocking breeders in the breeding pond, the fry can be collected at different intervals ranging from 6 – 60 days. In the breeding ponds, the first fry appears around 10 – 14 days after the breeders have been stocked. Either partial (by using dep nets, seines, and traps) or complete drain harvesting of fry is carried out. The fry is easily visible during the early morning and early evening, swimming in clusters and can be caught by hand net with very fine mesh size, counted and transferred to a suitably prepared fingerling pond. Major challenges in pond production of fry include reduction of spawning frequency, cannibalism among the fry, predation of small fry by other bigger fish, etc. Proper pond management by optimum fertilization of water, decreasing sediments, preventing entry of wild predatory fish, and regular harvesting can help overcome most of these challenges. Harvesting fry at shorter intervals and grading them to remove large individuals result in higher production of uniform-sized fry. The stocking rate for fry in the fingerling pond is 10 fish/m^2 of pond surface area. Supplemental feed of 28 to 30% protein should be fed to the fry about seven days after stocking.

Seed production in tanks

Concrete tanks are most suitable for the intensive seed production systems of tilapia. Although tanks are expensive to construct, they have several advantages over earthen ponds, and are more suitable in areas with limited freshwater availability or where the soil is too sandy for earthen pond construction. Although the number of fish that can be stocked is limited by the tank volume, tanks are amenable to better water management (by filtration or flow-through arrangement) and are easy to harvest giving greater yield of fry per unit area, compared to earthen ponds. Factors affecting spawning efficiency include tank size and shape, colour, water depth, and the material used for tank construction. Deep tanks (1 – 2 m) are found better for optimum reproductive performance of Nile tilapia. Artificial spawning shelters provided in tanks enhance the efficiency of seed production by increased courtship behaviour and spawning intensity, as well as synchronous spawning activity of the fish. In addition, a tank often needs aeration to support the high densities of fry that it supports.

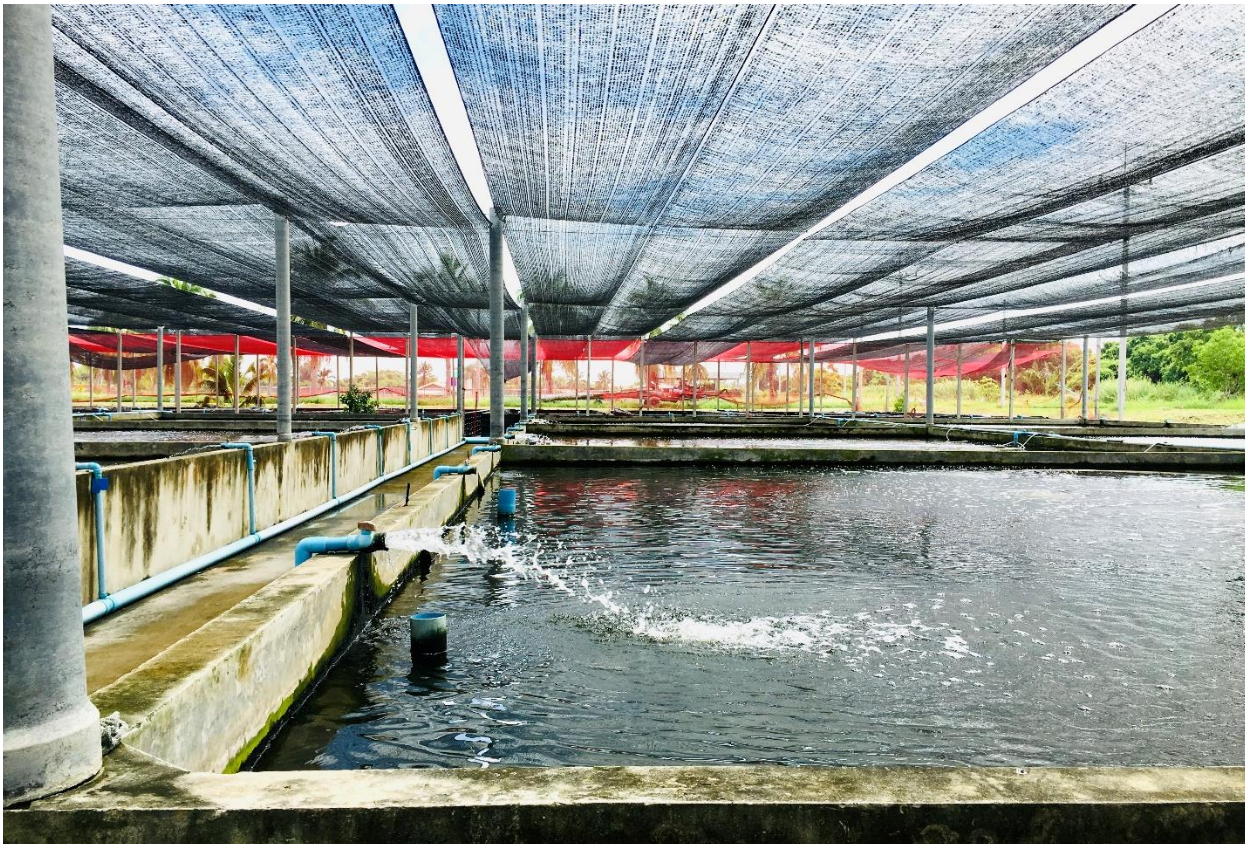


Figure 9 *Concrete tanks used for tilapia broodstock*

It is necessary to maintain enough tanks for holding male and female broodstock separately for conditioning (for 10 – 12 days) before they are transferred to breeding tanks. The size of fry and nursery tanks can range from <1 – 3 m^3 while the conditioning and production tanks can be over 30 m^3. The depth of water should be 80 – 90 cm. Select the females of 150 – 300 g size that are at the 'ready to spawn' stage and transfer them to the breeding tanks along with male broodstock at about the same size as that of females at a stocking density of 7 – 14 breeders/m^2 and at a male to female ratio of 1 : 2 or 1 : 3. Fry can be collected from 10 – 14 days after stocking breeders and they are transferred to nursery tanks or hapas set in nursery ponds for further rearing.

If the eggs are collected from incubating females, this is done using fine-meshed scoop nets, beginning 5 – 7 days of stocking breeders in the tank. The eggs are gently placed in small basins with water, counted, and transferred to the hatchery for incubation. Depending on the availability, egg collection can be continued for 10 – 12 weeks from a set of breeders in a tank. The breeders are transferred back to the conditioning tanks once the egg production declines.

Seed production in hapas

A hapa is a fine meshed net cage set up in a tank or earthen pond (like an inverted mosquito net) for stocking fish or small fry. It is made of polythene netting with the joints sewn with nylon thread and with the double-stitched seams to prevent splitting. The four corners of the top and bottom side of the hapa can be tied to bamboo or wooden poles that are driven onto the pond bottom for fixing them.

Hapas have long been used as an excellent hatchery system for tilapia, especially in the developing world. Hapas are easy and inexpensive to construct and set up, and they facilitate good management and seed harvest allowing greater and more consistent yield of uniform-sized fry per unit area than that from pond method. Hapas can also be used in conjunction with ponds by suspending in fertilized earthen ponds or in concrete tanks with clear water supply. Complete drainage of ponds to harvest fry can be avoided so that continuous fry production is possible using hapas.

Hapas can be used both for the semi-intensive production of fry by collecting the fry from breeder tanks at regular intervals or for intensive seed production similar to that in tanks. When hapas are suspended in ponds, the spawning of tilapia depends on broodstock density and sex ratio, broodstock conditioning and exchange, and other environmental factors like wind, water turbidity, and varying water levels. Sometimes a double hapa hatchery is used in which the broodfish are stocked in the inner hapa with a larger mesh size from which the newly hatched fry (swim-up fry) can freely come to the outer hapa or to the surrounding water tanks/ponds. This system was found to provide the least disturbance to spawning fish and, and reduce cannibalism among the fries.

Depending on its use, hapas of different size, design, and mesh size can be chosen. Smaller mesh size (1 – 2 mm) is used for fry and fingerling holding, while the bigger mesh (B-net; 5 – 6 mm) is used for holding bigger fish (example: broodstock for conditioning). A standard size for hapa is 1x1x1 m. A hapa measuring 3m x 3m x 1.5m is a suitable size for fry and fingerling production. The sides of the hapa, when installed, should extend about 40cm above the water surface, to prevent fish jumping out.

Use of hapas is the most economical means of tilapia seed production compared to pond and tank methods. However, one of the major disadvantages of the hapa system is that they need regular maintenance by cleaning to keep them free of fouling and to avoid clogging that will deteriorate the water quality inside the hapa. Hapas are also affected by strong winds and storms, and may become soft targets for poaching.

The standard protocols for seed production in hapas are similar to that of using other methods. When the hapas are fixed in ponds, the standard pond preparation procedures have to be followed for preparing the pond for breeding tilapia. After draining pond water check the pH and accordingly apply lime at the rate of 1 – 3 tons/ha depending on soil acidity and texture. Organic manuring by chicken manure can be done at 200 – 300 kg/ha to stimulate good plankton growth in the pond. Filtered water is let into the pond and filled up to a level of at least 1 m. Fix the hapa in the pond by tying the corners to long bamboo or wooden poles driven to the pond bottom. Adequate space is given between each hapa to allow sufficient water movement for better water quality. Regular maintenance of the hapa by cleaning the clogged mesh is to be done to maintain good water quality inside the hapas. After stocking the broodstock for seed production at the appropriate stocking density (4 – 5 broodstock/m^2) and sex ratio.

Figure 10 *Hapas fixed in a pond for rearing fry for sex reversal and for nursing before growout*

The fish are fed in the hapa at the rate of 3 – 5% of their body weight. Eggs can be collected from the female's mouth after 5 – 7 days of stocking in breeding hapas and they are transferred to the hatchery for incubation. After successive spawning 9of about 10 – 12 spawning) and when the yield of fry starts reducing, the breeders should be transferred to the conditioning hapas to prepare them ready for subsequent breeding.

Exercise:

- Prepare a breeder hapa from blue net of appropriate mesh size.
- Fix the breeder hapas in ponds and select broodstock of tilapia for stocking
- Prepare another concrete or fibreglass tank of about the same size and stock the same density and ratio of breeders
- Observe the behaviour of breeders in both the systems, and discuss in the class

Module 1: Nile tilapia seed production

Module 1.5: Egg Collection, transportation, incubation, and hatching of Nile tilapia

Session objectives:

To provide technical information on egg collection and incubation of Nile tilapia

Learning outcomes:

At the end of the session, the trainees will be able to apply the methods of collection, incubation, and hatching of Nile tilapia eggs

Session narrative:

Collection of fries from the mouthbrooding females breeders naturally incubating their eggs in ponds or tanks is considered as a less productive method of tilapia seed production in view of its known disadvantages. However, natural incubation of tilapia eggs for fry production is still a common method in countries or regions with limited resources for modern hatchery production. Artificial incubation of eggs collected from the mouth brooding females is a more popular method for production of good quality tilapia fry on a mass scale.

There are several benefits from artificial incubation of eggs, which include greater fecundity and production of uniform-sized fry, improved spawning synchrony, more frequent spawning and reduction of inter-spawning interval, reduction of hatching time, and elimination of cannibalism among the fry. This method also facilitates experimentation on tilapia genetics and reproduction. Specialized incubation units are used for artificial incubation and hatching of tilapia eggs and these systems can be designed and developed very conveniently and at lower costs compared to the modern hatchery systems of other freshwater fish.

Incubation units for Nile tilapia eggs

Simple, inexpensive, and easy-to-make units ranging from soft drink bottles and round bottom containers such as carboys and plastic containers, to more advanced conical upwelling jars are often used for artificial incubation of tilapia eggs. In a commercial hatchery, the fertilized eggs or yolk sac fry collected from the mouth of female are incubated in a series of round bottom plastic jars and flat trays connected to a recirculating system supplied with freshwater from an overhead tank. The hatched larvae collected in the tray are transferred into separate trays until their yolk sacs are resorbed and they become free swimming, at which time the larvae start feeding.

The fertilized eggs pass through the embryonic and larval stages in 10 – 12 days of time to complete one cycle of development at the optimum water temperature between 27 and 30^{0}C. This facilitates at least three cycles of first feeding fry every month in this hatchery system. The factors affecting the efficiency of the incubator systems include the developmental stages of the eggs, water quality and flow, and the type, size, and shape of incubators used. For example, it has been found that round-bottomed incubators realize better survival rates of fry (85%) compared to conical shaped containers (60%), while the hatching time is shorter in conical jars. The hatching time and survival rate of fry was also significantly better in downwelling round-bottomed jars compared to upwelling conical containers.

Figure 11 *Incubation jar for tilapia eggs*

Figure 12 *Egg hatching trays for tilapia (left) and free-swimming fry after yolk sac resorption (right)*

Important considerations in the setting up of an incubator system for Nile tilapia eggs with 30 hatching tray units are as follows:

- Hatching jar volume: 20 litres
- Estimated number of eggs in each jar: 25,000
- Water flow rate: 4 litre/min
- Hatching time: 65-72 hours
- Estimated number of hatched fry per tray: 23,000
- Estimated total first feeding fry per batch: 690,000 (23,000 x 30 trays)
- Estimated total first feeding fry production per month: Approx. 2 million (690,000 x 3 cycles)

Hatching of eggs and yolk sac resorption

The fertilized eggs start hatching in about 60 hours of loading into the incubation jar while the resorption of yolk sac is completed in about 6 days' time. The hatching time is affected by various factors such as the developmental stage of the egg collected from female fish, water temperature, water flow rate, broodstock nutrition, etc. The optimum temperature for proper egg hatching and larval development lies between 27 and 32^{0}C. Lower (below 22^{0}C) temperatures or extremely higher (33 – 35^{0}C) temperatures drastically reduce reproductive efficiency, egg quality, and hatchability in Nile tilapia. Improved pond temperature by increasing pond depth, the use of deeper hapas, shading, etc. has been found to enhance seed production.

Water flow rate in jars appear to have a major role to determine hatchability and larval growth in Nile tilapia. A water flow rate of 4 liter/min in a 20-litre jar was found to be optimal for tilapia seed production. Broodstock nutrition also affects hatching and larval development. Higher protein levels (35 – 40%) in the diets of broodstock favoured faster hatching (in 3 – 4 days) while lower protein level of 25% resulted in hatching in 4 – 6 days. Optimum socking density and feeding rate of broodstock is 3 female/m^2, and 1% of body weight/day, respectively.

Larval development

Several factors such as stocking density, food and feeding, photoperiod, water flow, and water replacement affect larval development and growth in incubation systems in a tilapia hatchery. A stocking density of 5 fry/litre appears to be optimum for hatchery-reared Nile tilapia fry. High stocking densities may cause excessive cannibalism and mortalities, as well as drastic water quality deterioration and stress to the fry. Because cannibalism has been found to be the major cause of fry mortalities in hatchery it is recommended to adopt size grading fry in nursery units to separate large sized fry from the stock, and also to use uniform broodstock of approximately the same age and size to produce uniform-sized eggs and fry.

Larval nutrition is also important to ensure high survival and growth of tilapia fry. The optimum crude protein requirement in larval feeds of Nile tilapia ranges from 35 – 45%, while it also depends on the protein source and the culture system. The optimum feeding rate of fry appears to range between 30 and 45% of body weight/day. Food colour also appears to have some effect on the acceptance of the diet by tilapia fry with more affinity to darker coloured (red and blue) feed than lighter coloured feed tested. The larval stages of tilapia are found to be more sensitive to photoperiod than fingerlings or juvenile stages. Fish fry subjected to longer (24 and 18 h) photoperiods had better growth performance than those exposed to intermediate or shorter (12 or 6 h) photoperiods.

Exercises:

- Harvest the eggs from the mouth of females in breeding hapa
- Set up and monitor an egg incubation and larval rearing (jar and tray system)
- Calculate fertilization rate, hatching and larval survival rate

Module 1: Nile tilapia seed production

Module 1.6: Sex reversal in Nile tilapia (Preparation of MT feeds and nursing fry)

Session objectives:

To provide detailed procedure on preparation of sex reversal feed of Nile tilapia

Learning outcomes:

At the end of the session, the trainees will be able to apply the techniques learned in preparing MT hormone feed

Session narrative:

A remarkable difference in the growth rate exists between male and female tilapia, with the male growing almost 50 percent faster than females under the same environmental conditions. This disparity often affects the success of tilapia farming when carried out in a mixed sex population of males and females together. Further, in a mixed sex culture system, the tendency for reproduction is high, which consumes high energy at the cost of growth and biomass. Unwanted reproduction in culture ponds also leads to excessive production of fry within the pond often leading to stunting of growth and water quality issues. Monosex farming of tilapia, particularly all male culture has become popular to take advantage of the superior growth performance of males in the culture system. By growing all male fry, the energy for reproductive activities such as nest building, courtship, guarding, etc. are saved and potentially oriented towards attaining more growth and body size of the male tilapia.

There are several methods of production of monosex fry of Nile tilapia that includes manual segregation of sexes, hormonal sex reversal, and several other techniques including genetic manipulation. Among these, manual sexing by examining the sexually dimorphic characters between male and female fish is done easily and had been the most common method in the past. However, this is an extremely labour intensive method, causes significant stress to the fish while manually evaluating and sorting of male and female, and often leads to inaccurate results because of human error. Therefore the use of hormones that can convert females into phenotypic males has, of late, become the most popular method for sex reversal and production of all male tilapia fry. The following section highlights the salient features of the monosex tilapia production technology, particularly the preparation of hormone feed, feeding protocol, and success rates of all male production.

Preparation of sex reversal feed

The androgenic (male) hormone 17α-methyltestosterone (MT) is the most common hormone used for successful production of all male tilapia fry. There are several methods of administration of hormones to fish including dietary supplementation, egg immersion, and systemic transfer by injections or silastic implants. Of these techniques, the dietary administration of hormone found to be safe and successful. The hormone is administered orally to fish through a specially prepared diet at the desired concentrations of the hormone in the diet fed to the fry at an early stage of its development, allowing sexual differentiation to bias more towards maleness rather than females. A dietary addition of 60 mg/kg of feed has been found to be the optimum dose for feeding tilapia fry to obtain nearly 100% sex reversal to male in Nile tilapia. The hormone-incorporated feed is fed to the early developing larvae of Nile tilapia from 7 to 21 days post hatching to get the most desired results of completely sex-reversed fry. These fry will then be further nursed by feeding with normal fry feed for one more month to the fingerling stage for stocking in grow-out culture systems. The protocol for preparation of the hormone and hormone-incorporated feed are explained below.

Materials required

- Synthetic hormone, 17α-MT
- Ethyl alcohol
- Magnetic stirrer
- Pelleted shrimp starter feed or fish meal of good quality
- Mixer for feed
- Glassware and plasticware

Preparation of stock solution

- Dissolve 5 g of 17α-MT hormone in 1 litre of ethyl alcohol using a magnetic stirrer
- Make up the volume to 10 litres by adding 9 litres of ethanol. This serves as a stock solution containing the hormone at a concentration of 0.5 g/ml of ethanol
- The stock solution can be stored in refrigerator at 4^0C for up to 6 months
- With the stock solution containing 0.5 mg of hormone per ml of alcohol, 120 ml of stock solution is required per kg of feed or fishmeal to deliver the required dose of 60 mg/kg feed
- Another 120 ml of fresh alcohol per kg fishmeal is added when preparing the feed for optimum mixing of feed with the hormone.

Preparation of 10 kg of MT feed

- Weigh 10 kg of feed (either high quality fishmeal or shrimp starter diet can be used)
- 1200 ml of the stock solution is required for 10 kg of feed
- The feed is churned well in a mixer with gradual addition of 600 ml of stock solution first and then another 600 ml of fresh alcohol to ensure proper mixing
- This mixing is repeated another 600 ml of the stock solution and alcohol
- After mixing the feed for about 15–20 min, collect and spread the feed-hormone mixture for drying under shade for about 1 h allowing alcohol to evaporate
- Drying under intense sunlight will cause degradation of the hormone.
- The dried feed can be packed in a plastic bag or kept in an airtight container and stored at room temperature, or at 4-7°C.

Feeding early developing fry by hormone feed

The recommended practice for sex reversal of newly hatched fry is to rear them in nursery hapas set in earthen ponds and feeding them with the hormone incorporated feed. A common area for a rectangular nursery pond is 0.4 ha with a depth of 1.5 – 2 m and provision for water intake and drainage. Nursey hapas may be fixed by tying them using nylon thread to bamboo or wooden poles just in the same way as breeding hapas are set. Water quality in the pond is maintained by regular water exchange and monitoring of the required parameters. Maintenance of appropriate water quality, particularly the temperature (29 – 32^0C) is critical to the success of sex reversal in tilapia fry. Protection from birds and other predators by completely covering the pond using net shading is important to obtain maximum survival for the fry. The common protocol for feeding hormone-incorporated feed to the fry for sex reversal is of hormone mixed feeds is shown in Table 3.

Table 3 Feeding protocol for tilapia fry for sex reversal using hormone-incorporated feed

Week	% of feeding
1	30 % of body weight/day
2	20 % of body weight/day
3	15 % of body weight/day

An example of the production of 2 million sex-reversed fry/month is shown below:

- Size of hapa: 8 x 2.5 x 0.75 m
- Number of hapas set up: 25 hapas
- Stocking density of fry in each hapa: 100,000
- Total number of stocked fry: Approx. 2.5 million
- Feeding rate: 15-30% of estimated body weight/day
- Feeding frequency: 5 times daily
- Duration of feeding hormone mixed feeds: 21 days
- Monosex all male fry production: Approx. 2 million per month

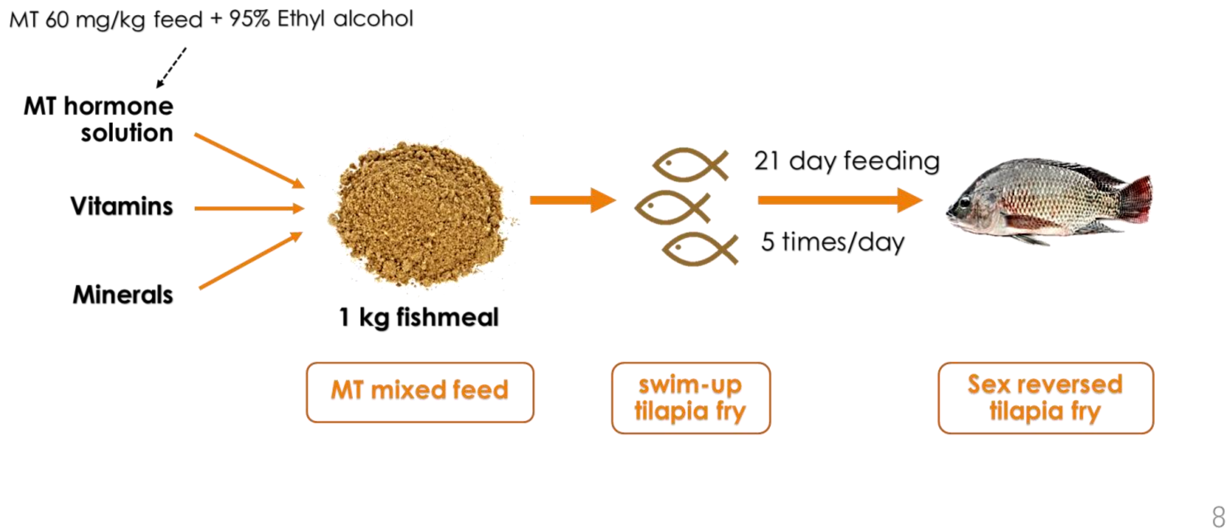


Figure 13 General flow diagram of feeding hormone feed for sex reversal of tilapia fry

Handling of fry

For maximum production of good quality fry of tilapia, it is important to handle the fry in a stress-free manner. Avoid handling fish in the noon time under intense sunlight, and as far as possible, limit fish handling during morning and cool evening period, mostly under shade. Never keep them in extremely crowded conditions or concentrate them in small containers or at the bottom of hapas or of tanks with little water. If the fish has to be held in crowded conditions (not more than 200 fry per litre) always provide adequate aeration or place them in a clean, flow-through water system to avoid any damage or mortalities. If the fish are piping at the surface (gasping for air at the water surface) it is a sign of very low dissolved oxygen levels and aeration has to be provided as soon as possible or exchange water in the container with clean and oxygenated water. The netting material used for handling fish such as that of hand nets should be of soft material and that of appropriate mesh size that will not inflict an injury to the fry. Slightly bigger mesh size than required will result in the fry getting gilled in the meshes causing permanent injury to the fry. Avoid panicking the fish by any means by sudden flashing movements that startle them or dropping them on the ground.

The sex reversed fry have to be nursed in well prepared nursery ponds or in hapas set in earthen ponds for growing them to the fingerling size before stocking in growout facilities. Standard protocols for preparation and management of the ponds and hapas have to be followed for production of good quality fingerlings of Nile tilapia that are suitable for further growout.

Pond preparation in nursery

Proper drying of the ponds will ensure that the soil organic matter gets oxidized and increases nutrient availability to the pond bottom. Drying also has a sterilizing effect in which most of the predators and pest get killed and any disease-causing pathogens removed. However, drying ponds in areas with acid sulphate soils need caution and are not suitable for drying. Water intake to the ponds should be filtered by appropriate mesh size (preferable of 150 µ) to avoid predatory and weed fishes from entering the pond. Small ponds from 400 to 100 m^2 are suitable for nursing tilapia fry. Protection from birds is also necessary to ensure good survival of the stock. Standard protocols for pond preparation and management can be adopted for nursery ponds as well and are explained elsewhere in this document (see session 2.2), and so are not elaborated in this section.

Exercises:

- Discuss in the class the key steps in the sex reversal process for all male production of Nile tilapia
- Prepare and feed the fry with MT feed at the standard protocols
- Visit an operating tilapia hatchery and discuss the seed production process and various components of the hatchery

Module 1: Nile tilapia seed production

Module 1.7: Sex determination of Nile tilapia

Session objectives:

To outline the procedure for sex determination of early-stage Nile tilapia

Learning outcomes:

At the end of the session, the trainees will be able to carry out the sex determination procedure for juvenile Nile tilapia

Session narrative:

Following the hormonal sex reversal of tilapia fry it may become necessary to determine the sex of juveniles grown in growout ponds to evaluate the success rate of sex reversal. While it is easier in larger fish to determine the sex of fish, it is difficult in juveniles or other smaller fish before attaining maturity in which case there is no externally dimorphic character distinguishing males and females. In tilapia it is possible to identify the sexes after they become 20 – 30 g size by visual examination of external sexual characteristics like the urogenital papilla. Guerrero and Shelton (1974) have devised a technique of an Aceto-carmine squash method for sexing juvenile fishes, and this technique is widely used in the case of juvenile fish when no phenotypic identification of sex is possible, as in tilapia to evaluate the success rate of sex reversal at an early stage of production.

Acetocarmine squash preparation

This method is applicable equally well for juveniles when their gonads are immature and for mature individuals during seasons their gonads have regressed, in fish both in fresh or preserved condition.

The acetocarmine stain is prepared by adding o.5 g of the granular stain to 100 ml of 45% acetic acid and then boiling for 2 – 4 minutes. When cooled the solution is filtered by a filter paper and can be used.

A small random sample of the 30 – 50 juveniles is taken for examination, and the fish have to be sacrificed and dissected using a sharp pointed surgical scissors and with the help of a dissecting microscope. The gonad appears thread-like lying along the anterodorsal cavity and is removed using fine forceps. The fish have to be sacrificed and the gonads are located after dissection using. A portion of the gonadal tissue is removed and placed on a glass slide. A few drops of aceto-carmine stain are added, and the tissue lightly squashed with a cover slip. The acetocarmine is readily absorbed by the gonadal tissue. The gonads are then examined under the microscope using magnifications of 25 to 100x. The male gonad is composed of fine granular like structure of spermatogonia and the female is characterized with the structure of circular oogonia.

Exercise:

- Conduct a comparison of manual segregation and sex determination through squash technique
- Discuss the results in the class

3. Module 2: Nile tilapia grow-out process

CHAPTER 3

Module 2: Nile tilapia grow-out process

Session 2.1 Principles of grow-out aquaculture

Session objectives:

This session overviews the principles of aquaculture applied to the grow-out stages

Learning outcomes:

At the end of this session, trainees can explain overall management aspects that should be focused during the grow-out stage of Nile tilapia culture

Session narrative:

There are six interrelated aspects to be considered during the planning stage of growout culture (Figures 1 and 2). They are:

1. Acquisition of high-quality seed (covered in detail in Module 1)
2. Water quality and waste management
3. Health management and biosecurity
4. Stock management and animal welfare
5. Nutritional requirements, feed manufacture, storage and feeding, and
6. Harvesting and marketing

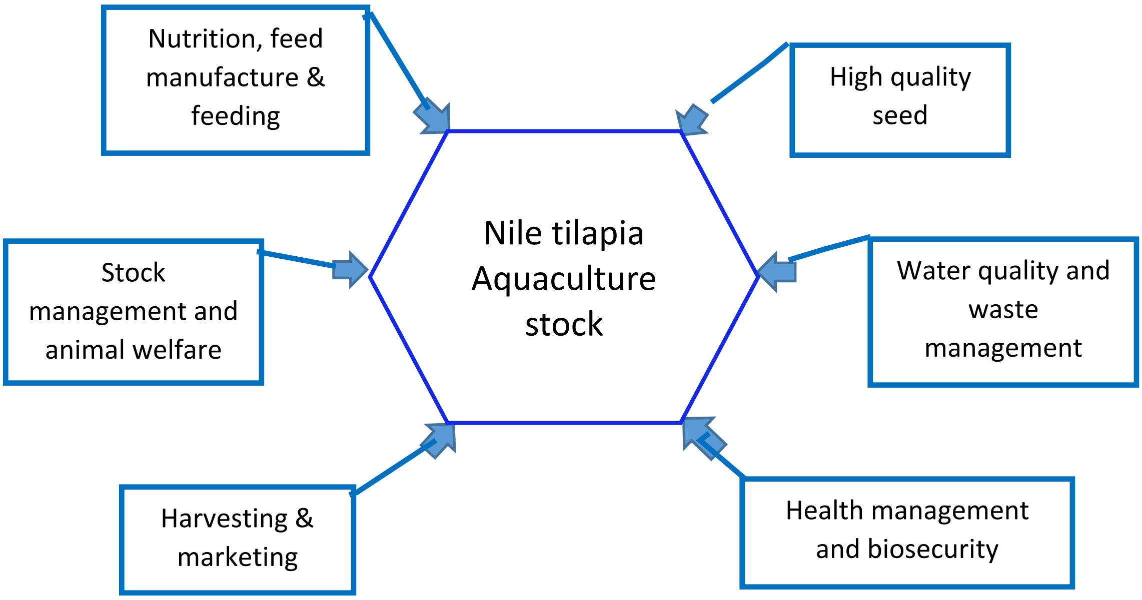


Figure 14 *Six areas of grow-out management in aquaculture*

High quality healthy seed is one of the most important parameters for the success of grow-out culture. Seed should ensure both high growth rate and survival that leads to highest possible yield at harvest. Culture duration is also determined by the quality of seed i.e., fast growing seeds reach marketable size in a relatively shorter time than slow growing seed (see Module 1).

Water quality: Fish does not utilize feeds efficiently if temperature and dissolved oxygen (DO) are not in optimal range, thus does not grow at a maximum rate. Temperature cannot be manipulated in grow-out systems but all other parameters such as Do, ammonia and nitrite management are essential for tilapia culture (see Session 2. 5 for details). Nile tilapia grows optimally at range of 0 to 10 ppt salinity.

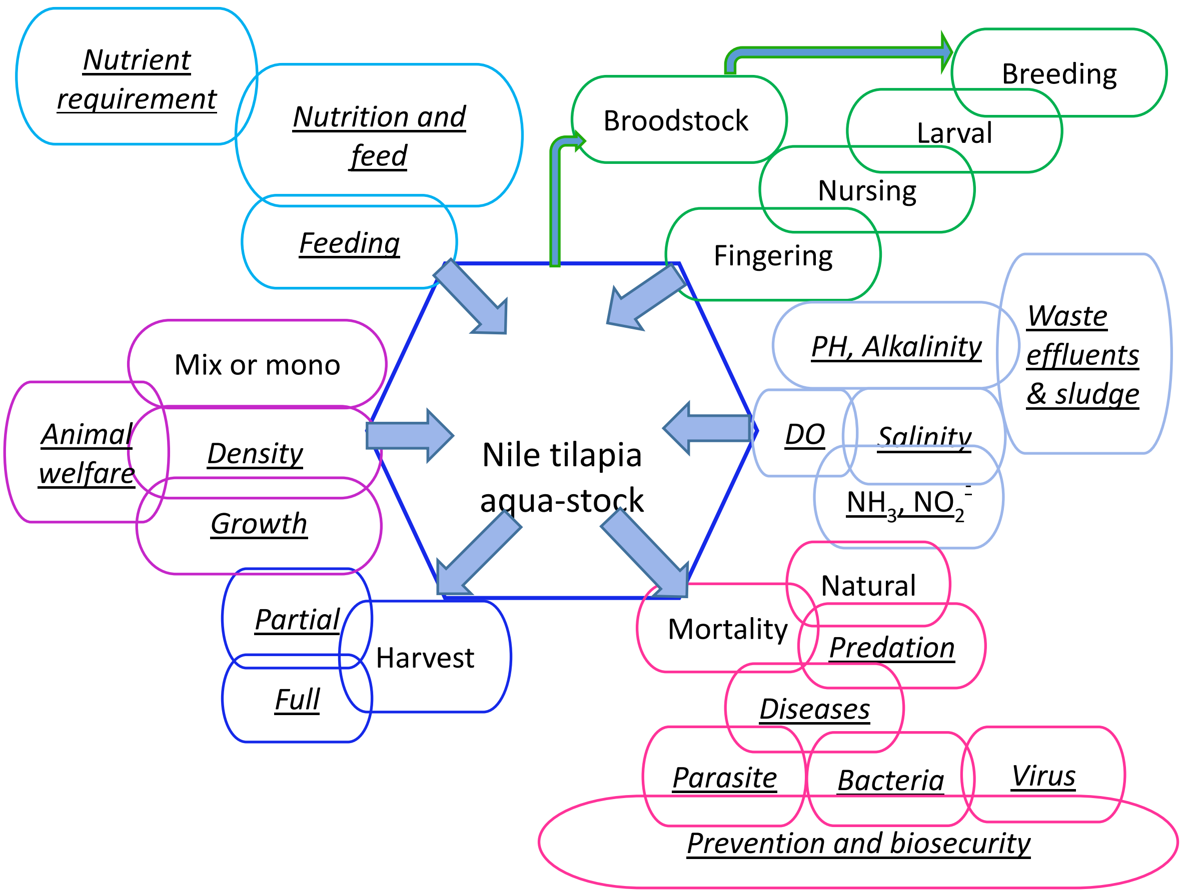


Figure 15 *Six areas of grow-out management in aquaculture in detail (underlined italics = parameters that should managed during the grow-out stage)*

Nutrition & Feeds*:* Either on-farm produced or commercially purchased feeds should satisfy nutritional requirement of the animal. The selection of feeds and feeding regimes are described in the session covering nutrition and feed (see Session 2.4 for details).

Health management and biosecurity: Nile tilapia is relatively resistant to diseases. However, bacterial and viral disease incidents are common during the cold and/ or hot seasons. Disease occurs when animals are stressed either due to unsuitable water quality parameters or too high stocking densities. Hence, the ability to prevent diseases are important at this stage as treatments of fish during grow-out period is impractical. Addition of antibiotics to feeds are ineffective as sick animals do not eat. A development of biosecurity and culture environmental management programmes are the only way to reduce disease incidents (see Session 2.6).

Stock management and animal welfare: The stock management is not only important for managing health but also for providing optimum space for culture animal to behave normally. Animal welfare can be guaranteed by providing good water quality and by maintaining health of the culture stock.

Harvesting and marketing strategies: The culture stock can be harvest partially or fully. Partial harvesting strategies are suitable when market size is small (market size = the number of potential buyers/ sellers of a product in a certain market) or fish are sold locally. Full harvest is done for when it is certain that all harvest can be sold to an agent or a processor.

Requirement of certifiers

If Nile tilapia is produced for export market, overseas buyers demand for a certified production process.

There is no standard certification system for Nile tilapia aquaculture, but international certification schemes usually look for the following aspects of culture management:

- *Legality* - property rights of the aquaculture site; and national regulatory compliances
- *Social relations* – good community relations; child labour; worker safety; and employee welfare
- *Environment* – sediment and effluent management; habitat damage; fishmeal and fish oil use/ biodiversity conservation; control of escapes, use of GMOs; culture animal-wildlife interactions; and storage and disposal of farm supplies/ chemicals
- *Animal welfare* – water quality management, welfare of cultured animal (crowding effect); and biosecurity, health and disease management
- *Food safety* - food safety, control of residues and contaminants, harvest and transport; and sanitation
- *Traceability* - record-keeping requirement

Hence it may be prudent to pay attention on these aspects of culture management if the producers intend export the product.

Exercises:

Class discussion:

Divide the class into homogenous groups (producers who practice similar type of culture systems e.g. pond culture, cage culture, supply fish for local market or urban market or a processor etc.) and let the group workout/ discuss the following questions:

1. What are the seed sources? Do the practitioners satisfy with seed quality? if not what are the alternative seed sources?
2. What are the market characteristics?
3. What quality products are demanded by the market (physical properties such as size and chemical contaminants)?
4. What quantities can be suppled?
5. What are the constraints?
6. How to resolve the constraints?

References for further reading:

- International Standards for Responsible Tilapia Aquaculture (2009) World Wildlife Fund (WWF). Published December 17, 2009. Available at:http://d2ouvy59p0dg6k.cloudfront.net/downloads/wwfbinaryitem14693.pdf
- Better Management Practices for Tilapia Aquaculture: A tool to assist with compliance to the International Standards for Responsible Tilapia Aquaculture Version 1.0 (2011) World Wildlife Fund (WWF). Published January 7, 2011. Available at: https://www.asc-aqua.org/wp-content/uploads/2017/07/ASC-Tilapia-Better-Management-Practices_v1.0.pdf

Module 2: Nile tilapia grow-out process

Session 2.2: Nile tilapia pond culture

Session objectives:

To introduce scientific information on Nile tilapia pond culture

Learning outcomes:

At the end of the session, trainees can design production targets of Nile tilapia culture in their farm facilities

Session narrative:

Grow-out phase is the production of marketable sized fish. The market demand for the size of fish varies according to whether the market is local or international, or supply fish as raw materials for further processing. While fish around 200 – 300 g might be able to sell in the local market, the processors producing tilapia fillet will demand 800 g fish.

Pond culture is one of the most widely used method of growing tilapia as it has several advantages:

1. fish can use natural feed (plankton, bacteria and detritus);
2. natural food production can be increased via pond fertilisation (using fertilisers containing nitrogen (N) and phosphorous (P) at a ratio of 3 to 1.
3. no external feed is required in extensive and lower level semi intensive culture systems;
4. production can be increased by providing supplemental feeding regime (providing around 50% nutrients from pelleted feed and extracting the rest from natural feed),
5. relatively low disease risk and it is easy to develop biosecurity system, and
6. farmers can avoid theft/ poaching easily.

Pond culture system is classified according to intensity of production (extensive, semi-intensive and intensive) or nature of the culture facility (e.g., earthen pond, tanks – concrete or fiberglass, raceways, and water recirculation systems). The relationship between intensity and different types of pond culture systems are shown below:

Physical structure	**Water use**	**Intensity**		
		Extensive	Semi-intensive	Intensive
Earthen static water ponds/ tanks	Intermittent water exchange to compensate for evaporation and seepage losses	Low stocking density – maximum > 1 fish per m^2; use natural feed as the food source	Stock 1 – 2 fish per m^2; ponds are fertilized using organic manures in combination with chemical fertilisers + supplementary feeding	Use aeration devices to supply oxygen; reported highest stocking density is 5 fish/m^2; commercial or farm-made nutritionally complete feed.
Earthen pond/ concrete tank water recirculation systems	Nearly 90% of water is recirculated daily	NA	NA	Very high stocking densities; juvenile fish are stocked 50 – 10 fish/ m^2
Raceways	Water flow through systems	NA	NA	SD is as high as recirculation systems

Pond design

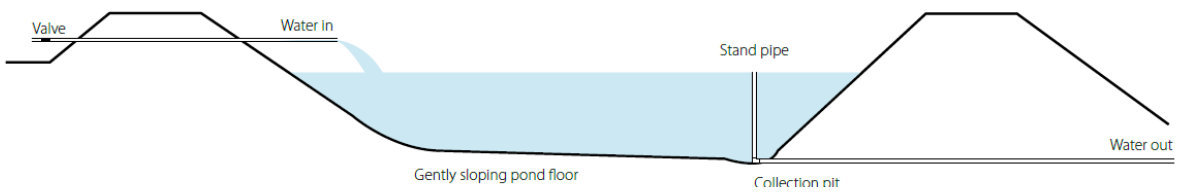
Pond design and construction is a complex engineering process, and it is recommended to consult a Civil Engineer to teach this section of the course (see references for engineering criteria). In general, the selected site should have the following minimum characteristics:

- An open sunlit area that is accessed legally,
- Enough space for the pond and service supply (such as stocking, harvesting and feeding fish),
- Easy access to transportation/ market,
- Legal year-round easy access to a clean water source (either surface or groundwater),
- Clay soil that can hold water (sandy soil is not suitable for pond aquaculture),
- An area that has no flood risks, and
- An area dedicated for waste treatment (sludge and effluents) before discarding to nature.

Number of ponds per site is dependent upon the production plan/targets. There is no strict guideline for determining individual pond size but should be a manageable size – usually ponds larger than 0.5 ha is difficult to manage. An individual pond should have following characteristics:

- Sloped pond walls – just high enough to retain desired water volume/ avoid fish scape
- Sloped bottom towards one deep end for draining
- Well-packed walls and bottom to avoid erosion and seepage (use rollers for compacting the bottom)
- Pond depth preferably 1.0 m at shallow end and sloping to 1.5-2.0 m at the drainage end
- Construct a collection pit at the deep end where sludge can accumulate and remove easily
- Deep end also served as the harvesting area
- Standing pipe to maintain water level and drain water

This diagram shows an ideal pond design.



Nursing for grow-out

Hapa nursing: Small fish (0.1 – 0.2 g) is nursed in hapa installed in earthen ponds. The stocking density is 1000 – 2000 fry/m^2. Hapa sizes vary but mostly in 8 x 5 in size but smaller hapa (3 x 2 m in size) are also used. Fish are fed with rice bran only of a mixture of fish meal and rice bran at a ratio of 1: 2-3)

Pond nursing: Tilapia fry also nursed in small (100 – 500 m^2) ponds. Ponds are drained, dried and limed at 500 kg/ha. After filling water, pond is fertilized with inorganic fertilizers (urea + triple super phosphate or any other fertiliser mixture containing N and P) to stimulate plankton growth/ Fish are then stocked at a rate of 100 -200 fish/m^2. Fish are fed with a mixture of rice bran and fish meal initially and later use small (1 mm) commercial floating pellets 2 to 4 time a day. Farmers usually nurse for 30 days (1 – 2 g fish) and then either sell for grow-out pond culture or further nursed up to 20 – 25 g for to sell cage or pond grow-out farmers.

Grow-out phase: A wide range of growout techniques are used in the growout phase depending on the targeted market. For example, Nile tilapia culture in Asia is conducted using a variety of inputs such as agricultural by-products (brans, oil cakes, vegetation, and manures), inorganic fertilisers and farm-made or commercial feed.

Fertilized pond culture: Common inputs of Nile tilapia pond culture in Thailand is manure (usually chicken but also use pig manure) and inorganic fertilisers (urea and triple super phosphate). Rice bran as well as bakery wastes are used as supplementary feed. Fertilisation strategies produce fish to a size of 200-250 g in five months and these fish are sold to the local market.

Animal manures provide nutrients that stimulate the growth of both phytoplankton and zooplankton, as well as bacterial flocs that are consumed by filter feeding Nile tilapia. The nutrient content of manures varies. Buffalo manure has much lower nutrient levels compared to duck and chicken manure. Obtaining sufficient nutrient levels from manures poses a danger of oxygen depletion from excessive loading of organic matter – the maximum loading rate of organic matter to Nile tilapia pond is 100 kg dry matter (DM)/ha/day. Therefore, a combination of manures with inorganic fertilisers is used in pond fertilization. AIT research revealed that applying chicken manure weekly at 200 kg DM /ha (optimum rate is 25 kg/ha/day), urea at a rate of 28 kg N/ha/week, and triple super phosphate (TSP) at 7 kg P/ha/week can provide a net harvest of about 4 tonnes/ha in 150 days at a stocking rate of 3 fish/m^2 (the extrapolated net annual yield is around 10 tonnes/ha).

Similar yields are obtained in Thailand solely with inorganic nutrients with highly alkaline waters (alkalinity as bicarbonate (HCO_3^{-1}) is buffer as well as a carbon sauce). Inorganic fertilisers are used at rates of 3 – 4 kg N/ha/day and 1 kg P/ha/day. It was reported that in Honduras, a yield of 3.7 tonnes/ha are obtained at a stocking rate of 2 fish/m^2 with weekly application of chicken litter at 750 kg DM/ha and urea at 14.1 kg N/ha in waters with sufficient natural phosphorus.

Fed-aquaculture of Nile tilapia: Farmers supply fish to niche market (supermarket or export) practice monoculture using commercial feeds. At lower stocking densities (1 -3 fish m^2), fish grow from 5 – 10 g (1 inch) to an average of 300 – 600 g range in 7 – 8 months without aeration. With aeration, fish can be stocked at relatively higher densities (5 – 10 fish/m^2) to reach 600 – 700 g in 7 - 8 months. The yield without aeration is in the range of 3.5 – 7.5 tonnes/ha and with aeration, yields as high as 12 – 18 tonne/ha is realized.

Formulated feeds are necessary to produce larger fish and obtain a higher market price. To reduce production costs for domestic markets in developing countries, two strategies are followed: delayed feeding and supplementary feeding. Research conducted at AIT showed that Nile tilapia stocked at 3 fish/m^2 can grow up to 100-150 g in about three months with fertiliser alone, and then given supplemental feeding at 50 percent satiation until the fish reach 500 g. Net harvest averages 14 tonnes/ha, which is equivalent to a net annual yield of 21 tonnes/ha.

Exercises:

Information on tilapia pond grow-out culture in Asia is summarized below:

- Pond size: 0.2 to 0.5 ha
- Aeration: 1-3 paddlewheel aerators per ha of surface area
- Stocking density: 30,000 to 37,500 fish/ha (3 – 4 fish / m^2)
- Feeding: Pelleted feed containing 28-35% crude protein are fed 2-3 times/ day
- Feeding rate: < 100 g fish at rates of 6 – 10% BW; 100 – 250g fish at rates of 3 – 6% BW and 300 – 800 g at rates of 1,5 – 3% BW
- Culture period: 150 to 180 days
- Gross yield ranges: 15-20 tonnes/ha
- Harvest body weight: 600-800 g/fish
- Food Conversion Ratio (FCR): 1.5 – 2.0

1. Assuming pond size is 0.2 ha and culture duration is 5 months (2 crops/ year), how many ponds are required to obtain 20 tonnes of fish/ year?
2. If the survival rate is 80%, how much pond area required to obtain 20 tonnes/ year.
3. If feed and paddle wheels are not available, how much fish can be produced using pond fertilization method in the area calculate under scenario 2?
4. If the fertilization rate is rates of 3 kg N/ha/day and 1 kg P/ha/day, how much urea and TSP should be added to ponds weekly?

References:

General information

1. Nile tilapia culture in earthen ponds (in Thailand). Available at: http://tilapiathai.com/asset/NILE%20TILAPIA%20CULTURE%20IN%20EARTHEN%20PONDS.pdf
2. Towers, L. (2010) How to farm Nile tilapia. Available at: https://thefishsite.com/articles/cultured-aquaculture-species-nile-tilapia
3. Yi, Y., and C. K. Lin (1997) A finishing system for large tilapia *Interim Work Plan, Thailand Activity 4* http://pdacrsp.oregonstate.edu/pubs/technical/15tch/4.d.1.pdf
4. Lin, C.K., Shrestha, M.K., Thakur, D.P, and J.S. Diana (1997) Management to minimize the environmental impacts of pond draining http://pdacrsp.oregonstate.edu/pubs/technical/15tch/15tech_TOC.html

Pond design and construction

5. Homziak, J C. David Veal, C.D. and D. Hays (1996) Design and Construction of Aquaculture Facilities in Dredged Material Containment Areas. Technical Report EL-93-11 Aquaculture Program July 1993, U.S. Army Corps of Engineers. Available at: https://www.researchgate.net/publication/235044540_Design_and_Construction_of_Aquaculture_Facilities_in_Dredged_Material_Containment_Areas

Site selection (example)

Mukami, N.M (2010) Assessing the potential of small-scale Aquaculture in Embu district, Kenya using GIS and remote sensing. M.Sc. Thesis Moi University, Kenya March, 2010. Available at: https://www.oceandocs.org/bitstream/handle/1834/9087/MSc%20Thesis%20Mukami.pdf?sequence=1&isAllowed=y

Module 2: Nile tilapia grow-out process

Session 2.3: Cage culture of Nile tilapia

Session objectives:

To provide technical information on Nile tilapia gage culture in freshwater environments

Learning outcomes:

At the end of the session, the trainees will be able to plan and design tilapia cage culture operations

Session narrative:

Nile tilapia, *Oreochromis niloticus,* is cultured in cages installed in freshwater rivers, irrigation canals, reservoirs and lakes and salinity tolerant red tilapia (*O. niloticus* x *O. mossambicus*) is cultured in freshwater as well as in brackish water lagoons, estuaries, and shallow seas. Relative to pond culture, capital investment in cage farms is lower than that of pond culture as land requirement and cage construction costs are low (Table 5). However, as natural food plays a minimum role in tilapia nutrition in cage culture, feed cost is high.

Table 5 *Comparison of Nile tilapia cage and pond culture*

Criteria	Cage culture relative to pond culture	Pond culture relative to cage culture
Capital investment	Low	High
Operation costs	High	Medium
Reported range of stocking densities - SD (fish/m^3)	50 – 150 (aeration might be needed at higher stocking densities; max initial stocking density ≤ 30 - 40 kg/m^2)	1 – 2 No feeding; fertilization only 2 -3 (feeding at 50% satiation without aeration) 4 – 10 (feeding + aeration)
Maximum harvest biomass (kg/m^3)	Around 120	1 – 5
Disease risk	High	Medium
Escapee risk	High	Low
Growth rate	High	Same (the lower the SD the higher the growth rate)
Environmental pollution	High	Low (if sludge and effluents are not disposed to nature)

The advantage of cage culture is that the culture system is supplied with ample dissolved oxygen (DO) and removal of metabolic waste from the cage provided with there is sufficient if the flow rate. However, if DO of the waterbody is low in the morning hours, emergency aeration devices should be readily available. The disadvantage of cage culture are risks of disease and parasite occurrences, fish can be easily escape from the cages, subject to poaching, and high potential for environmental pollution.

Cage design

There are several types of cages (Table 6) and these designs take environmental parameters and resource availability into account. Cages can be fixed to piles/ poles installed in the bottom of water body or floated using varicose floating devices such as empty barrels, Styrofoam floats or any other buoyant material. Fixed cages are less expensive, and can be designed without any engineering support. They are usually installed in shallow water bodies near the shore for easy access for fish stocking, feeding and harvest. The widely used floating cages have a buoyant frame or collar that support the net bag. The cage is anchored to the bottom or to a structure on the shore. The cages should be sheltered to protect from strong wave and wind energy; hence it is important to select a suitable site for cage culture

Table 6 Classification of cage culture systems

Parameter	Cage type
Placement in water	(1) Surface – Fixed or Floating (2) Submerged - submersible or permanently submerged
Place of operation	(1) Freshwater (2) Marine (3) Estuarine/ lagoon
Protection from wave energy	(1) Sheltered (2) Exposed - open water
Means of support for fixed or floating nature	(1) Fixed – fixed to piles or poles (2) Floating - place buoyant on the collar
Structure's rigidity or flexibility	(1) Rigid collar/structure and net mesh (2) Flexible – rigid collar and flexible mesh (nets)
Service access	(1) With catwalk (2) Without catwalk/ usually access and service by using a boat/barge
Operating parameters	(1) Biomass (low, medium, or high based on culture intensity) (2) Feeding method – manual or automatic feeders

Dimensions of 3 x 3 x 3 m to 5 x 5 x 3 m square cages (some farmers use 6 x3 x 3 rectangular cages) made of knotted polythene nets of 2 – 3 cm mesh size (smaller mesh is used for smaller fish) is used. Frame of the cage is usually made of galvanized steel (I inch) pipes with barrel floats with walking platforms made of wood or bamboo. Some farmers, especially cages in irrigation canals use bamboo frames with either barrel or Styrofoam blocks as floats. The latter floats need a boat as people cannot walk on them.

Many cage designs and models are described in literature (e.g., Cardia and Lovatelli, 2015). Among these, high-density polyethylene (HDPE) cages are widely used, because of the versatility of the materials used, the relative simplicity in the performance of the various farming operations, and the comparatively limited investment capital required. Technological improvements of HDPE cages are evolving with the availability of new materials and the various equipment items needed to service all cage arming operations

Site selection for freshwater cage culture

Since cage culture operations usually taken place in public waters, three major factors should be considered at the planning stage:

- Environmental parameters relevant to the cultured organisms:
    - ✓ Water quality (temperature, salinity, dissolved oxygen, suspended solids or turbidity)
    - ✓ Water exchange
    - ✓ Water current
    - ✓ Algal blooms
    - ✓ Disease organisms
    - ✓ Pollution
    - ✓ Fouling
- Environmental parameters relevant for the cages:
    - ✓ Water depth
    - ✓ Water current
    - ✓ Shelter (from water waves and wind)
    - ✓ Sea/ lake/ riverbed or bottom

- ✓ Pollution
- ✓ Fouling
- Legal/logistic criteria
    - ✓ Legal issues
    - ✓ Tenure rights
    - ✓ Lease permit process
    - ✓ Security (from theft/ poaching)
    - ✓ Proximity to market (access to market)
    - ✓ Political issues
    - ✓ Poaching/ theft

Legal, tenure rights and lease permit process of the country should be followed during the site selection. The site should also be in an area where both seed and harvested fish can be easily transported from/to the market but free from poaching.

The selected site should have an optimal range of temperature (25 – 32 °C), dissolved oxygen (preferably above 4 mg/L), pH (6 – 8) and ammonia (< 1 mg/L) and the water should be free of chemical pollutants. The cages should be installed at least 1 m above the bottom. The optimum water current is around 10-20 cm/sec will supply sufficient DO and remove metabolic waste but should not exceed 40 cm/sec as it can damage the cage. In lakes, when algal blooms occur and lower the, DO content in the early morning. This often happens due to domestic or industrial pollution, so the cages should be installed in areas away from human settlements/ industries. Fouling of cage nets is unavoidable but it can be minimized by drying and cleaning the net bag after each harvest.

Figure 16 *Tilapia cages set in Chao Phraya River, Thailand*

Effects of cage-fish farming on the environment

The effect of cage fish farming on the environment should also a consideration for the site selection – the site should be located away from the sensitive habitats such as breeding grounds of natural fish populations. Feed waste and sediment deposition of the bottom sediment may damage sensitive sites.

The sediment accumulated under the cages can be removed by setting sediments traps comprising a submersible pump. Dissolved nutrients such as nitrogen and phosphorous can be partially removed by growing floating aquatic vegetables near the cage site (Integrated Multi Trophic Aquaculture – IMTA)

Nursery cages

The stocking size of Nile tilapia in grow-out cages are around 20 – 30 g (and in some cases stocking size is 100 g) and thus seeds bought from hatcheries should be further nursed. Small fish (0.25 g) are stocked in 2 mm mesh nylon cages at stocking densities range from 500 – 700 fish that grow up to 1 g in two weeks. Fish are then transfer to cages with 4 mm mesh (Raschel nets with 4 mm mesh) cages to grow up to 25 g in 4 more weeks. Raschel nets with 4 mm mesh is used to nurse fish larger than 0.5 - 1 g. Fish are fed with powdered feed containing 30 – 40% crude protein initially. The mostly used ingredients in powdered feeds are fishmeal and rice bran in Asia but some farmers use corn and soybean meal in addition in the mixture to feed mall fish. Fish are fed 3 – 4 times for satiation. For bigger size fry, are fed with pellets containing 28 – 32% protein.

Grow-out cages

Stocking density and yield: Stocking density of fish is based on three parameters: water quality; water flow-through rate (water current) and cage size (smaller cages have higher flow-through rate than large cages). Fish with initial size of 20 – 100 g is stocked in grow-out cages at stocking densities ranging from 20 – 50 fish/m^3. The lower stocking is practiced in the dry season (in rivers and streams) where both water quality and flow rate decrease (see note below for stocking density calculation).

Relatively higher stocking density such as 40 - 50 fish fish/m^3 is practised when there is good water quality and cooler weather (October - February). Stocking density is reduced to around 20 fish fish/m^3 in the dry season (March – June) as water quality can be deteriorated (especially high water temperature). Average maximum yield of 6 X 3 X 3 m cages installed in Chao-Phraya River is around 2 tonnes per cage or 45 kg/m^3 of water volume (6 x 3 x 2.5 = 45 m^3). Fish grow from an initial weight of 25 to a final weight of 700 g in 4 months.

However, very high stocking densities are reported in Nile tilapia cage culture literature. Garcia et al (2013) stocked two different sized tilapias in 6 m^3 (2 x 2 x 1.5 m) at the Fish Farmers' Cooperative of Santa Fé do Sul and Region, Ilha Solteira reservoir, São Paulo, Brazil, and their results are shown in Tables 7 (nursing stage) and 8 (grow-out stage).

Table 7 shows that fish stocked at 10 kg/m^3 grew bigger, and had the highest growth rate and the lowest FCR of fish fed a commercial feed containing 42% protein. This implies a lower feed cost can be achieved by lowering the stocking density. However, if this is considered a nursing stage, it is better to stock fish at 40 kg/m^3 and then reduce stocking density at grow-out stage.

Table 7 *Growth performance of Nile tilapia (initial weight 78 g) reared at different stocking densities for 41 days in 6 m^3 cage in the Ilha Solteira reservoir, Paraná River, Brazil. (Gracia et al., 2013)*

Targeted production	*30 kg/m^3*	*80 kg/m^3*	*100 kg/m^3*	*120 kg/m^3*
Stocking density	**800 fish/ cage**	**2000 fish/cage**	**2500 fish/cage**	**3000 fish/cage**
Stocking density (calculated using IW)	*10.4 kg/m^3*	*26 kg/m^3*	*32.5 kg/m^3*	*39 kg/m^3*
Final weight (g/fish)	311.12 ± 13.0	260.17 ± 5.33	228.04 ± 5.77	222.21 ± 11.15
Weight gain (g/fish)	235.12 ± 14.79	168.63 ± 7.12	154.36 ± 11.43	149.39 ± 12.22
DWG (g/day)	5.73 ± 0.36	4.11 ± 0.17	3.76 ± 0.28	3.64 ± 0.30
Mortality rate (%)	3.45 ± 0.30	3.60 ± 0.27	4.00 ± 0.33	5.03 ± 0.55
Biomass (kg/cage)	251.17 ± 11.81	526.62 ± 9.77	574.63 ± 14.29	665.17 ± 37.02
Biomass (kg/m^3)	*41.86 ± 1.97*	*87.77 ± 1.63*	*95.77 ± 2.38*	*110.86 ± 6.17*
FCR	0.95 ± 0.06	1.36 ± 0.05	1.30 ± 0.09	1.35 ± 0.12

Table 8 shows that lower stocking density (100 fish /m^3) took 126 days to reach desirable final weight (800 g) but the highest yield (and revenue) was obtained by the highest stocking density. The cost of production per kilogram at all three stocking densities were similar. Authors recommended that maximum initial stocking density for juvenile Nile tilapia is 130 fish/ m^3 (initial weight around 200 g) which is equivalent to 30 kg/m^3.

Table 8 *Growth performance of Nile tilapia (IW not given) reared at different stocking densities until fish reach 800 g final weight in 6 m3 cage in the Ilha Solteira reservoir, Brazil (Gracia et al., 2013)*

Targeted production	*80 kg/m^3*	*100 kg/m^3*	*120 kg/m^3*
Stocking density	**600 fish/ cage (100 fish/ m^3)**	**800 fish/cage (133 fish/ m^3)**	**900 fish/cage (150 fish/ m^3)**
Estimated stocking density assuming IW = 200 g	*20 kg/m3*	*27 kg/m3*	*30 kg/m3*
Final weight (g)	808.45 ± 37.65	803.77 ± 31.23	857.50 ± 37.23
Weight gain (g)	565.68 ± 42.77	577.62 ± 33.46	631.52 ± 35.12
DWG (g/day)	7.86 ± 0.59	8.02 ± 0.46	8.77 ± 0.49
Mortality rate (%)	0.74 ± 0.28	1.35 ± 0.28	1.18 ± 0.45
Biomass (kg/cage)	500.78 ± 24.14	617.62 ± 24.87	743.90 ± 30.83
Biomass (kg/m^3)	*83.46 ± 4.02*	*102.94 ± 4.15*	*123.98 ± 5.14*
FCR	1.64 ± 0.13	1.76 ± 0.10	1.81 ± 0.11
Culture days	126	136	143

Feeding: Commercial feed containing 28 - 32% protein is fed for 2 to 3 times a day. The average FCR is 1.5 (a cage with 1,500 fish requires 2,250 kg feed for 4 months). Some farmers achieve lower FCR with constant monitoring and careful measuring the feeding response of fish (fish nutritionist or a trained person can determine satiation feeding response by observing the feeding behaviour of fish that change from vigorous and active to slow and sluggish feeding response – which is the satiation point.

Exercises:

1. Analyse the following data taken from cage culture literature in China. Can the system be improved to double the fish yield?

    - Commonly used cage dimension: 6 x 4 x 3 m
    - Stocking size: > 50 g

- Stocking density: 100-150 fish/m3
- Feeding: Pelleted feed containing 28-35% crude protein is fed 2-3 times/ day
- Feeding rates:
  - < 100 g fish - 7-10% BW
  - 100 – 250 g fish – 4 - 6% BW
  - 300 – 800 g fish - 1.5 - 4% BW.
- Culture period: 120 to 150 days
- Harvest size: 600-800 g;
- Gross yield: 30-60 kg/m^3 (note that average yield is around 30 – 40 kg/m^3)
- FCR - 1.5-2.0

2. Modified the following example if the expected yield is 120 kg /m^3

Stocking density for stocking in cages is calculated taking expected yield with previous experience. For example:

IF: Expected yield = 30 kg/ m^{-3}
Desired final weight of fish = 700 g
Water volume = 5 x 5 x 2 = 50 m^3 (assume average 2 m water depth of 2.5 or 3 deep cages)
Expected survival rate = 90% (experience an average of 10 % mortality previously)

THEN:
Number of fish to be harvested = 30/0.7 = 43 fish/ m^{-3}
Stoking density taking 10% mortality = 43/0.9 = 48 fish/ m^{-3}
Stocking density per cage = 48 X 50 = 2,381 per cage

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Module 2: Nile tilapia grow-out process

Session 2.4: Nutrition, feeds and feeding of Nile tilapia

Session objectives:

Feed is the major cost item in intensive aquaculture – especially cage culture of Nile tilapia. This session is designed to clarify the misunderstandings of nutrition, feed and feeding of fish.

Learning outcomes:

At the end of the session, the trainees are able to design feed management system for Nile tilapia

Session narrative:

Feed represents the major components in the operation cost of any animal culture. In intensive aquaculture, it can account for over 50% of farm-gate price (or gross revenue of the farm). Reduction of feed cost is a challenge for fish farmers, and it can be only achieved via better understanding of the concepts of aquaculture nutrition. Feed cost can be optimised by feeding fish to satisfy nutritional requirement of the animal. However, unfortunately, many aquaculture scientists confuse farmers by calling nutrient specification (% of nutrient in feed) as the nutritional requirement of fish. This session is mainly designed to clarify this misunderstanding and to show practitioners a procedure to reduce feed cost in Nile tilapia culture.

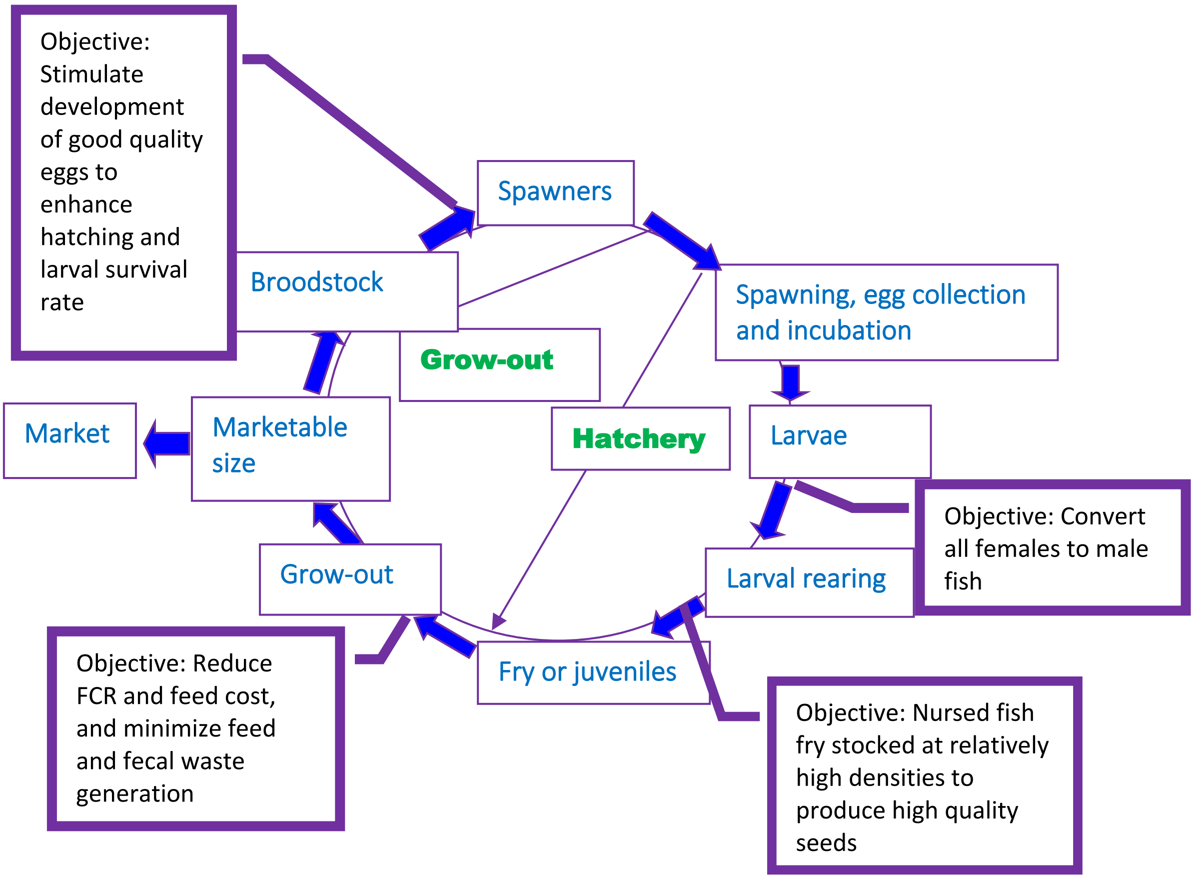

Figure 17 *Objectives of the feeding systems of Nile tilapia*

Issues to be considered at feed management design stage

- Feeding objectives
  Feeding system at the different stage has different feeding objectives as shown in Figure 1. The feeding system should be designed to achieve the objectives of feeding fish at the different stages of life cycle.

- Feed influences
  - ✓ Nutrient specification
  - ✓ Physical qualities - moist/ dry; sinking/floating
  - ✓ Contribution from natural feed –e.g. role of phytoplankton/zooplankton; detritus

  Nutrient specification refers to the percentage nutrient in feed e.g. 30% protein. Physical quality of feeds refers to whether feed is dry (moisture < 10%) or wet (moisture > 20%) or pellets are sinking or floating in water. Nile tilapia feed should be floating type for easy feed management. Contribution from natural feed determines how much pelleted feed should be added to the culture system.
- Animal influences
  - ✓ Nutrient requirement
  - ✓ Age/ size of fish – larvae, fry/ fingerlings/ juveniles
  - ✓ Physiological state – diseases/ brood-stock physiology

  Nutrient requirement of fish is dependent upon the age or body weight. Smaller fish need higher percentage of feed per unit body weight (kg) than larger fish. Influence of physiological state on the nutrient requirement is les known. If fish is affected by bacterial or viral diseases, they do not consume feeds.
- Biotic factors:
  - ✓ Stocking density

  Stressed fish consume less feed and extremely high stocking densities reduce feed intake hence growth.
- Abiotic factors
  - ✓ Culture system – pond, cages, recirculating system;
  - ✓ water quality – DO, ammonia, nitrite, temperature

  The culture system affects water quality parameters such as DO and ammonia. Fish do not eat if oxygen concentration in water is sub –optimal (DO should be > 4 mg/L). The highest feed intake take place when water temperature is around 30 °C. Ammonia and nitrite are toxic to fish and should be maintained at below 1 mg/L.

Nutrient specification vs. requirement

Nutrient specification of Nile tilapia specified by NRC is shown in the appendix and the book can be download from the website shown in the reference section. What NRC refer as nutrient requirement is the nutrient level (content) requirement of feeds i.e. a formulae recommended for feed manufacturers. For example, when we say Nile tilapia feed should have 32% protein implies that if we get 100 g of the particular feed, it contains 32 g of protein. NRC then also specifies what percentage of essential amino acids should be in that 32% protein e.g. 1.43% lysine. However, note that the bottom of the table mentioned that "the requirements have been determined with highly purified ingredients in which nutrients are highly digestible, therefore value presented represent nearly 100% bioavailability" This implies if the manufacturers use practical feed ingredients such as what bran, local fishmeal, soybean etc., the manufacturer should make sure to add more nutrients to feeds (than recommended by NRC) to compensate the low digestibility of nutrients. The reported range of protein specification by various authors are shown in Table 9. These ranges of protein content should be followed at the feed manufacturing stage to produce aquafeed.

Table 9 Protein specifications for Nile tilapia

Fish size	Weight range (g)	Reported range of protein specifications by various authors
Larvae (sex reversal stage)	0.01 g	40 - 50
Fry	0.1 - 1	35 - 40
Fingerlings	1 - 5	28 - 40
Juveniles/ adults	>20	24 - 32
Bloodstock	>100	35 - 40

Nutrient requirement refers to the requirement of the animal or unit weight of the animal (Table 10). For example daily protein requirements of different weight classes of Nile tilapia studied are given below (at temperature: 28– 30 °C, oxygen above 4 ppm, salinity 1 - 4 ppt). Column D of Table 3 shows the feeding rate of fish using feed with the protein specification of column C.

Table 10 Protein specification of Nile tilapia

A	B (experimentally found)	C (a value from Table 2)	D= (100/C) x B
Weight range (g)	Protein requirement (g protein/kg BW)	Recommended protein specification (%)	Feeding rate to satisfy protein requirement(g feed/kg BW)
1 - 10 11 - 35 36 - 100 100 – 250	20 - 25 12- 15 10- 15 10	40 35 30 30	50 – 63 (mean = 5.6% BW) 34 – 43 (mean = 3.9% BW) 40 – 50 (mean = 4.5% BW) 33 (3.3% BW)

Figure 18 shows the conceptual relationship between the nutrient intake and body weight (upper left) and relative nutrient intake (per kg or % BW) vs. body weight (upper right). As fish grows, absolute feed intake increases in positive curvilinear fashion (quadratic relationship) and relative feed intake decreases in a negative curvilinear fashion.

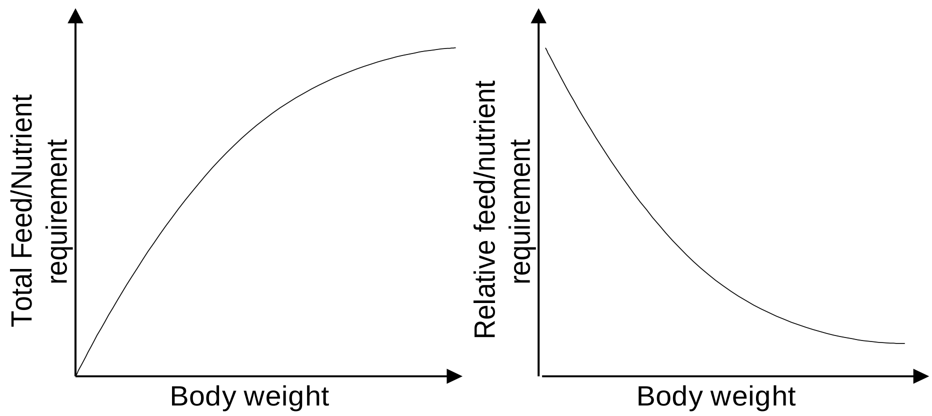

Figure 18 Relationship between feed/ nutrient requirement vs. body weight (left) and relative nutrient requirement vs. body weight (right) of fish

Figure 19 shows a sketch depicting the relationship between nutrient (e.g., protein) intake and growth of Nile tilapia. Growth rate increases as feed intake increases above the maintenance requirement until satiation. Physiologically maximum growth rate is the ability of the animal to process nutrient per unit time (day). There is a large fluctuation in feed intake at the highest growth rate and hence the economic feeding rate is around 80% satiation level. Feeding at 80 % satiation is also reduced feed waste and results in lowest feed conversion ratio (FCR = feed intake/ weight gains).

Natural feed can supply sufficient nutrient to support a certain biomass of fish. This biomass is called 'critical standing crop (Figure 20). Provided with water quality parameters are optimal, Nile tilapia's growth in a fertilized fish pond system is a function of the natural food availability, and fish size and stocking density (biomass) under a given fertilization regime. The system is said to contain a critical standing crop (CSC) when natural food is fully utilized for the maintenance and maximum growth. Above the CSC, nutritional deficits develop and fish should be provided with sufficient nutrient to obtain the desired growth. Further increases in fish yield, therefore, should be sought by addition of supplementary feed.

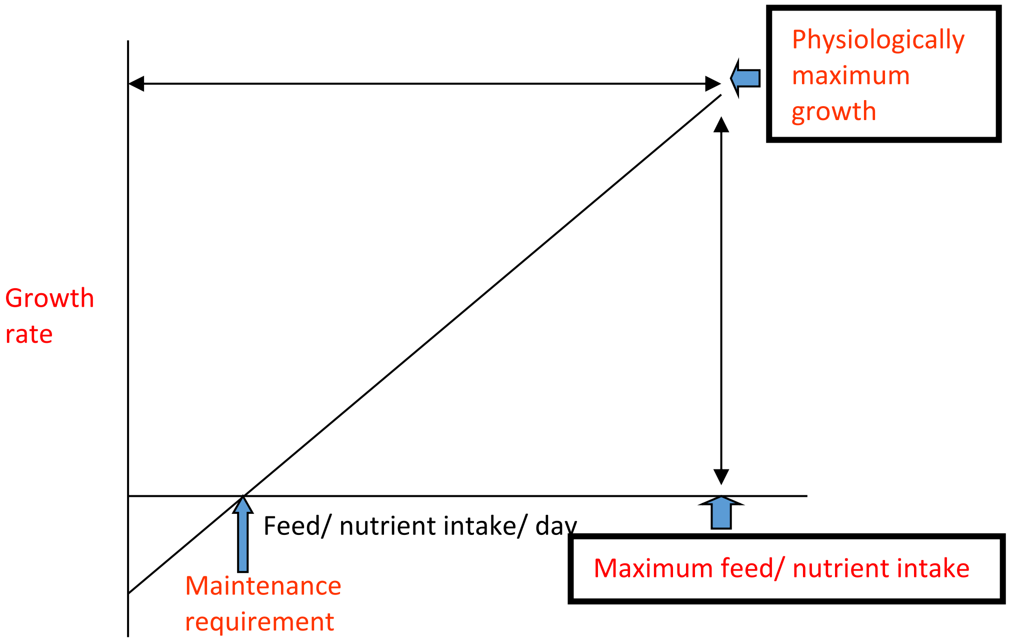

Figure 19 Relationship between feed/ nutrient intake vs. growth of particular weight of fish

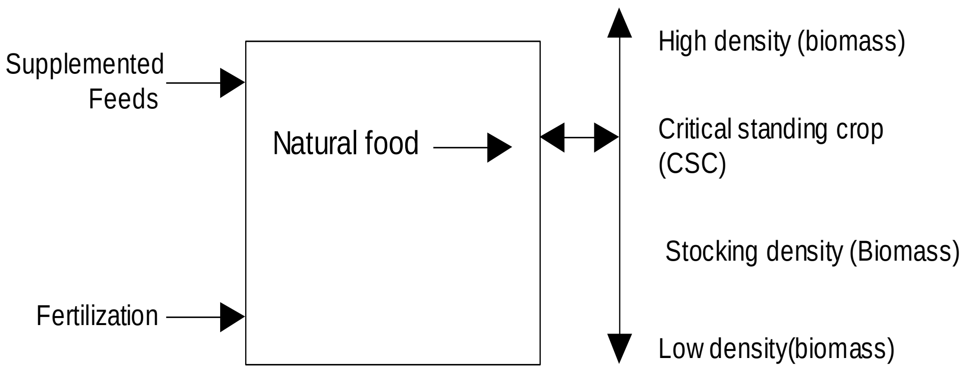

Figure 20 Critical standing crop of fish vs. nutrient (natural food) supply from pond culture system

Research conducted in AIT, Thailand showed that nutrient requirements of Nile tilapia satisfy by natural feed until fish biomass per m^2 (or m^3) reach until 200 g (2 fish weighing 100 g each/ m^2). Research also showed that FCR of fish fed pelleted feed containing 28 – 30% protein grown in clear-water tanks are on average is around 1.5. Fish grown at a density of 2 – 3 fish/ m^2 in fertilized pond system can have FCR as low as 0.75 indicating that natural food and pelleted feed each contribute to 50% nutritional requirement. Hence, instead of feeding at 100% satiation feeding for the entire grow-out period, feeding could be delayed until the fish reached an advanced size (100 grams) and could then be limited to half satiation ration. This would lower the feed cost and also environmental pollution.

Figure 21 summarises the metabolic fate of ingested nutrients by fish assuming the consumption of 100 KJ energy or 100 g protein by fish. There will be 10 – 30% loss at the digestion stage – higher digestible loss from low quality feeds. If amino acids are not balanced, there will be a higher excretory loss than 8% shown in the figure. The remaining energy is termed metabolizable energy that is available for growth. Inevitable losses are the cost of growth (energy loss during the chemical reactions related to growth and maintenance) and there are 15 – 30% losses due to daily losses/ replacement of mucus and scale. Whatever remain is the net growth or harvestable yield. In a typical aquaculture situation, net growth is around 25% of nutrient intake and 75% of the nutrients are loss during the production process.

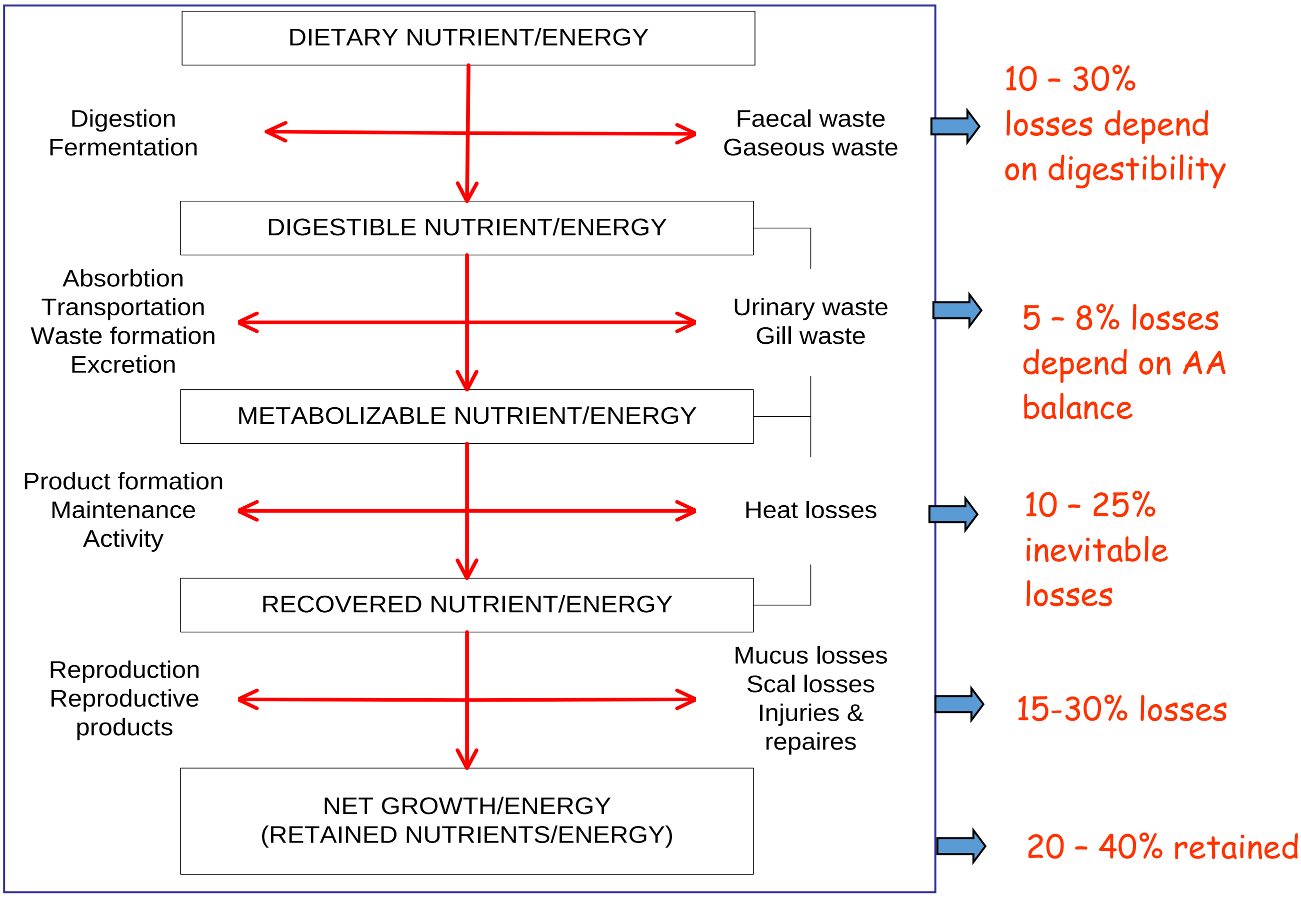

Figure 21 Nutrient losses through the growth process of fish

Exercises:

1. Discuss on aquaculture classification system for intensification of aquaculture based on nutritional inputs.
2. Discuss on the nutrient losses during the growth process. How can practitioners reduce the losses?
3. Define feed conversion ratio
4. Food conversion efficiency (FCE) = weight gain/ feed intake. If FCR = 1.5, what is the FCE?
5. A fish eats 5 g of dry matter of diet containing 30% protein. Fish produce 1 g of faeces containing 50% of protein. Calculate the dry matter and the protein digestibility of feed.

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Website - Monosex tilapia https://fishbd.wordpress.com/mosex-tilapia/

Appendix

TABLE 7-1 Nutrient Requirements for Channel Catfish, Rainbow Trout, Pacific Salmon, Common Carp, and Tilapia as Percentages of Diet, Milligrams per Kilogram of Diet, or International Units (IU) per Kilogram of Diet (as-fed basis)[a]

	Channel Catfish	Rainbow Trout	Pacific Salmon	Common Carp	Tilapia
Energy Base[b] (kcal DE/kg diet)—>	3,000	3,600	3,600	3,200	3,000
Protein, crude (digestible), percent	32 (28)	38 (34)	38 (34)	35 (30.5)	32 (28)
Amino acids					
Arginine, percent	1.20	1.5	2.04	1.31	1.18
Histidine, percent	0.42	0.7	0.61	0.64	0.48
Isoleucine, percent	0.73	0.9	0.75	0.76	0.87
Leucine, percent	0.98	1.4	1.33	1.00	0.95
Lysine, percent	1.43	1.8	1.70	1.74	1.43
Methionine + cystine, percent	0.64	1.0	1.36	0.94	0.90
Phenylalanine + tyrosine, percent	1.40	1.8	1.73	1.98	1.55
Threonine, percent	0.56	0.8	0.75	1.19	1.05
Tryptophan, percent	0.14	0.2	0.17	0.24	0.28
Valine, percent	0.84	1.2	1.09	1.10	0.78
n-3 fatty acids, percent	0.5–1	1	1–2	1	—
n-6 fatty acids, percent	—	1	—	1	0.5–1
Macrominerals					
Calcium, percent	R	1E	NT	NT	R
Chlorine, percent	R	0.9E	NT	NT	NT
Magnesium, percent	0.04	0.05	NT	0.05	0.06
Phosphorus, percent	0.45	0.6	0.6	0.6	0.5
Potassium, percent	R	0.7	0.8	NT	NT
Sodium, percent	R	0.6E	NT	NT	NT
Microminerals					
Copper, mg/kg	5	3	NT	3	R
Iodine, mg/kg	1.1E	1.1	0.6–1.1	NT	NT
Iron, mg/kg	30	60	NT	150	NT
Manganese, mg/kg	2.4	13	R	13	R
Zinc, mg/kg	20	30	R	30	20
Selenium, mg/kg	0.25	0.3	R	NT	NT
Fat-soluble vitamins					
A, IU/kg	1,000–2,000	2,500	2,500	4,000	NT
D, IU/kg	500	2,400	NT	NT	NT
E, IU/kg	50	50	50	100	50
K, mg/kg	R	R	R	NT	NT
Water-soluble vitamins					
Riboflavin, mg/kg	9	4	7	7	6
Pantothenic acid, mg/kg	15	20	20	30	10
Niacin, mg/kg	14	10	R	28	NT
Vitamin B_{12}, mg/kg	R	0.01E	R	NR	NR
Choline, mg/kg	400	1,000	800	500	NT
Biotin, mg/kg	R	0.15	R	1	NT
Folate, mg/kg	1.5	1.0	2	NR	NT
Thiamin, mg/kg	1	1	R	0.5	NT
Vitamin B_6, mg/kg	3	3	6	6NT	
Myoinsitol, mg/kg	NR	300	300	440	NT
Vitamin C, mg/kg	25–50	50	50	R	50

NOTE: These requirements have been determined with highly purified ingredients in which the nutrients are highly digestible, therefore the values presented represent near 100 percent bioavailability.

Module: Nile tilapia production process

Session 2.5: Fish feed formulation

Session objectives:

This session objective is to introduce feed formulation techniques for practitioners who wish to produce on-farm feeds

Learning outcomes:

At the end of the session, trainees will be able to formulate least-cost fish feed using Excel spreadsheets

Session narrative:

Feed formulation is application of fish nutrition concepts to prepare nutritionally balanced feeds. The following information is required prior to the formulation stage of feed formulation and manufacture:

1. Nutrient and energy specification
   - ✓ Crude protein specification - lower and upper limits (32% - NRC recommendation)
   - ✓ Amino acid specification – see NRC recommendations
   - ✓ Lipid and fatty acid requirements (Nile tilapia require0o.5% ω-6 (or n-6) fatty acids)
   - ✓ Vitamin and mineral requirements (dependent upon the culture system – natural feed contribution - and also processing losses)
   - ✓ Carbohydrate level: usually does not exceed 30 - 40 %
   - ✓ Energy specification – 3,000 Kcal/kg of feed or 12.6 KJ/of feed (NRC recommendation)
   - ✓ Protein to energy (P:E) ratio (mg protein/kJ) - around 20 – 25 mg protein/KJ or 90 - 100 mg/kcal
   - ✓ Fiber level: maximum 10 % preferably around 5%
   - ✓ Ash level: maximum 12 - 15 % is desirable

2. Available ingredients and their nutrient composition and prices
   - ✓ Protein and amino acids content
   - ✓ Lipid content – check whether the ingredients contain sufficient ω-3 fatty acids)
   - ✓ Vitamin and mineral sources (selection of ingredients containing vitamin and mineral reduce fortification requirements)
   - ✓ Proximate and essential amino acid (EAA) and essential fatty acid (EFA) compositions
   - ✓ Nutrient digestibility
   - ✓ Toxic/ anti-nutritional factors – to set upper limits (%) of the use particular ingredients

3. Functional properties of ingredients
   - ✓ Water absorption capacity
   - ✓ Gelation capacity

4. Physical properties of ingredients
   - ✓ Particle size
   - ✓ Bulk density

Details of nutrient and energy specification can be found in NRC (1993). Much of the information on widely used ingredients are available in Internet – for novel ingredients, laboratory analyses are required. Functional properties of raw materials such as gel formation capacity and water holding capacity are important as cooking the ingredients to make a gel can be used to bind all ingredients together. Gelatinization of starch and protein help to bind ingredients and increase water stability. If ingredients are pre-processed with low temperature, they have higher functional properties. Any ingredients that had been subjected to thermal processing loss gel formation capacity e.g. one cannot make an omelet using a boiled egg.

Preferably, the particle size should be small as 500 microns (half a millimeter) for better digestibility and also to produce water stable feed. If large particles are use in feed production, the pellets break easily. Bulk density is important for two reasons: (1) reduce the volume of feed; and (2) mixing ingredients is difficult when different ingredients have different densities. However, if extruder is not available, addition of ingredients with high bulk density (such as dried leaves) will produce low density feeds that might float for a few minutes.

Best-Buy techniques of dietary ingredients

The price of the feedstuffs used in diet formulations must be considered to formulate a cost-efficient diet. Feedstuffs can be compared with one another on the basis cost per unit of protein, energy, or amino acid. Following two examples shows how to select a protein and energy ingredients assuming their nutritional quality is the same.

Examples:

1. Fish meal (FM) containing 60% crude protein and the price is 15 Baht/kg. Squid meal (SQM) containing 75% crude protein and the price is 20 Baht/kg. What is the cheapest protein source?

FM: 1000 kg FM = 600 kg protein = 15 x 1000 = 15,000 Baht
1 kg FM protein = 15,000/600 = 25 Baht/kg

SQM: 1000 kg SQM = 750 kg protein = 20 x 1000 = 2,000 Baht
⍰ 1 kg SQM protein = 20,000/750 = 26.7 Baht/kg

2. Wheat bran (WB) containing 5020 kJ ME/kg cost 3 Baht/kg. Rice bran (RB) containing 4500 kJ ME/kg cost 2 Baht/kg. Which is the cheap energy source?

WB cost: 3/5020 = 0.0006 Baht/KJ ME
RB cost: 2/4500 = 0.0004 Baht/KJ ME

Feed formulation

For methods can be used for feed formulation. First two methods are simple and the last two methods requires Excel spreadsheet to formulate feeds:

1. Pearson's square method
2. Simultaneous equations
3. Computer spreadsheet – arithmetical approach
4. Linear Programming – Least Cost Feed Formulation

Following examples shows the four methods:

Pearson's Square method:

This is a good method for a beginner. Neglect positive or negative signs when using this method.
Examples:

1. A mixture containing 25% crude protein (CP) is required. Available ingredients are copra meal and fish meal which contain 20% and 60% crude protein respectively. How many grams of each feedstuff should be mixed to make a 100 g of 25% CP diet?

Copra meal 20 ———— 35 → (35/40) x 100 = 87.5%

25

Fishmeal 60 ———— 5 → (5/40) x 100 = 12.5%

100 g diet contains 87.5g copra meal and 12.5g fish meal. Back calculate to determine whether you have obtained the desired protein content for the diet.

2. Cotton seed meal and maize germ meal are known to contain 55% and 20% crude protein, respectively. It was decided to formulate a diet containing 30% crude protein for tilapias using above ingredients. What is the percentage composition of the dietary ingredients in the finished feed?

20 ....25 →25/35) x 100 = 71.4

30

55 .... 10 → 10/35) x 100 = 28.6

Simultaneous equation method: The simultaneous equations can be also used to calculate the % of ingredients that should be used in a feed mixture. Using examples given under square method:

1. P = g copra meal in 100 g feed mixture
   Q = g fish meal in 100 g feed mixture

   0.20P + 0.60Q = 25 (1)
   P + Q = 100 (2)

   (2) x 0.20 → 0.20P + 0.20Q = 20 (3)

   (1) - (3) → 0.4Q = 5
   Q = 12.5

   Substituting value for Q to equation 2:

   P + 12.5 = 100
   P = 87.5

Feed should contain 87.5% copra meal and 12.5% fish meal. Back calculate to determine whether you have obtained the desired protein content for the diet.

1. A diet containing 35% crude protein (CP) is required. Available ingredients are fish meal (FM) containing 60% CP, rice bran (RB) containing 10% CP and soy bean meal (SBM) containing 45% CP. Final product should contain animal protein not less than 1/3 of total CP. It is desirable to add 2% vitamin, 2% mineral, 4% extra lipid (?3 and ?6) and 2% Binder. Calculate the % ingredients in the feed mixture.

   Let P = g FM in 100 g feed mixture
   Q = g RB in 100 g feed mixture
   R = g SBM in 100 g feed mixture

Constraint for animal protein content:

0.6P = 35 □ 3 ------□ 0.6P = 11.67 (1)

Total protein content in the diet:

0.6P + 0.1Q + 0.45R = 35 (2)

To leave the space for other additives:

P + Q + R = 100 - {2(vit) + 2(min) + 4(lipid) + 2(binder)} (3)

P + Q + R = 90

Therefore,

0.6P = 11.67 (1)

0.6P + 0.1Q + 0.45R = 35 (2)

P + Q + R = 90 (3)

From (1) P = 11.67/0.6 = 19.44

Substituting value for P to equations (2) and (3):

To equation (2):

0.6 x 19.44 + 0.1Q + 0.45R = 35

0.1Q + 0.45R = 23.34 (4)

To equation (3):

19.44 + Q + R = 90

Q + R = 70.56 (5)

(5) x 0.45 0.45Q + 0.45R = 31.75 (6)

(6) - (4) 0.35Q = 8.41

Q = 24.03

Substituting P and Q values to equation (3):

R = 90 - (19.44 + 24.03) = 46.53

Computer spreadsheet method

If the percentage protein contents of dietary ingredients A_1, A_2, ... A_n are denoted by P_1, P_2, ... P_n, then the total protein content of feed mixture is equivalent to:

$(P_1/100) \times A_1 + (P_2/100) \times A2 + (P_3/100) \times A_3$ …….. $(P_n/100) \times A_n$ = Protein content

Where $A_1 + A_2 + ... + A_n = 100$.

These equations can be repeated in an Excel spread sheet for other components of the feed: dry matter, lipid, NFE, ash, fiber and moisture

Least cost feed formulation

Linear Programming, a simple yet powerful mathematical technique, can be used to formulate diets to minimize cost and optimize dietary nutrient content in the compound feed.

All the methods shown above have the following shortcomings:

- specifying multiple nutrient requirements (e.g. protein content, specific amino acids, and specific minerals) are difficult
- cannot find the lowest cost feed formulation; and
- requirements cannot be defined as > or equal/ and < or equal.

Those can be accomplished in Linear Programming using the same computer spreadsheet described above. Refer to Excel manual for details:

Least Cost Feed Formulation

Step 1: Decide the dietary nutrient level requirement for fish.

For example: Protein = 30%, Methionine = 0.6 %, Lysine = 1.2%, P = 0.7%.

Step 2: Decide the ingredients to be used and their compositions

For example:

- cassava (X_1), soybean meal (X_2),
- corn (X_3), rice bran (X_4),
- corn oil (X_5), fish meal (X_6),
- vitamin premix (X_7) and
- mineral premix (X_8).

Feed composition data (example)

Ingredient	Composition (%)						kcal/g	
	CP	CL	Met	Lys	P	Fib	DM	DE
Cassava (X_1)	4	3	0.05	0.04	0.02	7	93	3.0
Soybean meal (X_2)	45	8	2.9	0.7	0.65	8	90	3.6
Corn (X_3)	9	5	0.2	0.2	0.3	10	92	3.0
Rice bran (X_4)	12	10	0.25	0.3	0.8	9	89	2.5
Corn oil (X_5)	0	100	0	0	0	0	100	8.9
Fish meal (X_6)	70	10	2.1	5.7	1.7	4	90	3.7
Vitamin premix (X_7)	0	0	0	0	0	0	90	0.0
Mineral premix (X_8)	0	0	0	0	0	90	90	0.0

Step 3: Formulate the problem equations (Excel spreadsheet should be programed for the following equations)

For protein:

$$0.04\,X_1 + 0.45\,X_2 + 0.09\,X_3 + 0.12\,X_4 + 0\,X_5 + 0.7\,X_6 + 0\,X_7 + 0\,X_8 \geq 30$$

For Lipid:

$$0.03\,X_1 + 0.08\,X_2 + 0.05\,X_3 + 0.1\,X_4 + 1\,X_5 + 0.7\,X_6 + 0\,X_7 + 0\,X_8 \leq 8$$

For Fibre:

$$0.07\,X_1 + 0.08\,X_2 + 0.1\,X_3 + 0.14\,X_4 + 0\,X_5 + 0.04\,X_6 + 0\,X_7 + 0\,X_8 \leq 8$$

For Lysine:

$$0.0004\,X_1 + 0.007\,X_2 + 0.002\,X_3 + 0.003\,X_4 + 0\,X_5 + 0.57\,X_6 + 0\,X_7 + 0X_8 \geq 1.5$$

For Methionine:

$$0.0005\,X_1 + 0.029\,X_2 + 0.002\,X_3 + 0.0025\,X_4 + 0\,X_5 + 0.021\,X_6 + 0\,X_7 + 0\,X_8 \geq 0.56$$ For

Phosphorous:

$$0.0002\,X_1 + 0.0065\,X_2 + 0.003\,X_3 + 0.008\,X_4 + 0\,X_5 + 0.17\,X_6 + 0\,X_7 + 0X_8 \geq 0.7$$ For

Energy:

$$3\,X_1 + 3.6\,X_2 + 3\,X_3 + 2.5\,X_4 + 8.9\,X_5 + 3.7\,X_6 + 0\,X_7 + 0\,X_8 \geq 3.5$$

For total:

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 = 100$$

And

$$X_1 \geq 0$$
$$X_2 \geq 0$$
$$X_3 \geq 0$$
$$X_4 \geq 0$$
$$X_5 \geq 0$$
$$X_6 \geq 0$$
$$X_7 \geq 0$$
$$X_8 \geq 0$$

Step 4: Set-up Restrictions

For example:

- Cassava: $X_1 \leq 25$; $X_1 \geq 15$ – set a range; minimum 15% and maximum 25%
- Fish meal: $X_6 \geq 4$
- Vitamin premix $X_7 = 1$

Step 5: Set up objective function

- cassava (X1) = 3 B/kg
- soybean meal (X2) = 20
- corn (X3) = 10
- rice bran (X4) = 5
- corn oil (X5) = 100
- fish meal (X6) = 12
- vitamin premix (X7) = 400
- mineral premix (X8) = 250

$$3X_1 + 10X_2 + 6X_3 + 3X_4 + 50X_5 + 12X_6 + 200X_7 + 150X_8 = Minimum$$

Minimum price:

$$3X_1 + 10X_2 + 6X_3 + 3X_4 + 50X_5 + 12X_6 + 200X_7 + 150X_8$$

Step 6: Run the program using a linear programming package.

Output: Example EXCEL output

Objective Cell (Min)

Cell	Name	Original Value	Final Value
V9	FEEDCOST	22.36	22.77

Variable Cells

Cell	Name	Original Value	Final Value	Integer
C2	RB	23.82	15.00	Contin
E2	COPRA	0.00	0.00	Contin
G2	Cassavaflour	17.35	18.59	Contin
I2	Wheat flour	0.00	0.00	Contin
K2	Mineral	1.00	1.00	Contin
M2	FM	10.00	0.00	Contin
O2	SBM	45.83	63.41	Contin
Q2	Corn oil	1.00	1.00	Contin
S2	EGG	0.00	0.00	Contin
U2	Vitamin	1.00	1.00	Contin

Step 7: Re-Run (if solution cannot be found, relax constraints and rerun)

See the results and if not suitable modify restrictions and problem equations -- re-run. Repeat until that you satisfy with the answer.

Exercises:

1. Cotton seed meal and maize germ meal are known to contain 55% and 20% crude protein, respectively. It was decided to formulate a diet containing 30% crude protein for tilapias using above ingredients. What is the percentage composition of the dietary ingredients in the finished feed?

2. A mixture containing 25% crude protein (CP) is required. Available ingredients are copra meal and fish meal in which contain 20% and 60% crude protein respectively. if a farmer wants to add 20% cassava starch, 2% oil, 3% vitamin and mineral premix to the diet, calculate the % of fish meal and copra meal needed to be added to the feed mixture (Hint: adjust the protein level of the mixture to leave space for the other ingredients.

3. Use Excel software to formulate feeds followed by the methods described above

References:

There are no good references available in Internet for feed formulation. Refer Excel Manual for Linear Programming and practice before teaching the subject.

Module: Nile tilapia production process

Session 2.6: Feed production/ manufacture

Session objectives:

This session introduces the fundamentals of aquaculture feed production process and let the trainees to practice ways to produce water-stable farm-made feeds.

Learning outcomes:

At the end of this session, trainees will be able to produce water stable farm made feeds.

Session narrative:

The feed manufacturing involves in converting raw materials having widely ranging physical, chemical and nutritional properties into a homogeneous mixture and then shaped into feed pellets. The objective of feed manufacturing is to produce a fish feed which is nutritionally balanced to meet the requirements of fish grown in a particular culture system in a form which is palatable, digestible, cost effective, and enables maximum feed ingestion. The produced pellets should withstand normal handling procedures and water-stable to guarantee maximum feed ingestion. There are two type of aqua feeds: dry-feeds containing ≤ 10% moisture and moist-feeds containing 20 - 40% moisture. This session focused on the production of dry feeds. The overall process is shown in Figure 22.

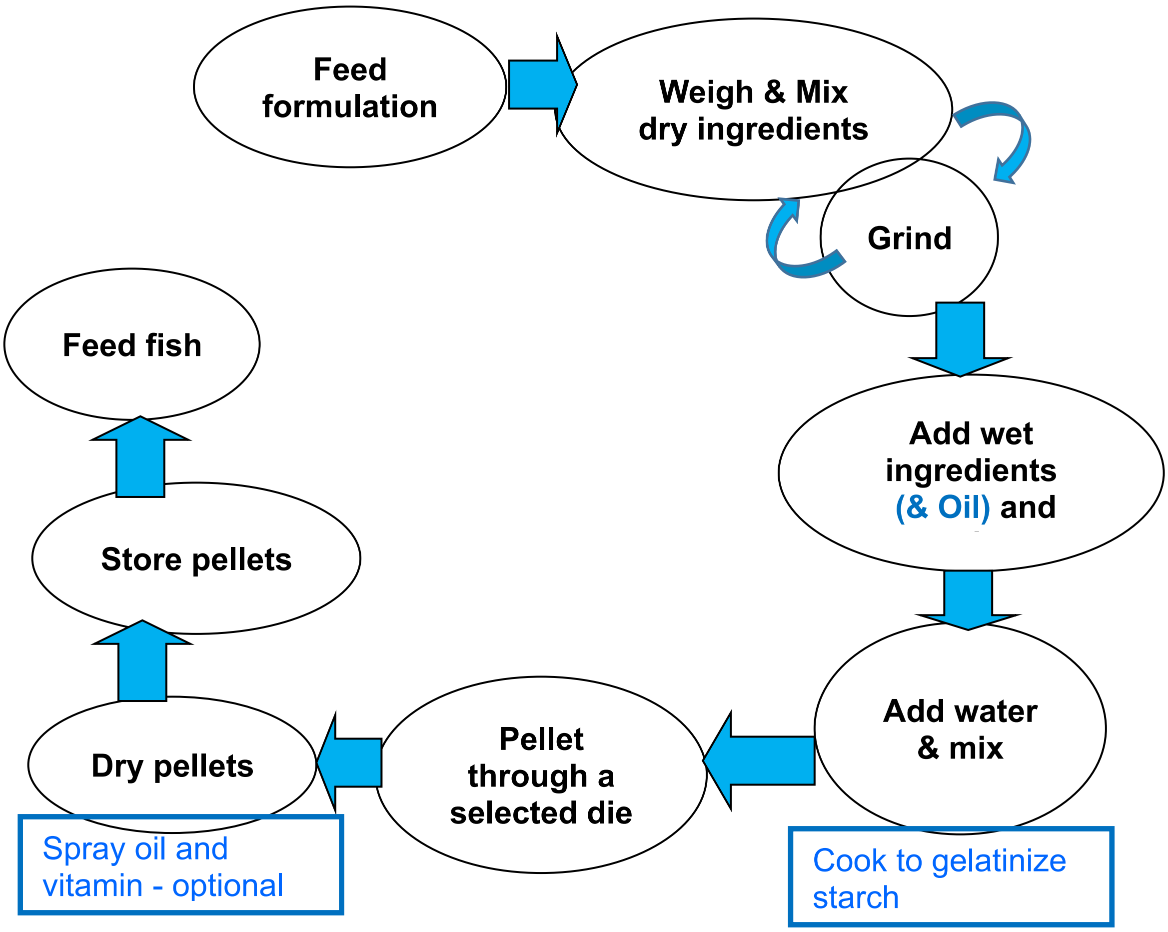


Figure 22 Flow chart on the feed manufacturing process

GENERAL PROCEDURE FOR COMMERCIAL FEED MANUFACTURING PROCESS

Inspection of raw materials: Prior to feed manufacture, raw materials should be inspected for contaminants and stored properly.

The raw materials might be collected or delivered with jute or loosely woven sacks in many developing countries. Care should be taken to inspect these materials for wetness, mould growth, and possible adulteration. The inspection procedure starts with visual examining a sample of feedstuffs for the colour and texture and then by smelling for rancid, ferment, musty smell, and tasting, if safe, for sour or bitterness of the feedstuffs. After the preliminary examining is completed, a sample of feedstuff should be screened by sieving or by using flotation (density) techniques to investigate the adulteration. The feed ingredients should be examined under a microscope for the contamination with small particles. Contamination of raw materials by large pieces of metals, stones, woods and metal strings could cause extensive damage to the machinery that can be removed by sieving and passing through a magnet before entering the grinder.

Storage of raw materials: To take the advantage of market price fluctuations of raw materials, and to counteract the seasonal availability, some raw materials should be stored for a relatively longer duration. It is a usual practice in many developing countries to store feedstuffs in jute or polythene sacks. Care should be taken not to use bags previously used to store fertilizers, pesticides, and chemicals. Feed ingredients should be stored under a roof, water-proofed, and well ventilated area that is not subjected to high temperatures and temperature fluctuations. The bags should be stacked a few inches above floor on wooden pallets, and away from walls to avoid condensation of moisture.

Raw material weighing: The accurate weighing according to the formula is one of the most important operations in feed manufacturing. The raw materials may be weighed before grinding and mixing or they may be pre-ground and then weighed and mixed. A great care should be taken when weighing micro-nutrients such as vitamins and minerals as they are used in small quantities and also they are the most expensive ingredients.

Reduction in particle size: The reduction of large particles to a desired size (smaller than 1 mm) improves digestibility and pelleting process. Fine particles are easy to mix to form a homogenous mixture. The grinding operation can generate heat (increase by 10 - 20°C) and generate dust. Hammer mills, which are impact grinders, are frequently used in feed manufacturing. Inside the grinding chamber contains hammers, which are fixed to the centre shaft, rotating at high speed. The impact of swinging bars on the raw materials and the impact of feed particles on particles result in material breakdown until they are small enough to pass through a perforated screen. Hammer mills generally work well with relatively high bulk density ingredients containing low moisture and fat. The moisture content normally should not exceed 13 - 14%.

Mixing: Mixing is an art rather than a 'science'. The primary objective of mixing is to produce a homogenous blend until a sample has a same composition as original formulation, so that each fish receives a balanced mixture of nutrients. Fish are relatively small and consume small quantity of food at a time. Each food particle should contain all nutrients according to the specification. Poor mixing results in a greater daily variation in daily nutrient intake. Mixing can be also used to improve the palatability of one or more unpalatable raw materials used in the dietary formulation.

Mixing farm-made feed: Manual mixing in a bucket or on a clean cement floor with the gloved hands can be used for the production of farm-made feeds used for small-scale aquaculture operations (< 5kg). Dry ingredient mixture is prepared by using a food mixture (or blender) and adding micro-nutrients (such as vitamins and minerals) gradually - small amount at a time. Starchy materials should be weighed separately and cook to gelatinize starch (to be used as a binder), add dry ingredient mixture to the gelatinized paste. If starch is not gelatinized, water should be added after homogeneous mixture of dry materials is achieved (dry extruders require wet dough with 30-40% moisture, depending on the ingredients' flow characteristics). The lipid fraction should also be added gradually (small amount at a time), preferably before the addition of water.

If a large quantity of farm-made feed is prepared, shovelling on a concrete pad can be used to mix ingredients in a manner similar to the dry mixing of cement and sand. The raw materials should be layered one above each other and then mixed and turned to form a heap adjacent to the original pile. Repeating this process at least three times may produce an acceptable mixture with even distribution of micro-nutrients. The even distribution of the colour of the mixture is usually a fair indication as to the homogeneity of the mixed feed. Small concrete mixtures or low cost food mixtures available in the market also can be used on farm feed mixing. It is cheaper to use conventional feed mixers for larger-scale feed mixing. Two types of mixtures are most commonly found in the feed industry: the vertical mixers and the horizontal mixtures.

Vertical mixers: A vertically running screw, approximately 8-10" diameter rotating at 100-200 rpm to continuously tumble and intermingle the raw materials as they are discharged in a fountain-type action in a vertical mixer. The characteristic nature of these mixtures is their slow action and the long-dwelling time. The raw materials are added to vertical mixtures either from the top from a cyclone or from the base of the screw. Mixing time usually lasts for 10-15 minutes. Mixing efficiency of the vertical mixers may be dependent upon:

- ✓ particle size and shape
- ✓ particle density
- ✓ electrostatic charge of particles.

Usually as "mixing" always accompanies with "unmixing", vertical mixers have the general tendency to encourage particle segregation, especially if too long mixing time is used.

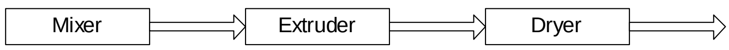
Horizontal mixers: These mixers are equipped with a horizontally turning mixing shaft. The paddles or agitators may be attached to the shaft. Homogeneous mixture is achieved by lifting, folding, and abrading raw materials against each other resulting in a relatively low mixing time (3-6 minutes).

Pelleting: Pelleting involves the compression of a mixed feed through the hole in a hardened steel ring or a plate (a die) by means of hardened steel rollers or horizontally running screw. The die forms the feed into pencil-like extrusions that are cut by knives into pellets of desired length on the leaving of the die. This process is energy intensive, demanding up to 50% of the total power requirement.

(1) Cold pelleting: Feed-mix is fed directly into the die head at room temperature in cold pelleting process. Approximately 15-16% moisture is added in this process without any heat treatment. However the term 'cold pelleting' is misleading since a considerable amount of heat is generated during the pelleting operation - the frictional forces generated during pellet extrusion can cause the temperature of pelleted feed to increase up to 60 - 70°C. The pellets should be dried and cooled to ambient temperature before stored:

(1) COLD EXTRUSION WITH SIMPLE MINCER – SINKING PELLETS

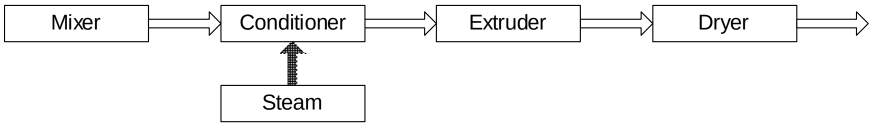
Cold extrusion-shaping process



(2) Conditioner pelleting: In conditioner pelleting, the feed mixture is directly pre-heated to a preferred temperature with dry steam (*i.e.* steam that contains no condensed droplets) in a small high speed mixer called conditioner. After conditioning, the feed mixture is compressed through a die to form pellets similar to cold pelleting. The pellets should be dried and cooled to ambient temperature before storage.

(2) HIGH TEMPERATURE EXTRUSION FOR SINKING PELLETS

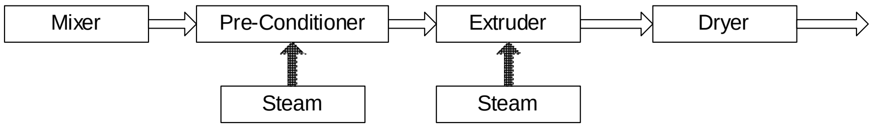
High temperature shaping and texturising process



(3) Wet extrusion: Single-screw or double-screw extruders, which are capable of processing raw materials containing relatively low moisture (<20%) were developed for the purpose of making puffed (low density) snacks. The same process is used for producing floating fish feeds.

(3) HIGH TEMPERATURE EXTRUSION FOR FLOATING PELLETS

High temperature expansion process



Wet extrusion is usually accomplished by steam conditioning before extrusion and steam injection into the extruder. Generally, activities in an extruder includes moving feed-mix in a steam-heated barrel surrounding a conveying screw, rotating in the tight fitting barrel, heats, and converting feed ingredients into a pasteurized mass (some machines are equipped with twin-screw extruders of co-rotating or counter-rotating). The screw consists of three sections: feed, compression (transition), and metering sections (see figure below). The feed section receives and conveys feed mixture into the extruder and pass to the transition section. Compression is achieved by increasing the diameter of the screw at the transition section (result in a conical screw at the extruder discharge). The compression of feed mixture causes increased temperature of the feed-mix and to convert it into a gelatinized mass. Since the screw contains continuous channels, the forward flow of materials increases the pressure at the extruder's discharge. The pressure within the barrel is further increased by direct steam injection to the barrel. The reduction of pressure of the gelatinized mixture, as it passing through the die, expand (puff) the pellets due to the expansion of internal moisture (as steam), resulting low density floating pellets.

Bagging: The commercial pelleted feeds are stored in paper bags. Bags are filled with feeds directly from the cooler or from holding bins and may be weighed on a scale balance, usually 20 kg of pellets per bag. Bags are hand/machine stitched or tied with a string or a metal tie. Polythene bags should not be used for storing feeds because of the risk of *sweating* and mould growth.

Quality control: Care must be taken to ensure the composition of the finished product is similar to the feed formula. The chemical composition of finished feeds should be regularly monitored. The moisture content of finished feed is extremely important. The following changes may be anticipated at temperatures between 20 - 30°C:

Moisture content (%)	Relative humidity RH (%)	Consequences
0 - 8	0 – 30	No significant biological activity
8 - 14	30 – 70	Possible insect infestation; mites may be infested when RH is above 60%.
14 - 20	70 – 90	Insect infestation and mould growth
20 - 25	90 – 95	Mould and bacteria growth
> 25	> 95	Bacteria growth and seed germination.

As a result of these consequences, there will be weight losses, quality losses and as a combined result of both losses there will be economic loss.

Storage: Feed bags should be stored in water-proofed well-ventilated area away from sunlight. Feed bags should not subject to high temperatures and temperature fluctuations. The bags should be stacked a few inches above floor on wooden pallets, and away from walls to avoid condensation of moisture.

Figure 23 *Feeds stored in a tilapia cage farm in Thailand for regular feeding*

OPTIONS FOR SMALL-SCALE FISH FEED MANUFACTURE

Objective of small-scale feed manufacture: To present a feed to fish which is nutritionally balanced to meet the requirements of the culture system being practiced in a form which is palatable, digestible, cost effective and enables maximum feed ingestion.

Problem encountered by on-farm feed producers: The formulations that meet the nutrient requirements often **do not** meet the fish (or fish farmers) requirements for a feed as it disintegrate in water before ingestion. We can use functional properties of feed ingredients to solve this problem

Nutrient	**Form**	**Functional state**
Protein - uncooked	Un-denatured polymer	Soluble, gel forming & thermo-setting – ACT AS A BINDER
Protein - cocked	Denatured polymer	Insoluble & inert – not a good binder
Starch - uncooked	Digestible polymers Native granules	Insoluble & inert – not a good binder
Starched -cooked	Gelatinized polymer	Soluble viscous gel– ACT AS A BINDER

A cold-extruded feed mixture shown below without subject to cooking is not water stable. Steam conditioning or cooking the mixture will give some stability to the pellets.

Ingredient	% added	Functional form	Comments
Rice bran	15.0	inert	As dough balls well rapidly disintegrate in water
Fish meal	12.5	inert	
Cassava	15.0	inert	
Soya bean meal	35.0	inert	
Ground nut cake	17.0	inert	
Fish oil	3.0	inert	
Vitamins	1.0	inert	
Minerals	2.5	inert	

A diet with water stability (30 minutes)

Ingredient	%	Functional form
Wheat flour	10.0	extensible protein
Rice bran	5.0	inert (I)
Sun-dried fish meal	12.5	partly soluble protein
Pre-gelled cassava	15.0	viscous gel
Soya bean meal	35.0	I
Groundnut cake	15.0	I
Fish oil	2.0	I
Vitamins	1.0	I
Minerals	2.5	I
Guar gum	2.0	viscous gel

Heating proves convert inert nutrient to soluble gel:

Cassava starch → insoluble → heat → soluble gel.
Rice bran starch→ insoluble → heat → soluble gel.
Fish/sun-dried fish meal → semi-soluble protein → heat → soluble gel
Full fat soya → semi-soluble protein → heat → Soluble gel

Soluble gel act as a binder and make water stable feeds Fair stability as dough ball, steam condition in a pelletizer to activate wheat gluten and cassava may provide more stable diet.

Exercises:

1. Prepare a water-stable fish feed in the laboratory using the following ingredients:

Ingredients	% added
Wheat bran	16
Fish meal	5
Cassava	20
Soya bean meal	35
Ground nut cake	20
Fish oil	2
Vitamins	1
Minerals	1

Procedure:

- Weigh all ingredients to prepare 1 kg feeds
- Keep cassava starch separately
- Mix all other dry ingredients together – add vitamin and mineral little by little and mix well
- Add oil to the dry ingredient mixture and mix well
- Ad 500 mL water to cassava and cooked - do not let dry
- As soon as gel is formed, add all dry ingredient mixture to cassava gel, mix and make a homogenous dough
- Extrude the dough through a mincer.
- Dry under shade at low temperature. If possible, use a fan.
- Collect feed to a paper bag, seal the bag and store in a cool place.

References:

Information related to Asia can be found at: https://enaca.org/?id=886&title=asia-pacific-consultation-on-responsible-production-and-use-of-feed-and-feed-ingredients

Module 2: Nile tilapia grow-out process

Session 2.7: Water quality management

Session objectives:

This session provides an overview of water quality management and emphasis on the importance of monitoring water quality in intensive aquaculture practices.

Learning outcomes:

At the end of the session, the trainees will be able explain the importance of water quality parameters and able to analyse some selected parameters (Dissolved Oxygen, Temperature, pH, Alkalinity, ammonia and nitrite).

Session narrative:

Successful aquaculture depends on the maintenance of good fish health. Poor water quality reduces growth and affects health of fish adversely.

A proper water quality management procedure is utmost important for keeping fish without stress so their immune system can resist pathetic bacteria present in waters. Fish diseases usually occur after stress from impaired water quality. Water quality management is also very important if water supply is limited or sub-standard quality surface water is the principal source.

Nile tilapia is able to withstand a wide range of water quality parameters including salinity, temperatures, ammonia concentrations, and dissolved oxygen.

Salinity: Nile tilapia tolerate up to 15 ppt and best growth is around 10 ppt) isosmotic pressure). However, they spawn best in lower salinities (5 – 10 ppt) and fish fry perform better at salinities less than 5 ppt.

Temperature: The best feed intake and growth at 30°C but tolerate 18 - 33°C.

Dissolved Oxygen: Nile Tilapia are able to tolerate dissolved oxygen levels less as low as 0.3 mg/L for few hours. The best growth rate is achieved by maintaining oxygen levels above 4 mg/L. Hence require some aeration in high density cultivation situations.

pH: Nile tilapia survive in pH ranging from 5 to 10, but optimal pH is between 6 to 9.

Ammonia: Increased ammonia concentrations above 1 mg L^{-1} stress Nile tilapia.

Ammonia Level	Effect on Tilapia
0.1 – 0.9 mg/L	Depressed feeding; some mortality may occur
1 – 2 mg/L	Mortalities, particularly among fry and juveniles
>2 mg/L	High mortality

Nitrite: Lethal concentration of Nitrite-N to Nile tilapia fish fingerlings is around 8o mg/ L and for adult 8 mg/L (4211 mg/L). Addition of chloride to water (as either calcium chloride or sodium chloride) protected both small and large fish from nitrite toxicity. However, it is advisable to maintain nitrite below 2 mg/L

Nitrate: High concentrations of nitrate stresses fish because nitrate limits the ability of haemoglobin to transport oxygen within the body. Nile tilapia can tolerate higher nitrate levels than many other cultured freshwater fish. For optimal cultivation, nitrate concentrations should be kept below 27 mg/L. To prevent nitrate problems in recirculating systems, chloride concentrations are often maintained at 100 to 150 mg/L chloride.

Water quality problems may develop trough:

1. Water intake - sub-standard source water quality
2. Sudden environmental phenomena (pond overturn during heavy rains and storms), and
3. Mismanagement of fish ponds.

Phytoplankton management: Phytoplankton are free-floating microscopic algae. Photosynthetic activity by large plankton populations can produce enough oxygen to cause oxygen super-saturation in water during mid-afternoon on bright sunlit days. Water quality problems fish ponds may arise from excess phytoplankton production that reduce dissolved oxygen during nigh time through respiration and increase pH by the evening reducing buffering capacity by using bicarbonate for primary production.

However, if there is no sufficient phytoplankton in water, ammonia and nitrite, toxic metabolites, accumulate in water. Thus, it is important maintaining a balanced phytoplankton population to maintain pond water quality. Phytoplankton growth is stimulated by addition of nitrogen and phosphorous – this principle is use in pond fertilization. This is called controlled eutrophication.

Phytoplankton bloom stimulated by nutrient inputs can crash when nutrients are depleted, which will reduce DO via bacterial decomposition of organic materials – so it is important to fertilize ponds regular maintain healthy plankton population. If there is no sufficient phytoplankton in water, ammonia and nitrite, toxic metabolites, accumulate in water. Thus it is important maintaining a balanced phytoplankton population to maintain pond water quality. Phytoplankton respiration may account for nearly 80% of oxygen consumption in water during night time, and respiration by large phytoplankton populations may deplete oxygen in ponds during sustained periods of cloudy weather. Hence, daily monitoring of DO in water is an important management practice.

Phytoplankton often tint the water green, but may also cause the water to appear blue-green, red or brown. If plankton populations are the principal source of turbidity in ponds, population densities may be determined by following methods:

1. Secchi disk visibility - a secchi disk is a flat, weighted disk, 20 cm in diameter, with alternate black and white quadrants. Water clarity is determined by lowering the disk into the water until no longer visible. Secchi disk visibility should be 20 – 30 cm. Lower visibility indicates excessive plankton.
2. Low dissolved oxygen in the early morning. If Do is lower than 2 mg/L in the morning, phytoplankton density should be reduced

Phytoplankton populations may be controlled by flushing ponds with new water - partially drain and refill with clean water. It is better to remove water from the pond, bottom as it removes accumulated sludge and nutrients from pond/

Feed and feeding: Faecal and excretory waste generated from feeding fish is also a principal source of mineral nutrients (N and P) in fish ponds. Feeding rates should not exceed 100 kg per hectare (preferably 50 – 75 kg/ha) unless DO is supplied via aeration. The following table shows feed input /ha at stocking density of 2 and 5 fish fed at 100% satiation. Feeding rate exceeds 100 kg/ha indicates why it not possible to conduct high-density fed-fish pond-aquaculture without aeration to supply DO.

Fish weight (g)	Stocking density (fish/m^2)	Feeding rate (100% satiation)	Feed input for 100% satiation kg/ha	Stocking density (fish/m^2)	Feed input for 100% satiation (kg/ha)
100	2	4	80	5	200
200	2	3	120	5	300
300	2	3	180	5	450
400	2	2	160	5	400
500	2	2	200	5	500

Dissolved Oxygen management: Nile tilapia can withstand low dissolved oxygen levels as low as I ppm for a few hours, but levels necessary for fastest growth is around 4 kg/L. DO levels lower than 2 mg/L stresses Nile tilapia, reduces feed intake and growth. It may not affect FCR or survival of fish. However, low DO associate with high pH and unionized ammonia (NH3) will make susceptible to diseases and increase mortality rate. Accumulation of bottom sediments associated with large microbial population and high phytoplankton density are the main courses for low DO. Hence, DO should be monitored regularly in culture ponds.

Reduced DO can be detected easily in Nile tilapia pond as fish come to the surface to breathe in the early morning. Do levels are around 2 mg/L, can be detected as it reduces feed intake. DO should be measured using a DO meter in the early morning before sunrise. The remedies for low DO reduction of phytoplankton density, removal of water, accumulated sludge and nutrients from the bottom of pond using a submersible pump, and oxygenation using aerators.

Toxic Metabolite management; Accumulation of ammonia, nitrite and hydrogen sulphide, which are toxic to Nile tilapia, should be reduced in fish ponds. Carbon dioxide (CO2) is a by-product of respiration is considered as a stress factors and make temperate water fish sluggish. However, this has not been observed in tropical fish ponds as CO_2 readily utilize by phytoplankton.

Ammonia is a by-product of deamination of amino acids (in protein) and fish can excrete it passively through gills. At pH lower tan 7, ammonia in water is in ionized ammonium ion (NH_4^+) form, which is relatively non-toxic to fish. Un-ionized ammonia (UIA - NH_3) is toxic to fish. The median lethal concentration (LC50) of UIA after-expose fish for 24, 48, and 96 h is around 1.5, 1.3 and 1 mg/L, respectively. Measurements of ammonia in water are the sum of NH_3 and NH_4 and are called total ammonia nitrogen (TAN) and it is common to have TAN around 1-2 mg/L (ppm) in ponds with intensive fish culture. However, if temperature is 30 °C and pH is 7, corresponding (to TAN concentration of 1 – 2 ppm) UIA range is 0.008 – 0.016 ppm, which is nontoxic (refer to an ammonia-pH-temperature chart in the Internet calculate the concentration of UIA in water).

Nitrite (NO_2^{-1}) is a product of bacterial reduction of ammonia and it can react with haemoglobin in blood to form methaemoglobin. When concentrations of methaemoglobin in catfish blood reach 20-30 %, the gill filaments become a chocolate brown colour and the fish are diagnosed as having "brown blood" disease. Nitrite toxicity can be controlled by adding calcium (agricultural limestone) to soft water or by adding salt to both soft and hard waters. Chloride (CI) concentrations between 15-30 ppm) usually prevent brown blood problems.

Hydrogen Sulphide (H_2S) is a product of anaerobic decomposition of organic waste by bacteria on the pond bottom. Any detectable level is considered detrimental to fish production. Hydrogen sulphide smells like rotten eggs, and hence may be easily detected. It also makes pond bottom sediment black. Only treatment is to remove sludge from the bottom using a submersible pump

Soil pH and Acidity: Pond water may be acidic, alkaline or neutral. Depending on this, water will react in different ways with substances dissolved in it. It will also affect in different ways the plants and animals living in the water. The measure of the alkalinity or acidity of water is expressed by its pH value. The pH value ranges from 0 to 14, with pH 7 indicating that the water is neutral. Values smaller than 7 indicate acidity and greater than 7, alkalinity. Fish production can be adversely affected by excessively low or high pH. Pond water with pH unfavourable for fish production can be corrected by using lime if the pH is below 6.5 in the morning.

Ensuring that soil pH and acidity are within acceptable limits is a necessary part of managing the alkalinity, hardness, and pH of the water, which were discussed above. The key is to keep soil pH at 6.5 or above, which will usually maintain water pH, hardness, and alkalinity at desirable levels. Drying the pond for at least two weeks after each harvest and applying lime (preferably agricultural limestone) to the pond before refilling and restocking help to correct soil pH.

pH: The quantity of hydrogen ions (H+) in water will determine if it is acidic or basic. The scale for measuring the degree of acidity is called the pH scale, which ranges from 1 to 14. A value of 7 is considered neutral, neither acidic or basic; values below 7 are considered acidic; above 7, basic. The acceptable range for fish culture is normally between pH 6.5-9.0.

Alkalinity: Total alkalinity is the sum of the bicarbonates (HCO_3^{-1}), carbonates (CO_3^{2-}) alkalinities; expressed as mg/L (ppm) of calcium carbonate ($CaCO_3$). Alkalinity is the capacity of water to neutralize acids without an increase in pH –this capacity is commonly known as "buffering capacity." Adding (HCO_3^{-1}) and carbonates (CO_3^{2-}) to water increase alkalinity (suitable range is 100 – 300 mg $CaCO_3$).

Some waters may contain only bicarbonate alkalinity and no carbonate alkalinity. Addition (or removal) of CO_2 to a solution does not change its alkalinity, since the net reaction produces the same number of equivalents of positively contributing species (H^+) as negative contributing species (HCO_3^- and/or CO_3^{2-}). Adding CO_2 to the solution lowers its pH, but does not affect alkalinity as at all pH values: $CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$. This carbonate buffering system is important to the fish farmer regardless of the production method used. In pond production, where photosynthesis is the primary natural source of oxygen, carbonates and bicarbonates act as a storage system for surplus carbon dioxide - by storing carbon dioxide, the buffering system prevents wide daily pH fluctuations. Without a buffering system, free carbon dioxide will form large amounts of a weak acid (carbonic acid) that may potentially decrease the night-time pH level to 4.5. During peak periods of photosynthesis, most of the free carbon dioxide will be consumed by the phytoplankton and, as a result, drive the pH levels above 10. As discussed, fish grow within a narrow range of pH values and either of the above extremes can be lethal to fish.

Water Quality Monitoring is an essential part of the management of intensive aquaculture. The important parameters to monitor is DO, Temperature, pH, ammonia, nitrite and alkalinity. The first two can be monitored using DO meter, pH is with a pH meter and the last three parameters are measured by using test kits. However, if fish are stocked below 2 fish/m^2, feed at a rate around 75 kg/ ha, main light-green colour (optimum phytoplankton density), and harvested at around 300 g size, regular monitoring might not be necessary.

Exercises:

Make available following equipment to the trainees: Do Mater, pH meter, test kits for ammonia, nitrite and alkalinity measurements. Visit a pond site, take water sample using a bottle (30 cm below surface) and measure the parameters.

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Module: Nile tilapia grow-out process

Session 2.8: Harvesting, transportation and marketing

Session objectives:

This session discusses different options for harvesting fish from ponds and cages, and post-mortem changes that are important making a harvesting plan.

Learning outcomes:

At the end of this session, trainees will be able to develop a harvesting plan for selling fish to the customers.

Session narrative:

At the end of pond and cage culture period, the fish have to be harvested from the pond for selling, storage, consumption or further processing. Throughout the globe, most of the small and medium-scale entrepreneurs (SMEs) sell fish at the farm gate to a third party (called agent, broker or middle-person) with an agreed price. In some instances, the broker carries out the harvest and in others, the farmer harvest and broker pack and transport the fish or the farmer himself may carry out the transportation. Farmers may harvest and sell directly (retail) to the customers.

Harvesting process

Three main harvesting methods are used:

1. Partial harvesting without pond drainage – harvest marketable size of fish using a seine net with bigger mesh size and leave smaller fish to grow (optionally farmer can re-stock with new fish fingerlings)
2. Partial or full harvest with partial pond drainage, and
3. Full harvest with complete pond drainage.

The choice of harvest method depends on factors such as market size, water availability, pond depth, and the labour available. If the pond is located in a water-stressed area, it is best to harvest fish with a cast or seine net without pond drainage in order to conserve the water for subsequent culture cycles. Deeper ponds are difficult to seine and should use cast nets for harvesting. For effective harvesting partial pond drainage is necessary for deep ponds prior to using a seine ne.

Partial harvest: Seining is typically labour-intensive. Even a relatively small-sized pond requires 3–4 people for effective seining. Seining is started from the deep end; the net is then pulled slowly towards the shallow end where it is pulled from the pond and fish are collected. A cast net is operated by a single person, who either stands on the dike or in a canoe/boat. A bigger mesh size is used in either the cast or seine to harvest larger-sized fish and leave smaller fish. Decreasing the mesh size will result in a more complete harvest.

Complete harvest: Total pond drainage is not required for complete harvesting Nile tilapia (unlike catfish harvest - since catfishes have the ability to burrow into the pond beyond the reach of the seine net, complete drainage is necessary).

However, the complete harvesting of all fish in the pond requires complete drainage. If the ponds have been laid-out properly (or farm has designed to allow to drainage one pond into another), it is possible to drain the entirety pond water from one pond into another, and then reuse the water for subsequent production cycles. If the pond is drained via a drain-pipe or drained by using a pump, baskets or hand nets can be used to collect fish going out with the water. Complete drainage after each production cycle is more common in water-abundant areas, and it enables all fish to be harvested and pond bottoms to be dried, cleaned, limed, and refill for the next stocking.

Sanitation: During and after harvesting fish, proper handling is essential for sanitation and prevent contamination with undesirable microbes. Use of harvesting equipment that cause a minimal physical damage to fish is important. This equipment should also be easy to clean and disinfect. In addition, harvesting should be conducted in the morning hours, not under the mid-day or mid-afternoon hot temperatures. Fish must be washed free of mud and other debris with running water immediately after harvesting.

Post-harvest processes

Rapid onset of *rigor mortis* after death of Nile tilapia makes it is essential to process as quickly as possible. *Rigor mortis* in Nile tilapia occurs between 1 – 6 hours depending on whether fish is partially alive or dead. High level of *rigor mortis* makes difficulties for filleting fish.

Rigor mortis

Theory: During or after harvest, fish death occurs. Upon the death the heart stops beating and the circulatory system ceases to supply the muscles with oxygen and fuels (such as glucose from glycogen). Since no oxygen is available for aerobic respiration, the muscle mitochondrial system ceases to function. To replenish ATP used for to power the various energy-consuming activities, skeletal muscle cells rely upon the anaerobic metabolism. For most teleost fish, glycolysis is the only possible pathway to produce ATP (energy) by using creatine phosphate (CP) and adenosine diphosphate (ADP) after death. Anaerobic glycolysis continues to regenerate some ATP and as the end product, lactate accumulate in the muscles – similar to live muscles after a vigorous exercise regime. Glycolytic activity then slows down, ATP concentration decreases due to the continuing various enzymatic activities in the membrane systems, and most of the nucleotides depletes in a few hours. As a result of depletion of ATP, biosynthetic reactions come to a halt, and the cell's ability to maintain its integrity is lost, especially with respect to membrane systems. Both ATP and ADP act as plasticizers for muscle fibres -actin and myosin and maintain muscles in a state of relaxation. When the intracellular level of these nucleotides declines post-mortem below 1.0 µ mole per g tissue, actin and myosin interact and the muscle enters *rigor mortis* (shortly *'rigor'*). A muscle with rigor turns stiff, hard, and inextensible and cannot be stretched significantly without breaking. The body of the fish in *rigor* is hard and often has a bent form due to the tension. During *rigor* the filleting yield will be very poor and farther processing is difficult.

Practice: *Rigor mortis* onset in Nile tilapia occurred more rapidly. Fish at ambient temperature reach rigor relatively slower than fish stored on ice. The phenomenon that tropical fish become stiff shortly after death when stored on ice has been termed as cold shortening. Cold shortening occurs when the fish muscle is chilled prior to the use up of all ATP. The chilling has an inhibiting effect on Ca^{2+}pump in the muscle and this creates a state of muscle contraction. In Nile tilapia (and other tropical finfishes), the level of ATP is still high enough to exclude the fish from being in *rigor mortis* but muscle contraction occurs. Cold shortening in tilapia has major implications in terms of handling fish in tropics for post harvesting processes. This was due to the fact that the fish muscle never appeared in a relaxed stage after *rigor mortis* even days after death. It is therefore recommended to fillet (if fish is produced for selling to a processing company) fish on ice within 60 minutes after death, and fish at ambient temperatures within 120 minutes after death.

Farmers, therefore, should have a plan what to do with fish before harvesting begins. The options are:

1. Live transportation (in water containers) of fish – if fish are sold to a processor for filleting

2. Normal transportation of fresh fish to local markets– without ice if *rigor is* to be delayed and with ice if *rigor* does not affect market price
3. Transportation on ice for cold storage (for later use or for export)

Cold storage of fish

There are a number of methods for preserving harvested fish to slow down decomposition and increase the shelf life (or storage time) of fish. Chilling is the process of lowering fish body temperature to 0°C, using ice or refrigeration. If fish is to be chilled, it has to be put in ice or a refrigerator immediately after harvest. The general rule of thumb is to use an ice-to-fish ratio of 2:1 for chilling with ice, with no fish left exposed above the ice. Freezing involves lowering the core thermal temperature of fish to about -18 °C. While chilling preserves fish for up to 15 days, fish can be frozen for up to one year. Salting and drying is a common preservation method in the tropics due to the abundance of sunshine and the intermittent power supply, which makes freezing unwise. Salting diffuses the water in the fish flesh, infusing it with salt. This dehydration allows fish to be stored for years after effective drying.

Exercises:

Harvest Nile tilapia from a pond and leave a few fish on ambient temperature and put others to an ice slurry (ice in water). Inspect the fish by manually for hardness. Fillet the fish after immediate harvest and after get stiff (rigor mortis). Discuss the experienced differences.

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Module: Nile tilapia grow-out process

Session 2.9: Health management and biosecurity in aquaculture

Session objectives:

The objective of health management and biosecurity in aquaculture is to reduce the risk of introduction (or contamination), establishment and spread of pathogenic and/or invasive agents. This is to be accomplished by means of a set of management measures. This session covers the current issues of major disease occurrences in Nile tilapia culture and introduce potential biosecurity measures farmers/ practitioners should take into consideration.

Learning outcomes:

At the end of this session, practitioners can design a biosecurity system for their farm

Session narrative:

Terminology

The following table define the terms such as disease control, health management and biosecurity used in this document:

	Disease Control	**Health Management**	**Biosecurity**
Management basis	Disease based	Farmed animal based	Risk assessment based
Place of application	Culture facility (hatchery & grow-out)	Culture facility (hatchery and grow-out)	Culture facility and Industry
Management target	Disease & pathogenic agent	Keep pathogenic agent away from farmed fish/ shrimp	Keep farms and industry (in a country/ province/region) free of pathogens
Goal	To cure disease	To prevent disease	To reach disease free status
Mechanism of action	Treatment of disease	Good aquaculture management practices (GMP or GAP)	Biosecurity plan and Standard Operation Procedures (SOPs)
Reason for action	Disease control	Cost-benefit / avoid boom and bust	Secure national/ farm economics
When to act	Disease occurrence	Production planning stage	Aquaculture planning stage
Emphasis	Technology	Management strategy and technology	Management strategy and technology

Introduction

Pathogens (bacteria, parasites, fungi, viruses) and infectious diseases are one of the major business risks of aquaculture. Diseases has contributed cyclical boom and bust phenomenon in aquaculture for last 30 years and hence a major attention on the disease prevention measures should be paid at the production/ business planning stage.

Nile tilapia can be infected with host of pathogens such as:

- common protozoan parasites – such as *Ichthyophthirius multifiliis*, *Trichodina* sp., *Eimeria* spp., *Myxosoma* sp., Nosem**a** sp., *Henneguya* sp., and Hexamita;

- monogeneans flukes and helminths such as *Acanthostomum* spp. and *Acanthogyrus* sp.;
- bacteria such as Pseudomonas sp., *Aeromonas* sp., *Flavobacterium columnare*, *Francisella* sp., *Streptococcus* sp.; and
- viruses such as TiLV.

A summary of symptoms of common bacterial and viral diseases occurring in Nile tilapia is shown in the following table:

Disease*	**Symptoms**
1. Motile Aeromonas Septicaemia (MAS)- Caused by *A. hydrophila and other species*	• Loss of equilibrium; • Lethargic swimming; gasping at surface; • Haemorrhaged or inflamed fins and skin; • Bulging eyes and opaque corneas; • Swollen abdomen containing cloudy or bloody fluid; and • Chronic with low daily mortality
2. Columnaris – Caused by *Flavobacterium columnare*	• Frayed fins and/or irregular whitish to grey patches on skin and/or fins; • pale, necrotic lesions on gills
3. Edwardsiellosis – Caused by *Edwardsiella ictaluri*	• A very few external symptoms; • Bloody fluid in body cavity; • Pale and mottled liver; • Swollen, dark red spleen; and • Swollen and soft kidney
4. Streptococcosis– Caused by *Streptococcus agalactiae and S. iniae*	• Lethargic and erratic swimming; • Dark skin pigmentation; • Exophthalmia with opacity and haemorrhage in eye; Abdominal distension; • Diffused haemorrhaging in operculum, around mouth, anus and base of fins; • Enlarged, nearly black spleen; and • High mortality.
5. Tilapia Lake Virus (TiLV)	• Lethargy, ocular alterations, skin erosions and discoloration (darkening) and exophthalmia (in Israel) • Discoloration (darkening) abdominal distension, scale protrusion and gill pallor (in Ecuador) • Loss of appetite, lethargy, abnormal behaviour (e.g. swimming at the surface), pallor, anaemia, exophthalmia, abdominal swelling, and skin congestion and erosion (in Thailand)

*See Dong (2018) and Dong (undated)– Reference 1 and 2 below for more details

Tilapia lake virus (TiLV) is the most a recent viral disease affecting Nile tilapia. At present, it has been reported occurring in three regions - Asia, Africa and South America - and the number of countries affected by has been increased rapidly. Currently, there is no cure for viral diseases in aquaculture. Vaccines and selective breeding have proved successful in reducing the severity of some viral diseases in the past. However, there is a large knowledge gaps relating to viral diseases such as TiLV and no effective, affordable vaccines are yet available.

Bacterial diseases can be cured using antibiotics. However, it is not recommended to use antibiotics that is used for human medicine to treat fish diseases. Misuse (and overuse) of antibiotics reduces their effectiveness for treating human diseases. Moreover, consumers reject antibiotic residue contaminated fish products and these products cannot be exported most of the other countries in the world. For these reasons, disease prevention is more important than cure. This is achieved vis setting up of farm level biosecurity procedures.

There are two related biosecurity programmes:

1. Biosecurity for aquaculture industry in a particular country or a region
2. Biosecurity of a farm – hatchery and/or grow-out system

Industry level biosecurity:

Biosecurity for the industry can be defined as the measures and activities aimed at preventing the spread and escape of pathogens in a farming environment. This requires the development of legal and regulatory framework, which are especially related to transportation of aquatic animal from one place to another, including import and export of live animals. The issues addressed in industry level biosecurity programme include development and strict implementation of regulatory and legislative procedures. These regulations are concerned with:

- Industrial Layout/ zoning (province/ country/ region)
- Disease notification and monitoring
- Quarantine procedures for import and export
- Quarantine procedures for disease affected areas/ farms
- Surveillance plan of epidemiology
- Management for live fish transportation/ potential disease carriers
- Role of veterinary services
- Farm surveillance/ traceability system
- Disease treatment
- Treatment of dead fish
- Disinfection measures
- Management of slaughter houses
- Fallowing procedures of farms
- Vaccination of non-infected animals
- Training program for personals

Farm level biosecurity:

The farms should follow the established industry level regulations. However, industry regulations normally do not specify what farmers should do inside their farms. The biosecurity issue important to the farms is to establish and implement a system or procedures to prevent the introduction of pathogens into a fish culture facility from outside or introduce pathogenic agent from one section of the culture facility to another section in the same farm (e.g. grow-out system contaminated from the hatchery, vice versa). The biosecurity plan of at farm level should be ideally addressed:

- **Planning measures:**
  - Farm placement (in a zone), design and construction
  - Production planning (water quality, culture stock, and feed management etc.)
  - Disease risk assessment (especially identify the points where disease agent can enter to the farm facility e.g. through seed, feed, other inputs, and visitors etc.)

- **Personnel management:**
  - Training for farm personals/ personnel management

- **Sanitary measures:**
  - Disinfection management (inputs, facility and equipment)

- **Input management (quality and contaminations)**:
  - Inlet and outlet water treatments
  - Seed (pathogen free)
  - Feeds (uncontaminated), and
  - other inputs such as net material, equipment etc.

- **Disease management measures:**
  - Disease diagnosis
  - Disease control (if preventive measures fail)
  - Emergency and contingency plan

Day-to-day biosecurity of farms involved in application of common sense sanitary measures and management procedures to prevent contact between cultured animals and pathogens. These precautionary biosecurity measures have following benefits:

- Reduce the occurrence of a disease outbreak
- Avoid high fish mortality
- Avoid high financial losses from the loss of fish (eliminate boom and bust cycle)
- Keep undisrupted farm production process
- For hatcheries, biosecurity avoids:
  - loss of clients, who will no longer trust the quality of the fry/fingerlings, and
  - high operation costs to clean up the premises after an outbreak.

Biosecurity does not have to cost any extra money for farm management as it based on the improved culture management practices. If biosecurity measures are not followed, more time and more money is spent for trying to cure a disease when it does occur. Following section highlight these common sense methods:

Biosecurity in fish hatchery:

1. Uncontaminated broodstock – TiLV transmits from mother to offspring. If contaminated broodstock are used, the hatchery will spread the disease among farmers.
2. Do not take live fish from outside without checking for diseases - bringing in fish carrying pathogens (mostly without showing signs of disease) from outside (other farms) can introduce pathogens to the hatchery.
3. Do not feed fish with live feed taken from outside
4. Maintain sanitary conditions of the hatchery – clean and sterilize all hatchery tanks and equipment
5. Do not bring contaminated equipment use then without disinfecting them
6. Check water source for contaminations
7. Do not let outsiders to enter to the hatchery without sterilising their hands and legs (no shoes from outside)
8. Treat the disease brood-fish and larvae– this can only be done in hatcheries as number of fish (and tanks) is relatively lesser than grow-out systems
9. The hatchery should have controlled access or areas (CAA – visitors can access this area) and Restricted Access Areas (RAA – visitors cannot access) the area. This is also can be accomplished by establishing sales centre away from the hatchery

Biosecurity for grow-out pond and cage culture:

1. Uncontaminated seeds – buy disease-free seeds from a certified hatchery. Check hatchery certificate before buying seeds. If seed are proved to be sub-standard quality (low survival and growth rate), change the hatchery during the next culture cycle.

2. If possible, send a sample of fish to a laboratory to test whether they are pathogen free
3. Buy seed from a nearby hatchery – long transportation stressed fish and make fish vulnerable for common pathogens
4. Both pond and cage culture – do not construct the farm next to another farm – keep at least 500 m distance between farms
5. The farm should have controlled access or areas (CAA – visitors can access this area) and Restricted Access Areas (RAA)
6. The farm should reduce water intake from outside sources and treat the water before adding to fish ponds
7. Risk assessment – assess the risk of disease occurrence – and identify critical control point to develop management procedures e.g. contamination of water source in dry season, contaminated feeds – especially live feed

Maintenance of healthy fish

The grow-out stage of fish includes four interrelated aspects and disease occurrences can be prevented maintaining physiological welfare of animals. Stress is an indicator of physiological welfare and it is important to manage following three aspects well (discuss during the previous sessions):

1. Water quality (and quantity) management;
2. Standing stock management (including stocking and harvesting strategies); and
3. Feed and feeding management

Stressed animals catch diseases easily. Maintenance of optimal water quality parameters (high DO; temperature between 25 – 30 °C; and no toxic chemicals) and stocking densities (< 5 fish/m^2 in pond culture and < 30 kg / m^3 in cage culture), and providing all essential nutrients are important factors contributing to well-being of fish. When fish are healthy, their immune system and immune activities continue to function at peak level, and thus avoid catching diseases.

Exercises:

Ask farmer/ practitioners to share their experience on; (1) biosecurity threats for their farms; (2) identify where the threats come from (critical points)? What are the common-sense sanitary and management measures that (can) have enhanced biosecurity of their farm? Make a list on blackboard/ whiteboard. Discuss on: What are the costs of implementing the identified procedures? What are the benefits? What are the constraints?

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Module 2: Nile tilapia grow-out process

Session 2.10: Aquaculture business management

Session objectives:

This session introduces the elements of an aquaculture business plan

Learning outcomes:

At the end of the session, trainees will be able to design a crude business plan for their farm

Session narrative:

Business basics

The major goal of commercial aquaculture is to maximize profits.:

- Profits = Total Revenue (TR) – Total Cost (TC)
- Total Revenue = Sum of all the sales receipts [Gross Income (GI)]

So to get higher profits, total revenue should be maximized and costs should be minimized.

Total revenue is dependent upon fish yield and farm-gate price ($ / kg). Fish yield is a function of survival rate (as a percentage of initial stocking density) and average body weight of fish. Farm-gate price is mainly a function of supply for a given demand of a particular market. When supply is high, the farm-gate price is low, vice versa.

So for grow-out farm, Total revenue = Initial stock x % survival/100 x Average weight of fish (kg) x Farm gate price ($/kg)

Farm gate price is controlled by the market forces beyond the control to the producers. There are three technical factors under producer control that can make revenue high: (1) Initial stocking density; (2) survival rate; and (3) final body weight of fish. These are affected by stock, water quality and nutrition management procedures described in the previous sessions.

Total cost has two components: (1) fixed cost for land and equipment for pond-fish farmers and cage frame, net-bag and equipment for cage fish farmers. Except land, all others depreciate the value over time and has to be replaced by new ones (equipment such as pumps, aerators, cage frame and net-bag for example). Operation cost include feed, fertilisers, electricity, and labour etc. Feed is the major cost item.

Total Cost = Fixed cost + Total operation cost
Fixed cost = cost of land, pond, cage, equipment etc.
Total operation cost = seed (fingerling), feed, oxygen supply, water pumping/ exchange, electivity etc.

Reduction of these costs requires best farm management procedures. When:

- Total revenue > the total costs → the business is generating a profit – economically sustainable aquaculture
- Total revenues < the total costs → the business is generating a loss – economically unsustainable aquaculture

Aquaculture business generate losses when revenue is smaller, and costs are high – both of these happens when initial business plan and production management procedures has not been established. Initial business plan should be developed considering the following questions:

- What to produce? e.g. Table sized Nile tilapia
- What quality? e.g. Weight of the fish; flesh quality; thin and long or fat and round fish
- How much to produce? Answer to this question is dependent on the following question.
    - For whom to produce? Identify the target market(s) (or agent/ booker/ intermediaries)
    - What is the target market size?
    - Can farmer switch the buyers/ middlemen when they bargain the farm-gate price?
- How to produce? Define the resources required (e.g. seed, feed, fertilisers) and how to combine them (e.g. stocking density, feeding regime) for efficient production.

Commercial aquaculture

Commercial aquaculture is defined as "fish farming operations whose goal is to maximize profits, where profits are defined as revenues minus costs (perhaps discounted)" (See Reference 2). The major deference between commercial and non-commercial aquaculture are:

Non-commercial aquaculture	**Commercial aquaculture**
Aquaculture is one of the economic activities – not the core	Aquaculture is the core economic activity
Family food and livelihood security driven	Business (making money) driven
Use food for family consumption and sell surplus in the local market	Sell products in the local and foreign markets/ market driven
Consumer satisfaction is a secondary goal	Business success dependent on the satisfaction of buyers/ consumers
Generate profits (for family income)	Generate profits/ profit driven
Family labour	Hired labour dependent
No wages	Pay wages/ salaries to employers
Create employment within family	Create employment – direct and indirect with supporting industry
Create input supply / output processing/ supporting market	Create input supply / output processing/ supporting market
No tax payments	Provide tax revenue to government

The production economics, the pricing of the product, record keeping, preparing financial portfolio, and business plan are described in detail in Reference 1 and 2. The following is the summary:

Development of a Business Plan for commercial aquaculture

A business plan is a document describing the farm business, its products (fish), how it earns money, its leadership and staffing, its financing, and its operations model. It addressees the major aspects of the farm business allow the farm owner to monitor the financial performance of the farm, and provides a guide for potential investors to take a decision whether to invest (or provide a loan) or not. A generic business plan includes the following three sections:

1. Description of the aquaculture business
2. Marketing plan, and
3. Financial documents/ statements

1. Business Description:

The first section describes the aquaculture business delineating farm site and the production system, and legal structure and management capacity, and the financial history of the farm. If it is for a new farm development, it is a document showing the proponent's vision on how will it earn money with the proposed operations model of the business and products, and other details essential to the business success.

2. **Marketing Plan:**

The second section shows the marketing plan composed of two sections: the market analysis and the marketing strategy. If the product is sold to an agent/ broker, the marketing plan is simple. Otherwise, the marketing plan identifies the markets, the distance between markets and the farms, accessibility of the market(s), the transportation costs, the frequency and scheduling of deliveries. the volume and size requirements of the market, and market price (or price history). This can be easily done with an exercise on SWOT analysis – farm's strength and weaknesses and external opportunities to grab (such as getting investment for) and threats (such as Nile tilapia imports from other countries/ region).

3. **Financial Documents/ Statements**

The third section presents the estimated financing requirements and show all the financial statements. Maintaining farm inventory (what equipment is in the farm, how much feed in stock for example) and other record-keeping (assets, resources, economic and financial data) is an essential part of farm management. This is the starting point for the preparation of financial statement for the farm. (see Reference 2 for details)

There are for important financial statements: (1) enterprise budget, (2) income statement, (3) balance sheet, and (4) cash flow statement.

Enterprise budget

The enterprise budget is an estimate of a fish farm's costs, revenues and profitability for a particular period (initially we assume the production targets and market prices). This will show whether the (proposed) fish farm is likely to be profitable over a chosen period (e.g. 5 year). A structure for an enterprise budget in shown in Table 11. If the farmer/ producer uses her own money for investment and the facility has been constructed in her own property, and assuming depreciation cost of land is negligible (but accounting depreciation cost of equipment). She can make a partial budget for the enterprise to see whether the gross margin is positive.

Table 11 *Enterprise budget for a Nile tilapia farm*

Item	Description	Unit	Quantity produced	Unit price	Total income/ Year
Sales of marketable Tilapia	Average revenue of whole table-sized Tilapia	Kg	A	B	A x B
Sales of other fish species	Average revenue of other categories of fish *(if practiced polyculture)*	Kg			
Total gross receipts (TGR) or Gross Revenue					**TGR**
Variable costs (VC)					
Fingerlings	Average expenditure of fish used for stocking	no			
Feed	Average expenditure of artificial feed	kg			
Fertilizer					
Urea	Ave rage expenditure of Nitrogen-based inorganic fertilizer	kg			
Triple super phosphate	Average expenditure of Phosphorus-based inorganic fertilizer	kg			

Lime	Average expenditure of material used to correct water acidity	kg			
Organic fertilizer	Average expenditure of compost, organic waste, etc.	kg			
Veterinary and pharmaceutical products					
Product 1	Average expenditure of this disinfectant/ sanitizer	kg			
Product 2 etc.	Average expenditure of this disinfectant	kg			
Employees					
Field workers	Average level of remuneration paid to people employed in field activities on a full-time basis	no			
Guards	Average level of remuneration paid to security staff	no			
Managers	Average level of remuneration paid to directors	no			
Secretaries	Average level of remuneration paid to people involved in secretarial activities of the farm	no			
Accountants	Average level of remuneration paid to people involved in accounting activities of the farm	no			
Drivers	Average level of remuneration paid to drivers of vehicles and other farm machineries	no			
Annual cost of service providers	Average level of remuneration paid to temporary specialized staff	no			
Other variable costs					
Maintenance and repairs	Average annual repair cost				
Fuel and lubricants	Average level of expenditures made on all kinds of fuel and lubricants needed on the farm during the year	L			
Electricity	Average level of expenditures on electricity consumed on the farm during the year	kwh			
Water	Average level of expenditures on water resources consumed on the farm during the year	m^3			
Interest on operating loan	Average level of interests paid to lenders (banks, etc.) of operating funds	%			
Total variable costs (TVC)				**TVC**	
Fixed costs (FC)					
Interest on investment loan	Average level of interests paid to lenders (banks, etc.) of investment funds	%			
Farm insurance	Average level of annual amount of money paid to ensure the farm during the year	ha			
Property taxes	Average level of annual amount of money paid as property taxes during the year				
Other fixed costs	Average level of other fixed costs not identified above				
Depreciation					

Support Infrastructure	Average level of the estimated annual reductions in the value of support infrastructure		
Equipment and machinery	Average level of the estimated annual reductions in the value of equipment and machinery		
Ponds	Average level of the estimated annual reductions in the value of ponds		
Total fixed costs (TFC)			
Total costs (TC)	**TC = TVC + TFC**		
Gross margin (GM)	**GM = TGR - TVC**		
Net returns (NR)	**NR = TGR - TC**		

Income statement

It is a financial statement that summarizes the financial transactions of the fish farm occurring over a selected period, usually a year. It contains the revenues, costs and the net returns. For example, the following list of items shows the transactions of cash revenue and expenses:

Revenues:

- Revenues
  - Sales of marketable Nile tilapia
  - Sales of other fish species
  - Total revenues (TR)

Expenses:

- Variable cash expenses (VCE)
  - Veterinary and pharmaceutical products
  - Wages of employees
  - Other variable cash expenses such as maintenance and repairs, fuel, electricity etc.
  - Total variable cash expenses (TVCE)
- Fixed cash expenses (FCE)
  - Interest on investment loan
  - Farm insurance
  - Property taxes
  - Other fixed costs
  - Total fixed cash expenses (TFCE)
- Total cash expenses (TCE)
- Net cash farm income (NCFI; income above cash expenses) = TR – TCE. Net cash farm income should be positive for a productive farm.

The detailed income statement taking fixed cost items can be found in Reference 2 and 3.

Balance sheet

Balance sheet is a financial statement showing farm assets, liabilities and net worth of the farm (See Reference 2 for details)

Cash flow statement

A financial statement containing the fish farm's total cash inflows and outflows over a given time period. The cash flow statement can be used to identify the borrowing needs of the farm, the loan repayment capacity, and when it might be possible for a loan to be repaid. This is an important financial statement to receive bank loans.

Exercises:

1. Conduct a SWOT analysis for aquaculture in the East African region or selected country/ area. This is a group exercise. Separate the class to several groups (>10 people per group) during the exercise.
2. Develop a crude business plan for a selected farm – group exercise

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4. Pedagogical requirements

CHAPTER 4

Pedagogical requirements

There are several more steps in the design and development process of training materials. They are specially related to:

- Trainers' (teachers) knowledge, skills and competence, and
- the methods of delivery - transferring knowledge and skill of the trainers to trainees

The teaching aids preparation:

The narrative in each session in the modules shows the important concept to be taught during the teaching sessions. The teaching aids (e.g. PowerPoint slides) should be developed by arranging the message in a logical and linear (easy-to-follow) fashion, similar to telling stories to children. Linear narratives have a beginning, a middle and an end, and the concept outlined in the narratives should be presented in that order. Logically arranged linear narratives are easy to understand as the story conveys the message by telling what happens from one point in time to the next without alienations and sub-plots. Fragmented narratives, on the other hand, jumble up the sequence of the story, and challenge the listener (or reader) to piece together the different components of the story to make sense.

The steps to prepare teaching aids are:

- Write down the elements of the message in detail for the introduction, body (content) and the end (closing).
- Select photographs/ sketches, i.e. visual aids.
- Select font size – usually 20 – 24 font size for medium size class (30 participants).
- Prepare PowerPoint slides/ check for accuracy.
- Practice the delivery – usually in extemporaneous mode.
- Perform in front of the class.

Instructors (Facilitators):

Instructors or facilitators help participants learn the concepts and develop their practical skills. The participants come to the course to enhance their knowledge and learn new skills to improve the fish production process. It is the duty of training facilitators to improve the knowledge and skills of the practitioners by demonstrating how to put theory into practice. Since practitioners have more knowledge of the practical aspects of aquaculture than the trainers, it is necessary to involve participants in the discussions and teaching process

The curriculum, training instructors and the team of organizers should have the following characteristics:

1. Clarity of the concept and ability of trainers to present concepts with precision and accuracy – clear teaching methods help to achieve learning outcomes at the end of the session/ course.

2. The capacity of the instructors – knowledge and skills of the instructors – is always good for designing the pedagogy as a team and developing team-teaching methods. If the members of the team have no sufficient knowledge and skills to train the trainees, it is better to recruit visiting trainers (faculty) from another institution to fill knowledge/skill gaps.

3. Consistency of the message – all instructors should contribute to setting up learning outcomes and means of achieving them - development of teaching method development and learning outcomes of the course/modules should go hand in hand. This requires planning sessions before starting the course – especially when different trainers contribute to the modules or visiting

trainers/ new teaching staff are recruited. There should be sufficient content overlap between the sessions to maintain the consistency of the messages.

4. Commitment – commitment of course organizers, teachers (trainers) as well as administrative and supporting staff, and financiers of the course is a must for the course's success.

5. Teamwork – ability to work in a team and contribute to both organisational aspects of the training and the curriculum content is essential for the course's success.

Training logistics

Training schedule/structure should be developed considering the followings:

- Optimal number of training days, e.g. the number of days trainers can commit to the training course without disrupting of their business activities
- Intensive training vs spread of training over a few weeks/ months, e.g. flexible training schedule vs rigid structure
- Best days of the week to conduct the training, e.g. weekdays vs weekend
- Best time of the day, e.g. evening classes vs whole-day
- Length of each session, e.g. length of class sessions and practical sessions

Appropriate training locations should be selected, taking relevant issues such as:

- Required training facilities, e.g. ponds, tanks, hapa nets, fish, laboratory facilities etc.
- Easy access to the training facility
- Accommodation for the participants
- Food and drink suppliers on site

Pre-assessment of trainees:

The following four questions must be answered at the beginning of a training course:

- **The target group:** Even if a general idea of the target audience attending the training course is already known, it is always good to know more about them – their nicknames, needs, wishes, hobbies etc.
- **Current roles:** What do members of this target audience presently do in their roles? How can the training help them to do their job better?
- **Knowledge/ skill gaps:** What gaps exist between the task of the job and knowledge/ skills? What do they need to know to carry out their roles successfully?
- **Expected learning outcomes**: Do the learning outcomes of the course match the requirements of the trainees (students)? Do you have to modify the learning outcomes? Will training help fill the knowledge/skill gaps?

Finally, realize that the lesson plan is just a plan like any other people make every day, but they rarely achieve 100% of the plan all the time – occasionally fail to achieve. John Wooden once said, “failure is never fatal, but failure to learn from mistakes and change might be”. It takes time to be a good teacher in adult education because each adult has his/her own set of learning outcomes when they attend a training programme –talented teachers are able to adjust the learning outcomes and teaching pedagogy to match the needs of adult learners.

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