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Tilapia Culture Review

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Abstract

This literature review has been written to examine different tilapia farming practices both in semi-intensive and intensive systems. Extensive culture is not mentioned since it is not considered to be a real commercial production as the control over the system is quite limited and even semi-intensive system is being replaced by intensive system due to technological developments, high demand and increasing market prices of tilapia. In first chapter, environmental and nutritional requirements are also mentioned as they are closely correlated and play a key role in a successful production. The results of some recent studies and experiments suggest that tilapia has some superiority over other culture fish like faster growth, ability to utilize different feeds, wide tolerance for high stocking densities and environmental conditions. In addition to these advantages, tilapia do very well in integrated culture systems both with aquatic species; carp and shrimps, also crops like tomato and lettuce as well. As a result, this study is conducted to prove the advantages of commercial tilapia production covering economic values.

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INTRODUCTION

Tilapia is a freshwater fish belong to family "Chiclidae". Today, tilapia is a general name used for three genera; Tilapia, Sarotherodon and Oreochromis (Dikel, 2009). Tilapias are naturally distributed in many different areas include African lakes and rivers, Nile River, Palestine, Israel and Syria. Then they were introduced into many tropical, subtropical or temperate regions of the world due to their fast growth, distinct resistance to diseases, ease to breeding and high tolerance to even some severe conditions which cannot be tolerated by other culture species. Main reason of these introductions was production of cheap protein source by tilapia farming in rural areas to fight against poverty. With time, tilapia has become a popular fish in market with white flesh, good taste. Therefore, formerly used extensive culture system which was mainly depending on primary productivity has been replaced by semi-intensive and intensive culture systems.

Today, day by day increasing demand for tilapia, higher market prices and technological developments have encouraged producers for bigger investments. Tilapias' low levels in food chain and ability to utilize different feed sources, reasonable growth rate and great adaptation for culture environment have been the driving force for the expansion of the industry. Moreover, their tolerance for crowding stress and suitability for integrated culture systems are the other advantages.

Integrated systems serve to improve feeding efficiency and water quality due to complementary feeding behaviors of culture species and produce a secondary product to be offered for market as an additional value.

1 ENVIRONMENTAL REQUIREMENTS

Although tilapia is known to be one of the most tolerant culture species for unfavorable environmental conditions, they have some limits as all the other aquatic species do. In commercial tilapia production, due to economical concerns, maximized growth and feeding efficiency is desired. Hence, a great attention should be paid for all the environmental parameters, as they are closely correlated and highly affecting production yield. These parameters and their effects are explained below;

1.1.1

Water Temperature: Intolerance of tilapia to low water temperatures is the most serious constraint for commercial tilapia culture. Even if water temperature is above the lethal limits and does not lead to direct mortality, this situation induces susceptibility for the fungus and infections occurrence. Tilapia cannot grow well below 16 C° and they cannot survive more than a few days below 10 C° (Tekelioğlu, 2005). Preferred temperature values are between 20 and 35 C°, reproduction takes place at 25 C° to 36 C° and feeding activity ceases when water temperature is down to 16-17 C° (Lim and Webster, 2006).

1.1.2

Salinity: Although tilapias are well known examples of fresh water, some strains are euryhaline and able to tolerate high salinity values. It has been suggested that tilapia have marine origins and undergone an evolution (Beveridge and Mc Andrew, 2000).

However, there are some serious limitations for commercial tilapia production in saline waters. For instance, Oreochromis spilirus has been reported to have low fecundity (Al-Ahmed 2001). In addition, Oreochromis niltoicus x Oreochromis mossambicus hybrid has failed to adapt at 35‰ (Alfredo and Hector, 2002).

1.1.3

Dissolved Oxygen: It is a well-known fact that increasing water temperatures lead to reduction of dissolved oxygen rate in the water (El-Sayed, 2006).

However, tilapias are known with their high tolerance at low ambient oxygen levels (reviewed by Kutty, 1996). A test reported by Tsadik & Kutty (1987) suggested that specific growth rates (SGR) were closely correlated with dissolved oxygen levels and following specific growth rates (SGR) were found with varying oxygen levels;

High dissolved oxygen: 90-100% of saturation (> 7mg/L)	SGR: 100%
Fluctuating dissolved oxygen (dial fluctuation)	SGR: 56%
Medium dissolved oxygen: 40-50% of saturation (3-4 mg/L)	SGR: 42%
Low dissolved oxygen: < 40% of saturation (0.2-2.2 mg /L)	SGR: 16%

In this trial it was also indicated that feed conversion efficiency increased with increased dissolved oxygen saturation up to 90% (Bergheim, 2007).

1.1.4

pH: Tilapia show best growth in water that is close to neutral or slightly alkaline (Lim and Webster, 2006). It is well known that pH level in freshwater species rearing ponds ranges between pH6.5 - pH8.5. This level can be kept under control with carbonate-bicarbonate buffer system. During daytime, as a result of photosynthesis activity, CO_2 level decreases and pH increases. In the nighttime, shift from photosynthesis to respiration, CO_2 is released into water in form of carbonic acid and pH drops. Since tilapia are mainly found in the areas where the primary productivity is quite intense, they have adapted to withstand wide ranges of pH, between pH5-pH11 (Tekelioğlu, 2005). Tilapia are able tolerate a wide range of pH from 3.7 to 11, but best growth is achieved between pH 7-9 (Ross, 2000) and growth is negatively affected in acidic waters (Lim and Webster, 2006).

1.1.5

Ammonia: It is the main form of the metabolic wastes excreted via gills and kidney of the fish. Excreted ammonia might be found in two different forms; un-ionized NH_3 form (UIA-N) , which is toxic to fish and ionized NH_4^+ form, which is far less toxic (El-Sayed, 2006). Toxicity of ammonia is closely correlated with pH level and to some extent, water temperature and dissolved oxygen concentration (Lim and Webster, 2006). Low levels of dissolved oxygen (DO) elevates ammonia toxicity (Lim and Webster, 2006) and when pH level exceeds neutral value, an increasing portion of total ammonia is converted from the ionic form (NH_4^+) to the toxic un-ionized (NH_3) form; toxicity tends to increase with the higher temperature (Soderberg, 1997). Tilapia mass mortality occurs in a few days just after their direct transfer to water that has ammonia concentrations higher than 2 mg. L^{-1} (Lim and Webster, 2006). On the other hand, extended (up to several weeks) exposure to un-ionized ammonia concentration above 1-mg. L^{-1} causes losses, particularly among fry and juveniles when the dissolved oxygen (DO) is low (Lim and Webster, 2006). Beside of mortality problems, un-ionized ammonia, even as low as 0.08 mg.L^{-1} may lead to poor appetite of tilapia (Popma and Masser, 1999).

1.1.6

Nitrite: It is toxic for fish since it immobilizes haemoglobin to carry more oxygen (Çağıltay, 2006). First, ammonia is oxidized into nitrite (NO_2) and then into nitrate (NO_3) through the activities of nitrifying bacterias, which are grown on organic matters (El-Sayed, 2006). Fish size is effective on tolerance of the tilapia to nitrite. It was found that smaller tilapia (4.4 g) were more tolerant compared to larger ones (90.7 g) (Atwood et al 2001). However, chloride is reported to reduce the toxicity effect of NO_2 (Yanbo et al., 2006). Therefore, chloride (Cl) level should be maintained in earthen ponds at a ratio of 10:1 (Cl: NO_2) (Durborow et al., 1997). On the other hand, final product of ammonia oxidization, nitrate is relatively non-toxic to tilapia; however, long terms of exposure to high levels of nitrate may affect immunity and increase mortality rate (Plumb, 1997).

1.2 NUTRITIONAL REQUIREMENTS

Quite similarly to the environmental parameters, feeding has also great importance. Feeds comprise the most expensive input of a commercial tilapia farm. If the given feeds are far from meeting the nutritional demands of tilapia, this situation will result in reduced growth and yield, which is the worst scenario in commercial production. On the other hand, if an excess amount of feed is given, it will be quite costly and in addition, uneaten feeds will negatively affect the water quality and indirectly will lead to the same results.

1.2.1 PROTEIN

Proteins are made of amino acids. Fish cannot synthesize some of these amino acids, thus they must be readily available in the diet. Tilapias require the same 10 essential amino acids as other fish species, terrestrial animals and humans as well. These amino acids are valine, arginine, histidine, threonine, lysine, isoleucine, methionine, phenylalanine, leucine and tryptophan (Lim and Webster, 2006).

Table 1.1: Essential amino acid requirements of tilapia as % of dietary protein: (Modified from Fagbenro, 2000)

Amino acid	Nile tilapia (Oreochromis niloticus)
Lysine(Lys)	-
Arginine(Arg)	4.1
Histidine(His)	1.5
Threonine(Thr)	3.3
Valine(Val)	3.0
Leucine(Leu)	4.3
Isoleucine(Iso)	2.6
Methionine(Met)	1.3
Cysteine(Cys)	2.1

Phenylalanine(Phe)	3.2
Tyrosine(Tyr)	1.6
Tryptophan(Try)	0.6

Although several other factors like salinity, water quality and temperature are affecting tilapia protein requirements, tilapia' protein requirements for protein in their diet tend to decrease with the increasing size, as many other fish species. While 20-30 % dietary protein is required for adult tilapias for optimum performance, for juvenile tilapias this value ranges between 30-40% (Gunasekera et al., 1996a, b; Siddiqui et al., 1998a, b; El-Sayed et al., 2003).

1.2.2 LIPIDS

Lipids are known to have protein-sparing effect. It was showed that the level of protein in the diet of Nile tilapia (Oreochromis niloticus) can be reduced from 33.2 to 25.7 percent by increasing dietary lipid from 5.7 to 9.4 percent and carbohydrate from 31.9 to 36.9 percent (Li et al. 1991).

However, it has been reported that the dietary lipid level in excess of 12 percent depressed the growth of juvenile O aureus x O. niloticus hybrids and increased the accumulation of carcass lipid (Jauncey, 2000). In addition, excess levels of lipid may cause difficulties with feed pelleting process. However, extruded feed where fat is added after the pelleting process has eliminated this problem. Typical oil content of commercial tilapia feed is usually around 4-5%. (Orachunwon, Thammasarat, & Lohawatanakul, 2001)

ESSENTIAL FATTY ACIDS (EFA)

"More recently, reports have suggested that hybrid tilapia require both n-3 (omega-3) and n-6 omega-6) fatty acids and it has been proposed that diets for farmed tilapia should contain 0.5-1.0 % of both n-3 and n-6 PUFA". (Lim, Yildirim-Aksoy, & Klesius, 2011; Ng, 2005). Not only for meeting the nutritional demand of tilapias to support maximum growth, essential fatty acids are also important for final fatty acid content of tilapia fillets. Farmed tilapia, with enriched n-3 PUFA content, may present some significant health benefits to consumers such as; effects on cardiovascular system (Lecerf, 2009; Russo 2009), autoimmune (Ruxton, Reed, Simpson, & Millington, 2007) and inflammatory disorders (Calder, 2006).

Roughly, it is estimated that aqua feeds comprise 90% of the global supply of fish oil (FO) and due to expanding aquaculture industry; supply will imminently not meet the demand (Tacon and Metian, 2008; Turchini et al., 2009). Considering the high demand, shortage in supply and tremendously increasing prices of fish oil (FO), much research is conducted on finding suitable lipid sources as an alternative for fish oil (Turchini et al., 2009)

Although the vegetable oils are more cost effective compared to fish oil and always readily available, not much is known about their effects on tilapia production. However, several authors have reported some promising results. In a recent study, red hybrid tilapia was fed the crude palm oil (CPO) based diets from stocking to marketable size, they have figured out that the gonado-somatic index of both the female and male fish was much bigger compared to fish fed the fish oil based diet (Bahurmiz and Ng, 2007)

1.2.3 CARBOHYDRATES

Fish do not have a specific requirement for carbohydrates, as they need lipids and proteins due to their several functions other than being energy sources. However, carbohydrates are added in fish diets because they have protein sparing effect, functional as pellet binders and serve as precursor for the formation of various metabolic intermediates required for growth (NRC 1993).

"It was reported that the protein sparing effect of carbohydrates (dextrin or starch) in hybrid tilapia (Oreochromis niloticus x Oreochromis aureus) only occured when the dietary protein level was suboptimal" (Shiau and Peng, 1993).

It has been reported that feeding frequency affected the utilization of dietary carbohydrates by O. niloticus x O. aureus hybrids. "As feeding frequency increased from 2-6 times per day, so did carbohydrate utilization -especially of glucose although this was still much lower than for fish feed either starch or dextrin" (Beveridge and Mc Andrew, 2000). It is also demonstrated for O.

niloticus x O. aureus hybrids, that larger fish utilized carbohydrate better than smaller ones (Tung and Shiau 1992, 1993).

Carbohydrates could have anti-nutritional factors in content, which may result in reduced utilization by fish. It was found that wheat bran, which contains protease inhibitor, might negatively affect food digestibility (El-Sayed et al., 2000).

1.2.4 VITAMINS

In fertilized earthen ponds, tilapias are stocked from small to moderate densities to obtain required vitamins depending on natural food organisms (Shiau and Lin, 2006). Since natural food organism are limited or totally absent in intensive systems, required vitamins must be readily available in the formulated diets of tilapias (Shiau and Lin, 2006).

Deficiencies of vitamins are resulted in some specific problems, which are listed below;

- **Vitamin B_1 (Thiamin):** Thiamin level of 2.5 mg/kg of diet was reported to meet the demands for maximized growth (Lim et al., 1991). Vitamin B_1 deficiency in red hybrid tilapia (Oreochromis mossambicus x Oreochromis niloticus) fingerlings, which are cultured in seawater showed, reduced growth, lower feed efficiency and low haematocrit (Shiau and Lin, 2006).
- **Vitamin B_2:** For juvenile Nile tilapia (Oreochromis aureus), vitamin B_2 requirement was reported as 6 mg/kg of diet (Soliman and Wilson, 1992a). Reported deficiency signs were; anorexia, reduced growth, high mortality, fin erosion, abnormal body color, dwarfism and cataract (Shiau and Lin, 2006).
- **Vitamin B_3 (Niacin):** Two different optimum values have been reported depending on the diet used. These are 26-mg/kg for fish fed a glucose diet and 121-mg/kg for fish fed on a dextrin diet (Shiau and Lin, 2006). Deficiency symptoms of vitamin B_3 were; hemorrhage, deformed snout, gill and skin oedema, fin and mouth lesions (Shiau and Suen, 1992).
- **Vitamin B_5 (Pantothenic acid):** 10 mg of vitamin B_5/ kg of diet has been reported to be sufficient to maintain healthy status of Nile tilapia (Oreochromis niloticus) (Soliman and Wilson, 1992 b). Reported deficiency symptoms were; poor growth, hemorrhage, sluggishness, anemia,

hyperplasia of cells of gill lamellae and increased mortality (Soliman and Wilson, 1992 b).

- **Vitamin B_6 (Pyridoxine):** For juvenile hybrid tilapia (O. niloticus x O. aureus) reared in freshwater, optimal dietary requirements were 1.7-9.5 mg/kg of diet containing 28% crude protein and 15.0-16.5 mg/kg of diet containing 36% protein (Shiau and Hsieh, 1997). Reported clinical deficiency signs were; low growth, high mortality, abnormal neurological signs, caudal fin erosion, mouth lesion and convulsions (Shiau and Lin, 2006).
- **Vitamin B_7 (Biotin):** For hybrid tilapia (O. niloticus x O. aureus) required vitamin B_7 amount has been determined to be 0.06 mg/kg of the diet (Shiau and Chin, 1999). Deficiency symptoms include; poor growth, reduced hepatic pyruvate carboxylase and acetyl CoA carboxylase activities (Shiau and Chin, 1999).
- **Vitamin B_9:** Reported vitamin B_9 requirement for Nile tilapia (Oreochromis niloticus) is 0.5 mg/kg of the diet (Lim and Klesius, 2001). Deficiency symptoms are; reduced feed efficiency and feed intake, poor growth (Lim and Klesius, 2001).
- **Choline:** Dietary requirement for hybrid tilapia (O. niloticus x O. aureus) was estimated to be 1,000 mg/kg of diet (Shiau and Lo, 2000). Specific symptoms for choline deficiency are; poor growth, reduced survival, reduced blood triglyceride and phospholipids concentrations (Shiau and Lo, 2000).
- **Vitamin B_{12}:** There is no reported specific requirement for vitamin B_{12} as it is produced in gastrointestinal tract of tilapia via bacterial synthesis (Shiau and Lung, 1993).
- **Vitamin C:** Reported requirement for hybrid tilapia (O. niloticus x O. aureus) is 19 mg/kg of the diet (Shiau and Hsu, 1999). Specific deficiency symptoms are; poor growth, lordosis, scoliosis, reduced feed efficiency, anemia, exopthalmia, hemorrhage, gill and opercular deformities (Shiau and Hsu, 1999).
- **Vitamin A:** For hybrid tilapia (O. niloticus x O. aureus), requirement is reported to be 5,850-6,970 IU /kg of the diet (Hu et al., 2006). Deficiency symptoms are; low growth, abnormal movements, restlessness, exopthalmia,

pot belly syndrome, reduced mucous secretion, high mortality, haemorrhage (Shiau and Hwang, 1993).

- **Vitamin D:** It was reported that vitamin D is not essential for Oreochromis aureus (O' Connel and Gatlin, 1994). On the other hand, for hybrid tilapia (O.niloticus x O. aureus), suggested amount is 374.8 IU/kg of the diet (Shiau and Hwang, 1993).
- **Vitamin E:** For hybrid tilapia (O. niloticus x O. aureus), determined requirement is 42-44 mg/kg of the diet with 5% lipid content and 60-66 mg/kg of the diet with 12% lipid content (Shiau and Shiau, 2001). Specific deficiency symptoms are; anorexia, reduction in weight gain and feed efficiency, muscle degeneration, skin hemorrhage,ceroid in liver and spleen, and abnormally colored skin (Roem et al., 1990).
- **Vitamin K:** Estimated dietary requirement for hybrid tilapia (O.niloticus x O.aureus) is 5.2 mg/kg of the diet (Lee, 2003). Poor growth and low plasma prothrombin have been observed when tilapia was fed vitamin K free-diet during 8 weeks (Lee, 2003).

1.2.5 MINERALS

- **Magnesium (Mg):** For Nile tilapia dietary magnesium levels of 0.59-0.77 (Dabrowski et al., 1989) and for blue tilapia 0.5-0.65 (Reigh et al., 1991) have been reported to be sufficient. On the other hand, dietary magnesium deficient diets resulted in reduced growth, low tissue magnesium concentrations and abnormal tissue mineralization (Lim and Webster, 2006). In addition, excess amounts of magnesium (3.2 g /kg) when the dietary protein was suboptimal (24%) resulted in low hematocrit, hemoglobin and sluggishness, and depressed growth as well (Dabrowski et al., 1989).
- **Manganese (Mn):** 12 mg/kg of manganese is the recommended value for Nile tilapia (Watanabe et al., 1988). Lim and Webster (2006) reported that deficiency of manganese leads to specific problems like; reduced growth, anorexia, equilibrium loss and increased mortality.
- **Zinc (Zn):** Required level of dietary zinc for Nile tilapia has been reported as 30 mg/kg of the diet (Elhamid Eid and Ghonim, 1994).
- **Potassium (K):** Specific dietary requirement of K for optimized growth, gills Na^{+}-K^{+} ATPase activity and K retention of hybrid tilapia (O.niloticus x O. aureus) was determined as 0.2-0.3 g / kg (Shiau and Hsieh, 2001).
- **Calcium (Ca):** O'Connell and Gatlin (1994) obtained best growth and high concentrations of minerals in bone and scale of blue tilapia that were reared in water with < 0.1 g Ca. L^{-1} and fed purified diets supplemented with 7.5 g (0.75%) Ca.kg^{-1}.
- **Iron (Fe):** It has also been considered to be an important mineral in tilapia diet. It has been suggested that 150-160 mg/kg of diet from iron citrate meets the Fe demand of hybrid tilapia (O. niloticus x O. aureus) (Shiau and Su, 2003).

2 SEMI-INTENSIVE SYSTEM

Semi-intensive culture can be described as producing fish depending on either pond fertilization or supplemental feeding additional to the fertilization process. As a result of low inputs and low stocking densities in the system, low-cost fish is produced. Hence, a successful pond fertilization is a prerequisite in order to delay commercial feeding or totally eliminate it. Semi-intensive culture method is quite common for small scale producers in developing countries.

2.1.1
Pond Fertilization

Fertilizers can be defined as substances that are used in ponds to promote the primary productivity. These substances are divided into two groups; organic and inorganic fertilizers. Whereas organic fertilizers are natural and comprise various nutrients, inorganic fertilizers are man-made and comprise high amounts of one specific nutrient.

"The main objective of pond fertilization is to stimulate the primary productivity in fish ponds and enhance autotrophic and heterotrophic microbiological food production" (El-Sayed, 2006).

Nitrogen (N), phosphorus (P) and carbon (C) are considered to be the major inputs of fertilization process (El-Sayed, 2006). In a fish pond, average nutrient composition of phytoplankton comprises 45-50 % C, 8-10 % N and 1% P, which gives a roughly ratio of 50:10:1 (Edwards et al., 2000).

Liming is also an important procedure that may serve to several improvements on water quality and productivity. These include; stabilization of pH at 7-8 , increase of phosphorus availability and CO_2 amount in order to enhance photosynthetic activity. Most prominent liming materials are; quick lime (CaO), sloked lime ($Ca(OH)_2$) and ($CaCO_3$).

Important criteria for a successful fertilization process can be summarized as below;

Characteristics of the pond: Pond structure should be known for a sustainable and efficient fertilization. As an example the more mud the bottom contains, it tends to absorb more phosphorus (P) (Shrestha and Lin, 1996 a, b). Hence, exact phosphorus (P) requirement for pond fertilization is determined by type of the bottom soils and their phosphorus (P) saturation (Knud-Hansen, 1992).

Type of manure used: Different animal manures like cow manure and chicken litter have been successfully used but their availability might be the limiting factor for use. However, for instance buffalo manure is not recommended for pond fertilization, since it causes drop in dissolved oxygen (DO) due to respiratory demands of bacterias (Edwards et al., 1994a). Also it was reported that only 6% of buffalo manure nitrogen was released as soluble, reactive phosphorus (P) (Shevgoor et al., 1994)

Season of the year: A study was conducted in Panama and Honduras. 10,000 Nile tilapia per hectare were stocked into the ponds and weekly fertilized with 1,000 kg.ha-1 chicken litter. 141 to 150 days production cycle was applied during the dry and rainy seasons in each country. Layer chicken litter was used in Honduras and it was composed of 88.9 % dry matter. In Panama, broiler chicken litter was used, which was composed of manure, rice hulls, feathers and waste feed. It was averaged 89.8% dry matter. As a result, although no seasonal significant differences were observed in Honduras, in Panama the yields for dry season were considerably greater. Better results of dry season might be linked to the decreased light penetration into the pond and high turbidity as a result of heavy rains (Green et al.1990).

Next table shows the yields obtained during similar culture periods in two different countries, both in rainy and dry seasons. Same fertilization procedure with chicken manure were applied and densities/ hectar were same for all the treatments

Table 2.1: Comparison of effect of seasonal difference on fertilization process, in two different countries (modified from El-Sayed, 2006)

Country	Density/ha	Fertilization	Culture period	Yield(mt/ha)	Season
Honduras	10.000	Chicken manure(1000 kg.ha-1)	152	1.76	Rainy
Honduras	10.000	"	150	1.71	Dry
Panama	10.000	"	149	2.07	Dry
Panama	10.000	"	141	1.68	Rainy

2.1.2

Periphyton-based Pond Culture

Periphyton is referred to organisms living attached on submerged materials or substrates (Van Dam et al., 2002). In a periphyton-based culture system, different rigid materials like bamboo poles or woody branches are fixed in shallow waters such as ponds or lagoons to enhance the growth of sessile aquatic biota known as "periphyton". "The periphyton community comprises of bacteria, fungi, protozoa, phytoplankton, zooplankton, benthic organisms and a wide range of invertebrates" (Milstein, 1997; Azim et al., 2001). Therefore, with the enrichment of natural productivity, such a system serves to provide natural food for fish have omnivorous or herbivorus feeding habits. Most of the tilapias have the ability to use phytoplankton and as well as periphyton (Dempster et al., 1993, 1995). It has been indicated that substrate type used and manuring process have a significant effect on periphyton productivity and fish production as well (Azim et al 2001 b). Recent studies showed that periphyton-based system is very applicable for tilapia culture. "It has been reported that 10 bamboo poles/m2 resulted in increase of fish yield 20% to 100% (Azim et al.,2001; Keshavanth et al; 2004 ; Milstein and Lev, 2004)". In another study it was found out that bamboo poles produced more and better periphyton compared to jute stick and branches of hizol tree (Azim et al., 2001). It has been found that rearing of blue tilapia on natural periphyton showed quite similar values in growth, survival and yield compared to fish fed on pelleted diets. Therefore, it is resulted in a significant reduction in feed costs (Milstein and Lev 2004).

2.1.3

Supplemental Feeding

After a proper fertilization, natural food supply can meet the demands in semi-intensive systems, however, supplemental feeding is a necessity when larger fish cannot obtain enough nutrients from plankton alone and growth begins to slow down. This critical point is defined as "critical standing crop" (CSC) and there are several factors determine the time of "critical standing crop", such as stocking density of fish and fertilization.

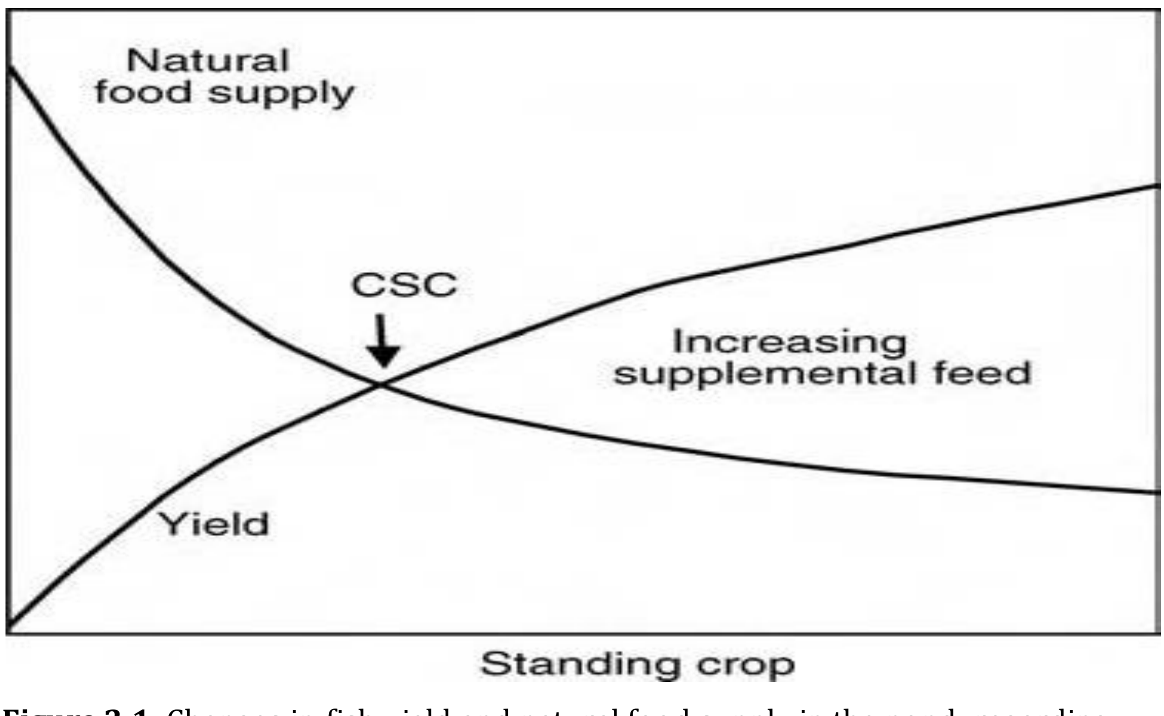

Figure 2.1: Changes in fish yield and natural food supply in the pond, regarding to "critical standing crop" (CSC) and supplemental feeding (Modified from De Silva, 1995)

Semi-intensive system is mainly practiced in developing countries and local market prices of tilapias are quite low. Therefore, the use of high-quality commercial feeds are not recommended in such systems due to economical concerns (Yakupitiyage, 1995)

In a study, formulated feed was replaced by chicken litter fertilization during the first 60 days periods of tilapia rearing without significant impacts in frame of yield or production economy. Sex-reversed Nile tilapia were stocked into ponds as 20,000 ha-1 with an average weight of 18.6 g. Tested pond management strategies were feed only (which includes 23 % crude protein), layer chicken litter only (1,000 kg. ha-1/week, on dry matter basis) for the first 60 days which followed by feed only (3% of fish biomass, daily basis), or layer chicken litter (500 kg.ha-1/ week, on dry matter basis) plus feed (1.5% of fish biomass on daily basis). Mechanical aeration and water exchange were not used during the 151-days trial period. Only insignificant differences were observed among treatments and the values were; 4,470 , 4,522 and 4,021 kg.ha-1 for feed-only, chicken litter and feed afterwards and chicken litter+ feed treatments , respectively (Green 1992). As a result, fish growth had slowed down in the chicken litter then feed treatment by day 61, which was an indicator of the exceeded critical standing crop (CSC), that means natural pond productivity was not sufficient to maintain rapid growth of tilapia (Green 1992; Green et al. 2002). It was found out that delayed provision of formulated feed in fertilized ponds until individual fish weights reach from 100 g up to 150 g for each one, may obtain an improved input utilization efficiency (Diana et al.,1996). In this study, sex-reversed Nile tilapia with an average weight of 15 grams were stocked into ponds at 30,000 ha-1. All the ponds were treated with urea (60 kg.ha-1) + triple superphosphate (34 kg.ha-1) combination as fertilizer every week. Formulated feed with 30% crude protein content was offered daily at 50% of the ad libitum rate once fish reached individual weights of 50, 100, 150, 200, 250 g. When each fish was weighed 500-600 g, ponds were harvested. Mechanical aeration and water exchange processes were not used. First feed offer was after 38, 80, 153, 178, or 234 days, respectively, for the 50, 100, 150, 200 or 250 g treatments. In all treatments, during the fertilizer only stage, tilapia growth rate average was 1.17 g.day-1, which was quite lower than 3.10 g.day-1 average growth rate reached during the feeding stage. By day 38, critical standing crop was reached and considerable growth rate increase was observed with the given formulated feed. Delayed initiation of feeding until fish reach 50 to 100 g, did not show any effect on growth, final size, and yield grow-out duration in compare to the other treatments.

Table 2.2 : Means of final individual weight, growth rates during the fertilization and feeding strategies, yield and feed conversion ratio for all-male Nile tilapia (30,000.ha-1) reared in fertilized ponds (Lim and Webster, 2006).

Treatment (g)	Duration (days)	Final weight (g per fish)	Growth rate during		Yield (kg.ha-1)	Feed conversion ratio
			Fertilizer only (g per day)	Feeding (g per day)		
50	236	593	1.44	2.78	15,396	1.14
100	236	596	1.15	3.29	15,372	0.93
150	265	534	1.21	3.48	14,132	0.93
200	305	627	1.17	3.27	15,920	1.02
250	328	488	1.03	2.76	12,952	0.87

2.2 INTENSIVE SYSTEM

These systems are highly dependent on high stocking densities, high quality commercial feeds and quite big investments. Therefore, sustainable and feasible production in an intensive system is greatly determined by a long term project, the technology in use and sustainable access to tilapia seeds.

2.2.1 INTENSIVE TANK CULTURE

Tilapia culture in tanks is widely practiced in many countries particularly where there is a shortage of fresh or brackish water supply. Tanks are generally smaller than typical earthen ponds and mainly made of materials like concrete and fiberglass. Success of these systems highly depends on tank size and shape, stocking density and water exchange/ water flow rate (velocity).

Tank size and shape: It has been reported that fry and nursery tanks are smaller than 1-3 m3 and production tanks are larger than 30 m3 (Martin et al., 2000). Culture tanks are mainly in rectangular or circular shapes. Rectangular tanks are easy to construct but have many serious disadvantages compared to circular tanks. Low water circulation and presence of dead-spots on the corner of the rectangular tanks deteriorate water quality due to anaerobic conditions and create stressful conditions for the fish. On the other hand, circular tanks are devoid of dead-spots.

Stocking density and fish size: Stocking density is highly effective on yield and performance of the fish. "Maximum density depends on fish size, water flow, aeration and the culture system adopted" (El-Sayed, 2006). In a trial, Nile tilapia were stocked at 40 fingerling (4 grams) /m3 in concrete tanks. At the end of 415 days, average final weight was 544 g (21.7 kg/m3). When 19 grams of larger fingerlings were used at 64 fish /m3, final weight was 361 g (23.1 kg /m3). As the third step of trial, when the 40 grams of much larger fish were stocked at

42.6 fish /m3 , they reached 323 g (13.4 kg /m3) in 164 days (Siddiqui et al. 1991a).

Water exchange and flow rate: Water exchange and flow rate are mainly effective on water quality. Continuous water exchange can maintain optimum water quality but it is costly, while low levels of water exchange or absence of water exchange more likely to result in reduced water quality. A well balance is needed for the optimum water flow rate, as low water flow rate results in accumulation of potential toxic substances like feaces, uneaten feeds, and some other metabolites may accumulate in the fish tanks and deteriorate water quality (El-Sayed, 2006). On the other hand, very high water flow rate stresses the fish for a continuous swimming activity which leads to reduced growth and increase in mortality (El-Sayed et al., 2005b). It was reported that best growth and FCR was obtained at a continuous flow rate of 0.5-1.01/ min/kg for Nile tilapias reared in outdoor tanks in Saudi Arabia (Siddiqui et al.,1991b)
Table below shows the comparison of circular and rectangular tanks within 5 different perspective, which are significantly important for maintaining healthy status of fish, better utilization of given feeds and stocking densities.

Table 2.3: Comparison of circular and rectangular tanks (modified from Dikel, 2009).

	Circular Tanks	Rectangular Tanks
Carrying capacity	Regarding to tank shape and flow of water, fish can be stocked at 100 kg/m3 or at higher densities	Feed wastes and feaces are accumulated in tank corners. Water flow is not favorable and maximum stocking density can be 70 kg/m3.
Disease	With a sufficient water flow, metabolic wastes are removed and therefore dead spots are eliminated.	Due to poor water flow, feaces are accumulated in dead spots and suspended solid wastes lead to toxic conditions.
Feed distribution	Feed distribution is very good as a result of high water velocity but this situation may result in some feed loss due to spiral-shaped movement of water in the center.	Feed distribution is not so good. If fish does not feed on bottom, feeds are accumulated in the bottom. High amounts of accumulation become harmful.
Cleaning	Feaces and uneaten feeds are removed from drainage pipe by high water flow rate.	Wastes can be removed by drainage system so slowly due to poor water flow. Accumulated wastes in the tank bottom not only deteriorate water quality, also tilapia does not utilize the feed fall on those wastes.
Survival	Good environmental	Unfavorable

	conditions and practical procedure allow handy fish production, and unhealthy/ diseased fish are eliminated.	environmental conditions create problems and reduce tilapias' tolerance. Moreover, handling after stressful conditions lead to mortality.

2.2.2 CAGE CULTURE

Cage culture is defined as the rearing of fish in water-suspended materials covered with nets whereas it keeps the fish inside, also serves to exchange of water with the surrounding water column. It has been practiced for different fish species for many years all over the world. Cage culture differs in many ways like; cage construction material, cage size, stocking density and its specific advantages compared to pond farming are listed below;

* Relatively low capital investment is needed compared to other culture systems.
* Easier management and monitoring and therefore, early detection of stressors and diseases
* Parasites and diseases can be treated economically
* Efficient use of all the available water resources
* Cage movement and relocation flexibility
* Easier harvesting and chance of partial harvesting
* Optimum use of artificial feeds and close monitoring of their response for the feeding process
* Allows high stocking densities
* Improves feed utilization and growth rates
* Reduction of pressure on land resources use
* As the eggs fall the bottom passing through the mesh, excessive reproduction of tilapias may be lessened.
* It is easier to control predator and competitor species (El-Sayed, 2006).

Limiting factors are;

- With the presence of harsh weather conditions, construction of sheltered areas or relocation might be required.
- For different units like hatchery and processing, strategic planning might be required.
- Due to high levels of dissolved oxygen requirement, a strong water current is needed to empty out the metabolic wastes inside the cages. Periodical cleaning is needed against rapid fouling of fish nets.
- Sometimes small fish schools may enter the cages and feed on those artificial feeds. In addition, these natural fish populations may infect cultured fish.
- Risk of theft.
- Capital investment may wear in a short period.
- Presence of accidental risks, for example: construction failure (Dikel, 2009).

There are many factors determine the success of tilapia cage culture like; water quality, cage size and type, stocking density. Whereas water quality is considered to be an external factor, tilapia culture efficiency can be improved with relevant use of cages and correct stocking density.

Cage size and type: Tilapia cage culture is practiced in many countries all over the world and hence cage types considerably vary. In addition to commonly used cages made of cheap and local materials, quite modern HDPE cages are used as well (Dikel, 2009). “Breeding cages and fingerling production cages are generally smaller than fattening cages, while experimental cages do not usually exceed a few cubic meters” (El-Sayed, 2006). As larger cages seem to suit tilapia production better according to better growth, reduced feed loss and improved survival even at low dissolved oxygen values (McGinty, 1991), commercial tilapia cages tend to be larger up to 600 m3 (Orachunwong et al., 2001).

Stocking density: Stocking density is highly effective on individual growth performances of tilapia and total yield. Whereas increases stocking density may improve total yield, it will show up with a reduction on individual fish growth. In floating cages in Thale Noi, in Thailand, Nile tilapias were stocked at 30, 100, 300 and 500 fish/ m3 and were fed a weed-based diet during 3 months. The best production and yield were achieved at 500 fish /m3 but individual growth was better in lower stocking densities (Chiayvareesajja et al., 1990). In another study in Cukurova University Fisheries Faculty in Turkey, overwintered 56 g of Oreochromis aureus x Oreochromis niloticus hybrids were stocked into 200 m2 pond in 4 m3 floating cages with two different stocking densities; 10 and 18 fish /m3. At the end of 90 days, whereas 145-160 g hybrids were obtained from the cage stocked at 18 fish /m3, 215 g individuals were obtained from the cage stocked at 10 fish /m3 (Dikel, 1997).

Table 2.5: Intensive cage culture of tilapia in some countries (modified from El-Sayed, 2006)

Species	Red Tilapia	Chitralada strain	O. n (Thailand)	O. n (GIFT) (Philippines)	O.n (Lesser Antilles)
No/m3	158	100	50	20	300
IW (g/fish)	58.3	75	103	73.9	73
ADG (g/day)	3.74	4.43	3.57	0.8-0.9	3.8
SGR (%)	------			0.9-1.0	1.49
FCR	1.44	1.50	1.30	2.8-3.3	1.30
FW (g/fish)	506.5	606.5	403	156.6-162.6	616
Yield (kg/m3)	57.1	59.2	19.65		18.2
S (%)	71.2	97.7	97.6	96-99	97.7
Culture period (days)	120	120	84	90	143

Remarks	20-32% cp feeds, 12 m3 cages, suspended in a river	30% crude protein diet, cages suspended in 330 m3 ponds. Aeration improved growth compared to non-aerated ponds.	6 m3 cage in ponds, fed either commercial feed, farm-made yeast or compost diet.	36% cp floating pellets, cages suspended in a 2 ha runoff pond.
Referances	Orachunwong et al., 2001	Yi and Lin (2001)	Fitzsimmons et al. (1999)	Rakocy et al. (2000a)

O.n, Orechromis niloticus; IW, initial weight; ADG, average daily gain; SGR, specific growth rate; FCR, feed conversion ratio; FW, final weight; GIFT, genetically improved farmed tilapia

2.2.3 GREENWATER TANK CULTURE

Harsh climatic conditions, land use and freshwater supply are the limiting factors for tilapia production in many areas. At this point re-circulating greenwater technology has been considered as an appropriate method for commercial production of tilapia, where the environmental conditions are constraints (Cole et al. 1997).

As the culture method name indicates, culture water has a green color due to enhanced development of photosynthetic algae. The function of the system basically depends on the nitrifying bacteria suspended on organic matter. These bacteria oxidize nitrite (NO_2) and highly toxic ammonia (NH_3) to nitrate which is relatively harmless.

When this process serves to improve the water quality, it also produces bacterial protein for tilapias due to their filter-feeding ability (Kochba et al., 1994, Avnimelech et al. 1994).

Feaces, feed wastes and dead algae are removed from the system in sludge form in tank bottom. Interplay of air-lift pumping with air diffusers maintain a constant circulation of detritus, feaces and plankton (Alam and Al-Hafedh, 2006).

Continuous removal of solid wastes and aeration are the main inputs for the system. However, biofiltration might be taken out of the system to cut capital costs, also maintenance and management needs of the system (Martin 2000).

Although greenwater tank culture can be performed with different tank sizes, shapes, filtration methods and feeding strategies, they all have the same production goals; high production, minimized water discharge and maximized nutrient utilization (Martin et al., 2000). "The major disadvantage of algal based systems are the wide diurnal variations in dissolved oxygen, pH and ammonia-nitrogen and the long term changes in algal density and frequent die-offs'" (Burford et al., 2003)

Advantages of using greenwater culture system are summarized below;

- Efficient water use
- As it contains bacteria and planktons, it has a nutrient cycle for tilapias. Therefore, it leads to a reduction on feeding expenses
- Nutrient enriched bottom sludge in these systems can be used for some agricultural products like green pepper.
- Regarding to the harvest and stocking, system has a quite easy management
- It has an intensive production capacity and profitable both for small-scaled and big-scaled production plants (Dikel, 2009).

Greenwater tank system of University of Virgin Islands was described and tilapia species' suitability was evaluated in a series of several studies. Whereas 5% of water exchange on daily basis did not show any improvement on fish growth, survival or yield over a zero water exchange system, sludge removal significantly resulted in better fish performance (not on survival though). On the other hand, weekly application of aluminium sulphate at 51.5 mg/l resulted in increased growth and yield of Nile tilapia (Rakocy et al 2000, a, b). It was reported that Nile tilapia in greenwater tanks with 26 fish/ m3 stocking density which fed with a 32% crude protein feed, reached biomass of 13.4 kg/m3, 1.41 as FCR value and survival rate of 99.3 %, only with an 0.23% of water exchange on daily basis (Martin et al.,2000).

A trial was carried out to evaluate water quality parameters in a greenwater system. Mixed sex Nile tilapias (Oreochromis niloticus) with an average weight of 29.26g (± 6.75 g) were stocked at a density of 40 fish /m3. Pelleted feeds with 34% protein and 5% fat content were used to satiation for 20 minutes twice a day, at 08:00 in the morning and 16:00 in the afternoon. Heaters and thermostats were installed to maintain the temperature at 28 ± 1 C. Water flow rate was approximately 7.0 L / minute so that entire volume of circulates through the clarifier once in a day. 28 air diffusers were connected to an air blower for the continuous aeration. When the system was close to its carrying capacity, water sampling was initiated (Alam and Al-Hafedh, 2006).

Table 2.6: This shows Diurnal variation of some chemical parameters in the water of the greenwater fish-rearing tanks in the month of May 2002. Each value is the average of two samples from all three greenwater fish culture tanks.*Un-ionized ammonia (NH3-N) values are calculated from TAN concentration by following Huguenin and Colt ,1989 (Alam and Al-Hafedh, 2006).

	Parameters (mg/L)							
Time	CO2	DO	pH	TAN	NH3-N	NO2-N	NO3-N	TDS
06:00	11.3	4.1	6.2	1.7	0	0.63	46.00	4440
08:00	8.2	5.6	6.1	1.7	0.002	0.65	38.53	4490
10:00	7.4	6.2	6.6	1.6	0.003	0.69	42.75	4820
12:00	7.6	5.8	7.3	1.2	0.026	0.69	35.00	4780
14:00	6.9	6.5	7.1	0.9	0.006	0.83	31.51	4430
16:00	8.1	6.1	6.8	0.8	0.006	0.86	44.25	4360
18:00	10.3	4.8	6.4	1.9	0.004	0.87	52.25	4870
20:00	12.6	4.2	6.1	1.5	0.002	0.84	52.54	4730
22:00	12.5	4.5	5.8	1.7	0.002	0.85	38.00	4360
24:00	13.7	4.1	5.9	1.6	0	0.86	42.25	4230
02:00	12.4	4.3	5.9	1.7	0.002	0.86	61.04	4210
04:00	12.1	4.1	5.8	1.8	0.002	0.74	59.75	4260

CO2, carbondioxide; DO, dissolved oxygen; TAN, total ammonia nitrogen; NH3-N, un-ionized ammonia; NO2-N, nitrite-nitrogen; NO3-N, nitrate-nitrogen; TDS, total suspended solids

Results: Un-ionized ammonia (NH3-N) and total ammonia nitrogen (TAN) levels should be kept below 0.005 mg/L and 1 mg/L respectively for commercial production (Timmons and Ebeling, 2010). In this trial, un-ionized ammonia values were generally lower than 0.005 mg/L.

Moreover, toxicity for aquatic species is known to be occur with more than 50 mg/L of free CO_2 (Heinen et al. 1996) and in this trial, maximum CO2 value was 13.7 mg/L which is quite low. In addition, pH value tends to decrease during night when there is an increase in CO2 level. Whereas present CO2 values are far from being toxic, with the increasing value of pH, ammonia is converted to a less toxic ammonium form (Lawson 1995).

As a result, total ammonia nitrogen (TAN) values seem to be the biggest problem in the system, which is generally higher than 1 mg/L. However such a system is still applicable for commercial tilapia production.

2.2.4 RECIRCULATING SYSTEMS

A water recirculation system can be defined as a closed system that incorporates the water treatment and reuses the water in the system, while only less than 10% of the total water volume replaced on daily basis.

Table 2.7: Water and Land Use per kg of Production of Tilapia and a Relative Comparison to an Intensive RAS Tilapia Farm (RAS assumed to discharge 5% of system volume per day) (Modified from Timmons and Ebeling, 2010)

Species and System	Production Intensity (kg /ha/y)	Water required (Liter / kg)	Ratio of System's Land or Water Use to RAS Use	
			Land	Water
O. niloticus (Nile tilapia) RAS produced	1,340,000a	50	1	1
O. niloticus (Nile tilapia) pond	17,400	21,000	77	420

Characteristics of these systems are water reuse, minimized effluent discharge and optimized water conservation (El Sayed, 2006). A study was carried out on the effects of solid removal on tilapia production and water quality in continuously aerated tanks. Solid removal resulted in increased final weight and net-yield but there was no difference in compare to solid removal absent system (Cole et al., 1997). Nitrification treatment systems play a vital role for fish culture in re-circulating systems in order to keep the ammonia and nitrite levels at acceptable values. Significant amount of oxygen can be used and large quantities of ammonia-nitrogen can be produced due to decomposition of solid wastes and uneaten or indigestible fish feeds (Losordo et al., 1999). Therefore these systems must be designed to maintain desired levels of dissolved oxygen (> 6 mg /L) and minimize CO_2 (< 20 mg /L) (Losordo et al., 1999)

A closed system is known as the DEKEL system was described, where there is a water recirculation between concrete grow-out ponds and earthen reservoir which serves as a biofilter (Mires and Amit , 1992). The system was maintained a suitable water quality for tilapia culture and the net yield was reached 19.5 kg/m2 in 1990. Later, another closed system was evaluated referred as O2BIO, which was supported by pure oxygen supply and a biofilter. Higher production yield was obtained but it was less cost-effective (Mires and Anjioni 1997).

In the first table below, although O2BIO system's total pond area is half of the DEKEL system, 4 times greater water exchange was applied and energy consumption was significantly higher in O2BIO system. In support, even though O2BIO system has higher yield, profits ($/kg) are almost same. Moreover, high investment necessity of O2BIO system is another disadvantage.

Table 2.8: Technical comparison of two different tilapia culture recirculation systems (Modified from Dikel, 2009)

	DEKEL	O2BIO
Total pond area (m2)	2000	1000
Total water volume (m3)	2000	800
Feeding period (day)	153	350
Total fingerling number	134,258	216,000
Fingerling (unit/kg)	3.6	3.6
Circulation pump (hp)	31.00	40.0
Water exchange (%)	5	20
Total feeding (kg)	82,830	108,000
Feed conversion	2.22	1.80
Total oxygen(kg)	0	54,000

Oxygen(kg O2/kg fish)	0	0.9
Energy: circulation pump (kw-kg/fish)	2.29	4.2

Table 2.9: Recirculation system outputs (Modified from Dikel, 2009)

	DEKEL	O2BIO
Total annual product (kg)	37,280	60,000
Total annual product (kg/m2)	18,64	60,00
Profit ($ /kg)	0,68	0,70
Profit ($/m2)	12,61	41,90
Overwintering additional values ($/m2)	4,18	---
Investment ($/m2)	88,24	600,00

2.2.5 BIO-FLOC SYSTEM

Intensive aquaculture brings with it two major problems. The first one is, as only 20-30% of feed nutrients are retained by fish (Avnimelech and Ritvo, 2003) the rest is accumulated in culture water, and it deteriorates water quality, the second is discharge of culture water which contains compounds like ammonium, phosphorus and organic carbon may affect receiving water bodies and result in eutrophication (Piedrahita, 2003; Sugiura et al., 2006). In addition to these, when high water exchange is practiced in system, it causes low feed utilization (Avnimelech, Y., 2006).

For decades, re-circulating system has been considered as the main application for intensive rearing of several species, which also include tilapia. But capital investment cost of re-circulating system, increased consumption of energy and labor costs have been the driving factors for an alternative rearing system. Earlier studies on tilapia culture in activated suspension ponds showed that tilapia grew fairly well on low protein content feeds and feeding on suspended particles led to a reduction in feed costs. Also water use efficiency was improved (Avnimelech,1999 ; Milstein et al., 2001 ; Serfling, 2006). At this point, bio-floc (BFT) system might overcome chronic problems of intensive farming such as; high production costs, maintaining stable water quality, and water treatment.

In bio-floc (BFT) system; culture water is constantly aerated and agitated, and with the retention of uneaten feeds and excreta of fish, a microbial community is grown which improves water quality by feeding on these organic wastes and serve as a feed for fish afterwards.

A study was carried out to evaluate the bio-floc technology in light-limited tanks for Nile tilapia (O. niloticus) culture. Two bio-floc treatments and one control were used in indoor tanks with 250 liters capacity. For BFT treatments two different feeds were used with 35% and 24% crude protein contents, and for control without BFT, feed with 35% crude protein was used. Bio-floc tanks were treated with aeration and agitation procedures by a dome diffuser. Three kilograms of Nile tilapia were stocked into each tank. 1.5% of the total fish biomass was applied as daily feed amount. Bio-floc tanks were supplemented with wheat flour in order to maintain ideal C:N ratio. Nutritional quality of bio-floc system was satisfactory for tilapia. No mortality was observed and survival rate was 100%. 45% higher net production in BFT tanks was the indicator of utilization of bio- floc by fish as a feed source. There was no significant difference between in terms of fish growth/production for two BFT tanks treated with 35% and 24% crude protein feeds. As a result, although the survival rate was 100% and better results were achieved in BFT tanks, system was far from being commercially feasible and therefore it would be advised to modify the system for a commercial production (Azim and Little 2008).

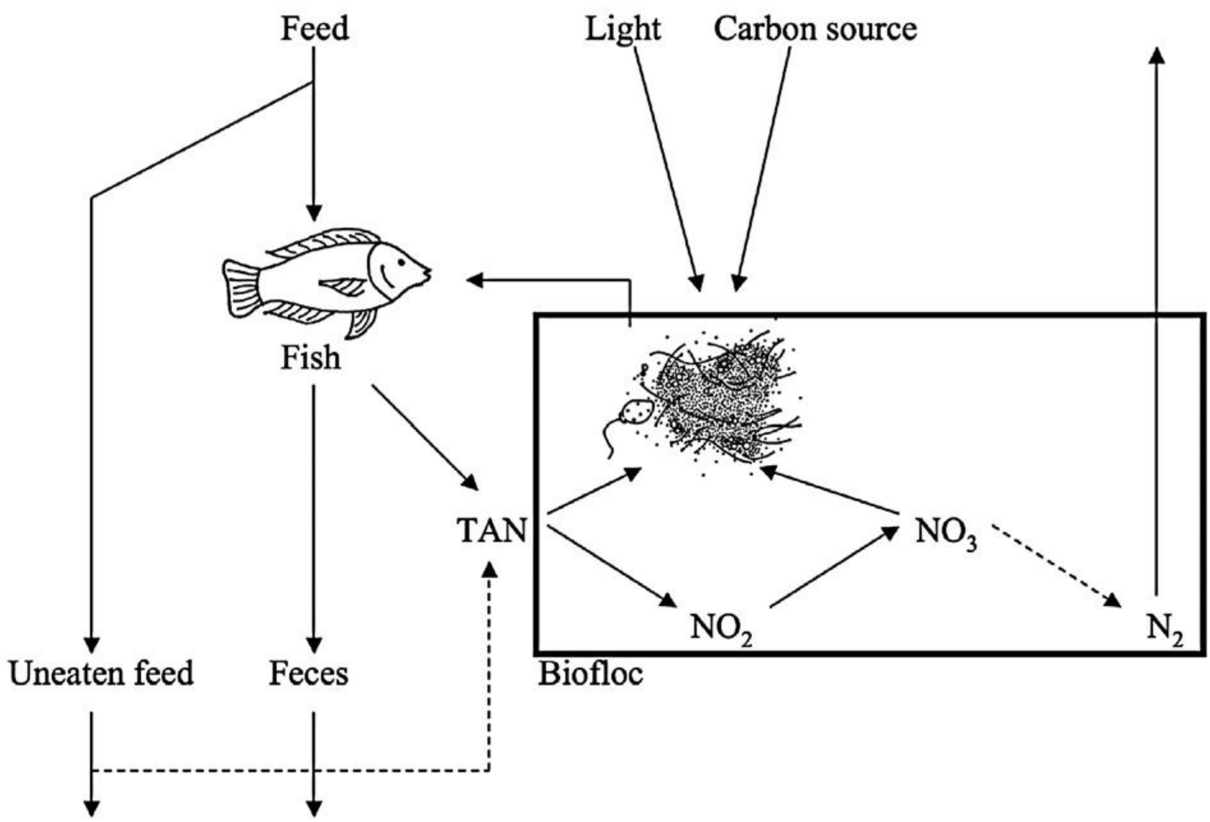

Figure 2.2: Nitrogen cycle in bio-floc ponds (Crab et al., 2007)

In bio-floc systems, different than greenwater systems, a high C:N ratio is desired and heterotrophic bacteria growth is supported. In greenwater systems, heterotrophic bacteria act like competitors for autotrophic bacteria and may threat the functionality of the system.

In this system, accumulation of toxic inorganic nitrogen like NH4 and NO2 is prevented by keeping a high C:N ratio and the uptake of ammonium by the microbial community (Avnimelech et al., 1994 ;Mc Intosh, 2000).As a supporting fact, high C:N ratio in feed (higher than 15) was reported to immobilize the ammonium (TAN, total ammonium nitrogen) in microbial community and serves to limit the accumulation of TAN in the culture water (Avnimelech 1999)

Carbon rich and protein poor ingredients carbohydrate sources like starch or cellulose are added into the ponds to keep the C:N ratio higher than 10.

In intensive bio-floc systems, protein utilization by fish was found to be almost two times higher than the conventional pond systems due to conversion of excreted nitrogen into the microbial protein (Avnimelech et al.,1994).

INTEGRATED TILAPIA CULTURE

3.1 AQUAPONIC SYSTEM

Formerly, semi-intensive pond production was the main method for tilapia farming particularly in developing countries. Today, with the increased demand for tilapia in the market, climatic changes and year round production chance, shortage of fresh water supply and the increasing land costs have been the driving factors for the use of intensive indoor re-circulating systems

In aquaculture facilities, regardless of fish species being farmed, wastes that disposed to water basically can be divided into three groups; 1) uneaten feeds, 2) indigestible feed substances and 3) feaces. In addition, metabolic products such CO_2 and total ammonia nitrogen (TAN) might be considered as the fourth group. In aquaculture, with presence of those three factors; phosphor, ammonia, suspended solid particles amount increase and dissolved oxygen level in culture water dramatically drops. As well, increasingly stringent environmental regulations make aquaponics a major solution to overcome these critical problems (Lennard, 2004).

Aquaponics is the integrated production of plants (hydroponic) and fish in a water re-circulating system with the biofiltration process by nitrifying bacteria (Tyson et al., 2007) , while hydroponic is referred to plant production without soil and in a limited area in compare to land based plant production. Bacteria in the gravel and associated with the roots of the plants play a critical role in the nutrient cycle; absence of these organisms would stop the functioning system (Rakocy, 1999a ; Diver, 2000). Hydroponic system has several advantages alone. A well known superiority of hydroponics over conventional agriculture is, the year-round production of crops when the supply is decreased due to seasonal changes. The second one is considered to be the elimination of soil-borne diseases, as the crops are grown in an aquatic medium.

In an aquaponic system, hydroponic subsystem functions as a biofilter and improves the water quality. Basically, solid particles in nutrient-rich effluent water are removed and then culture water goes to hydroponic system, stripped of the substances like ammonia, nitrite, nitrates and phosphorus compounds.

Afterwards, this cleaned water is collected in sump, which is a reservoir ,can be pumped back to the fish tanks.

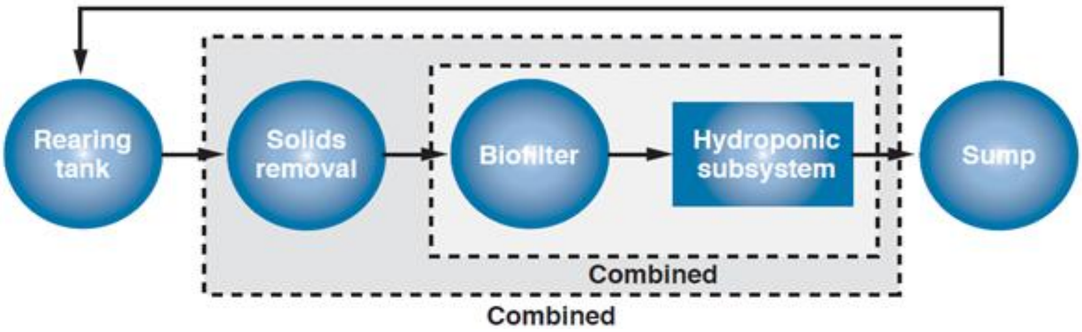

Figure 3.1: Optimum arrangement of an aquaponic system (Rakocy, et al., 2006) Effluent water, normally needs to be discharged is absorbed by plants as fertilizer. However, nitrifying bacteria treat the water by oxidizing the highly toxic ammonia (which is excreted by fish gills) first into nitrite and eventually to nitrate, which is less toxic.

Mainly 16 nutrients are needed for plant growth and these are; nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), sulfur (S), chlorine (Cl), iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu) and molybdenum (Mo) (Rakocy et al., 2006). Generally 10 nutrients are provided in an aquaponic system by fish and only external supplementation of Ca, K and Fe is needed depending on their present amounts in culture water (Rakocy and Bailey, 2003). However, three other nutrients carbon (C), hydrogen (H) and oxygen (O) are provided by the culture water in form of H2O and CO2. As a result acid production of nitrification, pH drops and additional base is required to keep the pH around 7.0-7.5 (Rakocy and Bailey, 2003).

Table below shows the efficiency of an aquaponic system. Although there is no significant difference for feed conversion ratio (FCR), superiority of the system comes up with the ammonia accumulation. In addition to this significant difference, 97% ammonia removal means minimized water exchange and a better water quality.

Table 3.1: Fish Growth and Nitrate Removal for Fish-Only Systems and Aquaponic Systems (Modified from Lennard, 2006)

Parameter	Fish-only	Aquaponic
Fish FCR	0.87 ± 0.01	0.88 ± 0.0
NO3 accumulation (mg /l)	52.20 ± 5.28	1.43 ± 1.09
NO3 removal (%)	0	97

Several advantages of aquaponic systems are listed below;

Metabolic wastes of fish serves as an organic fertilizer which enables to well growth of plants.
Hydroponics is considered to be a biofiltration method that facilitates intensive recirculating system.
As only fertility input is the fish feed and all the nutrients undergo biological process, aquaponics is the method to introduce organic hydroponically-grown products to the market.
Food producing green houses yield two products from a single production unit, which naturall y appeal for niche marketing and green labeling.
Being a water re-use system, aquaponics allow to produce fresh vegetables and fish in arid regions and where the water supply is the limiting factor.
Aquaponics is a sustainable food production model with the bio-integration of plant and animal agricultures, and where the recycling of nutrients and water filtration are linked (Rakocy, 1999 a ; Diver, 2000).

Tilapias are hardy fish species as they tolerate various water conditions such as pH drops, low dissolved oxygen levels. They also tolerate high stocking densities which is quite common for indoor intensive systems, far better than the many other species. Therefore they do well in such systems.

Many different plants, vegetables and herbs can be integrated into aquaponics system but success differs in terms of their different requirements for pH, temperature or in economical perspective, harvesting periods and growth rate.
A comparative study was conducted to compare the production of tomatoes and lettuce grown with blue tilapia in an aquaponic system and their production in conventional soil system. A faster growth observed for vegetable production in aquaponic system and even tomatoes flowered two weeks earlier than soil-grown ones (Anadu and Barho, 2002). Lettuce (Lactuca sativa) is considered to be another good candidate for aquaponic systems as it is a hardy plant grow quite fast (Resh 2001) and allows quick profit and turnover of the different nutrients in the system by harvesting within 4-5 weeks (Rakocy et al., 2006).

A demonstrative aquaponic system trial was carried out at the University of the Virgin Islands to show the sustainability of such a system on commercial basis. During 2.5 years of continuous production of red tilapia and three varieties of leaf lettuce, there were 19 tilapia and 112 lettuce harvests. Three farm sizes consisting of 6, 12 and 24 units were analyzed (Bailey et al., 2001). Each unit of the system was composed of 4 fish tanks and they were stocked every 6 weeks with 800 tilapia fingerlings for grow-out , which weigh 30-50 g. Production cost of each tilapia fingerling was $1.23. Fish were harvested after stocking and restocking was immediately applied. Each system produced 357 kg of red tilapia every 6 weeks and there were 8.7 production cycles every year. Sale price for red tilapia was 5.51 $ per kg. As there were three different lettuce varieties (romaine, red leaf and green leaf), lettuce seedlings were planted weekly at two different densities either 48 or 60 plants per sheet. Mature plants were harvested after 4 weeks of growth period and then were packed at 24 heads per case and sold. New seedlings were immediately transplanted into the harvest area just after the sale. For each system, there 52 weekly lettuce harvests per year and sale price of a case of lettuce was $20.
Extruded and complete floating tilapia feeds with 32% protein content were used. For the first week, fish were fed 6% of initial body weight on daily basis and to satiation with weekly increased amounts in the remainder weeks. Feed cost was $0.66 per kg.

Tilapias can tolerate wide ranges of pH between 5-11. On the other hand, nitrifying bacterias are reported to be inhibited below a pH of 6.5 (Tyson et al 2007). Therefore, chemical supplements; KOH, Ca (OH)2 and iron chelate were used to maintain desired levels of pH, which is higher than 6.5

All other production costs and values are shown in the tables. In the first table, as there were 8.7 production cycles per year and harvest biomass was 357 kg, 8.7x 357=3,094 kg gives the quantity per unit. Multiplication of this value with $5.51 sale price and number of the units gives respectively; $102,334-$204,668 and $409,336 receipt from tilapia sale. On the other hand, total costs have significantly higher values than the tilapia receipts. As it can be seen from the table; for 6 units: tilapia receipt is $102,334 and total costs are $154,589 , for 12 units: tilapia receipt is $204,668 and total costs are $266,678 and for 24 units: tilapia receipt is $409,336 and total costs are $518,355. As a result, total costs clearly exceeded tilapia receipts and this situation gave negative returns for 3 farms respectively; $-52,255 , $-62,010 and $-109,019.

In the second table, multiplication of case price of lettuce and quantity gives the receipt for lettuce. These values are respectively, $20 x1,820 x 6= $218,400 for 6 units , $20 x 1,820 x 12 = $436,800 for 12 units and $20 x 1,820 x 24= $873,600 for 24 units. For lettuce production; for 6 units: lettuce receipt is $ 218,400 and total costs are $135,385 , for 12 units: lettuce receipt is $436,800 and total costs are $243,271 , for 24 units: lettuce receipt is $873,600 and total costs are $486,453. Different than tilapia production, returns were positive for three farms and they were respectively; $83,015 , $193,529 and $387,057 for 6 units, 12 units and 24 units.

Table 3.2: Yearly enterprise budgets for the tilapia production component of three model aquaponic farms having 6, 12 and 24 units (Bailey et al., 2001)

		Units	Cost /Unit ($)	Quantity per unit	Value per 6 units ($)	Value per 12 Units ($)	Value per 24 Units ($)
Receipts	Tilapia	kg	5.51	3,094	102,334	204,668	409,336
Variable costs	Fingerlings	Ea.	1.23	7,200	53,136	106,272	212,544
	Feed	kg	0.66	5,260	20,829	41,658	83,315
	KOH	kg	1.30	100	780	1,560	3,120
	Ca (OH)2	kg	0.12	100	72	144	288
	Electrical	kWh	0.10	10,400	6,240	12,480	24,960
	Supplies	unit	2,423.20	1	14,539	29,078	58,157
	Manager	unit	variablea	0.083	20.000	20.000	25.000
	Labor	unit	150,000.00	0.083	15.000	15.000	30.000
	Maintenance	unit	150,000.00	0.083	7,500	7,500	15,000
Total VC					138,096	233,692	452,384
Income above VC					35,762	29,024	(43,028)
Fixed Costs	Depreciation		1,896.68	1	11,380	22,760	45,520
Total FC					11,380	22,760	45,520

Total of above costs					149,476	256,452	497,904
Net returns					47,142	51,784	88,568
Other Costs	Land charge	Ha/ yr	247.00	0.025	43	86	173
	General overhead	% VC	2.8 %	30,176.13	5,070	0,139	20,278
Total Costs					154,589	266,678	518,355
Returns to Risk& Management					52,255	62,010	109,019

Table 3.3: Yearly enterprise budgets for the lettuce production component of three model aquaponic farms having 6, 12 and 24 units (Bailey et al., 2001)

		Units	Cost /Unit ($)	Quantity per unit	Value per 6 units ($)	Value per 12 units ($)	Value per 24 units ($)
Receipts	Lettuce	Cases	20	1,820	218,400	436,800	873,600
Variable costs	Seedling transplants	Ea.	0.05	67,600	20,280	40,560	81,120
	Boxes	ea	2.00	1,820	21,840	43,680	87,360
	Chelated Iron	kg	5.70	17	581	1,163	2,326
	Electrical	kWh	0.10	5,200	3,120	6,240	12,480
	Manager	unit	Variable a	0.083	20,000	20,000	25,000
	Hired Labor	unit	15,000.00	0.083	45,000	90,000	180,000
	Maintenance	unit	15,000.00	0.083	7,500	7,500	30,000
Total VC	Total VC				118,321	209,143	418,286
Income above VC					100,079	227,657	455,314
Fixed Costs	Depreciation		1,829.45	1	10,977	21,953	43,907
Total FC					10,977	21,953	43,907
Total of Above					129,298	231,096	462,193

Costs							
Net returns	Net return				89,102	205,704	411,408
Other Costs	Land charge	Ha/yr	247.00	0.034	148	299	598
	General overhead	%VC	2.8%	35,345.23	5,938	11,876	23,752
Total Costs					135,385	243,271	486,543
Returns to Risk& Management					83,015	193,529	387,057

In the table below, tilapia and lettuce production values are shown together. For 6 units, 12 units and 24 units, total revenue values are $320,734 , $641,468 and $1,282,936 respectively. On the other hand, total costs are $289,973 , $509,949 and $1,004,898. Therefore, returns to risk, in other words profit values were $30,761 , $131,519 and $278,038 for 6 units, 12 units and 24 units respectively.

Table 3.4: Enterprise budgets for three model aquaponic farms with 6, 12 or 24 tilapia and lettuce production units, and necessary infrastructure to support fingerling production, lettuce seedling production, water storage, land costs and general overhead (Bailey et al., 2001).

		Costs per 6 units ($)	Costs per 12 units ($)	Costs per 24 units ($)
Revenue	Fish	102,334	204,668	409,336
	Lettuce	218,400	436,800	873,600
Total revenue		320,734	641,468	1,282,936
Variable Cost	Fish	138,096	233,692	452,384
	Lettuce	118,321	209,143	418,286
Total VC		256,417	442,835	870,670
Income Above VC		64,317	198,633	412,267
Fixed Cost	Fish	11,380	22,760	45,520
	Lettuce	10,977	21,953	43,907
Total FC		22,357	44,714	89,427
Total VC and FC Costs		278,774	487,548	960,097
Net Returns		41,960	153,920	322,840
Other Costs		11,199	22,400	44,801
Total of All Costs		289,973	509,949	1,004,898
Returns to Risk		30,761	131,519	278,038

As tilapia production costs were considerably higher than the sale income, negative results were achieved. However, these negative results were compensated by the profitable lettuce production and integrated system achieved positive results.

It is clear that profitability of such a system increases by the increased production capacity. While profit for tilapia-lettuce combined system for 6 unit was $30,761 , this value was $278,038 for 24 units.

Results and discussion: Aquaponic systems come up with several superiorities over a conventional recirculating system. In this perspective, elimination possibility of purchasing and operating a separate biofilter, having a secondary product in the system and reduced water exchange rates are the biggest advantages for a feasible commercial production

However, the key element of designing an aquaponic system is the ratio between the daily feed input and the plant growing area. If the ratio of daily feed rate to plants is too high, this will result in rapid accumulation of nutrient salts and eventually may reach phytotoxic levels. If this ratio is too low, then plants will show up with nutrient deficiencies and nutrient supplementation will be required (Rakocy et al 2006).

As it can be seen on the previous experiment, although the integrated system was feasible, tilapia production alone gave negative results. Therefore, market demands and gate prices for the selected products should be analyzed in a detailed way. In addition, as a basic demand-supply principle in economics, sale price of any agricultural product tends to increase when the supply gets limited in some unfavorable seasons due to climatic conditions. Therefore, shorter intervals for the harvesting of selected crop might be an advantage. Another important criterion is the keeping the total production close to carrying capacity limit and having larger production units as increasing profit was demonstrated proportional to the increased production capacity in the previous experiment.

3.2
TILAPIA POLYCULTURE

Polyculture is the practice of farming more than one different species in the same production area. Motivating principle for such a system is believed to be the maximizing fish production and improving the water quality by stocking different species with different feeding habits due to better utilization of the feeds in the system (Naylor et al., 2000; Mc Vey et al., 2002 and Davenport et al., 2003).

Appropriate combination of fish species with the proper stocking densities was reported to result in better utilization of the available resources, maximization of synergistic fish-fish and fish-environment interactions and keeping the antagonistic ones at minimum levels (Milstein and Svirsky, 1996). In addition, best tilapia performances and the highest total yield were reported when the tilapias were the primary species in polyculture systems (Milstein 1995)

Tilapia is considered to be a suitable specie for such systems as they tolerate crowding stress, a hardy fish for low water quality and do not tend to show cannibalistic behaviors. Therefore, tilapias are cultured with several different aquatic species like; carp, grey mullet, catfish and freshwater shrimp (Cardona et al., 1996 and Yossef, 2000).

3.2.1

Tilapia-Shrimp: Shrimp culture is a common practice in many countries, particularly in Asia. However, “white spot” and “vibriosis” are two main diseases create serious problems for shrimp production. In addition, high nitrogen and phosphorus wastes are obtained (Midlen and Redding 1998) due to unutilized feed, which includes uneaten and undigested feeds (Lin, 1995; Burford and Williams, 2011). It has been reported that only 21-22 % of total nitrogen and 6% of total phosphorus are retained in the shrimp biomass and the rest are retained both in water and sediment (Briggs and Funge-Smith, 1994; Jackson et al., 2003a). Tilapias have been considered to be effective for the utilization of the wastes in culture water and many studies have been conducted for tilapia-shrimp polyculture. However, shrimp-tilapia polyculture systems have not succeeded as a result of decreased growth and yield of shrimp, due to the challenge for food between two species which suppresses shrimp growth (Wang et al., 1998).

In a study by the Southeast Asian Fisheries Department Center has shown that Nile tilapia hybrid has an antibacterial effect on luminous bacteria and positively affect survival rate of shrimps (Tendencia et al., 2006).

A detailed study was conducted to show the effects of different stocking densities of Nile tilapia (Oreochromis niloticus) and white shrimp (Litopenaeus vannamei) in different aspects. In this study, in an integrated closed recirculation system, outdoor tank system was used with 6 different treatments: T1, single shrimp tank system; T2, closed recirculation system without tilapia; T3 to T6, integrated closed recirculation system with the tilapia-shrimp stocking density ratio of 0.01, 0.025, 0.05 and 0.075, respectively. Shrimps were stocked at a density of 40 shrimp/m-2 for all the treatments. Shrimps were supplied from a commercial hatchery and were kept in nursery tanks during six weeks before being stocked in the experiment tanks. The average shrimp weight was 1.41 ± 0.85 g. Juvenile tilapias were supplied from a commercial farm and had an acclimation period for 25 ppt salinity before stocking. Initial tilapia weight was 108.2 ± 14.7 g. Culture period was 8 weeks for shrimps and 7 weeks for tilapia as they were stocked one week after shrimps. Shrimps were fed with commercial pellets five times a day at 5 hours interval (07:00,12:00,17:00, and 22:00 h), while there was no feeding for tilapia.

Table 3.5: Shrimp and tilapia stocking density in this experiment

Treatment	Shrimp stocking density (shrimp m-2)	Tilapia stocking density (fish m-2)	Shrimp: Tilapia ratio	Tilapia: Shrimp ratio
1	40	----	----	----
2	40	0	----	0
3	40	0.4	100:1	0.01
4	40	1	40:1	0.025
5	40	2	20:1	0.05
6	40	3	13:1	0.075

Results:

Shrimp Growth: T2 obtained the highest mean individual weight while it was the lowest in T6. Total weight of shrimp at harvest was highest in T2 with 3085 g and it was 2262 g for T6. Lowest FCR value was 1.13 and belongs to T2.

Tilapia Growth: T3, where the lowest tilapia stocking density was applied, highest tilapia growth was achieved and therefore, mean weight at harvest was the highest in T3.

Conversion rate of feed nitrogen: Increasing tilapia density in integrated system (T2 to T6) resulted in reduction of conversion of feed nitrogen into shrimp biomass. On the other hand, conversion rate of N to tilapia biomass did not show any significant differences between treatments. For total (tilapia+ shrimp) biomass, results were quite different as while single shrimp tank (T1) had the lower values, high rates were achieved in tilapia-shrimp integrated system in T2 to T5.

Table 3.6: The conversion rate of feed nitrogen (%) into shrimp, tilapia and waste of integrated closed recirculation system (treatment 1: single shrimp tank system; treatment 2; tilapia-shrimp ratio of 0 ; treatment 3: tilapia-shrimp ratio of 0.01; treatment 4: tilapia-shrimp ratio of 0.025; treatment 5: tilapia-shrimp ratio of 0.05; treatment 6; tilapia-shrimp ratio of 0.075).

Treatment	Shrimp	Tilapia	Shrimp + Tilapia	Waste
1	40.4 ±2.0	-----	40.4 ± 2.0	59.6 ± 2.0
2	47.6 ± 2.9	-----	47.6 ± 2.9	52.4 ± 2.9
3	45.0 ± 1.3	6.08 ± 0.72	51.0 ± 0.6	49.0 ± 0.6
4	44.2 ± 0.6	6.87 ± 2.14	51.1 ± 1.6	48.9 ± 1.6
5	40.8 ± 1.0	7.67 ± 1.81	48.5 ± 1.3	51.5 ± 1.3
6	38.5 ± 1.3	6.95 ± 1.85	45.4 ± 0.8	54.6 ± 0.8

Conversion rate of feed phosphorus: Increasing tilapia density in the integrated system led to decrease of the phosphorus conversion value (T2 to T6). Single shrimp tank system (T1) showed a low value. For total harvest biomass (tilapia+ shrimp), increased values for phosphorus retention were observed with increasing tilapia density. T1 achieved the lowest value among all the treatments. As inversely proportional to phosphorus retention, retention rate into waste was the highest for T1 with 80.1% and lowest for T6 with 56.2%.

Table 3.7: Conversion rate of phosphorus (%) into shrimp, tilapia and waste of integrated closed recirculation system (treatment 1: single shrimp tank system; treatment 2; tilapia-shrimp ratio of 0; treatment 3: tilapia-shrimp ratio of 0.01; treatment 4: tilapia-shrimp ratio of 0.025; treatment 5: tilapia-shrimp ratio of 0.05; treatment 6: tilapia-shrimp ratio of 0.075).

Treatment	Shrimp	Tilapia	Shrimp + Tilapia	Waste
1	19.9 ± 0.9	-----	19.9 ± 0.9	80.1 ± 0.9
2	23.4 ± 0.8	-----	23.4 ± 0.8	76.6 ± 0.8
3	21.7 ± 0.8	10.5 ± 1.1	32.2 ± 0.4	67.8 ± 0.4
4	21.8 ± 0.5	15.7 ± 3.4	37.5 ± 3.0	62.5 ± 3.0
5	19.1 ± 0.3	22.0 ± 7.5	41.2 ± 7.8	58.8 ± 7.8
6	18.9 ± 0.5	24.8 ± 5.7	43.8 ± 5.2	56.2 ± 5.2

Effects on economic return: Both two treatments, T5 and T6 showed low economic return compared to others, as a result of lower individual weight of shrimps at harvest. In addition, low market price of tilapia might be considered as the second factor in this situation. In present study, tilapia price per kg was set at 28 Thai Baht (THB), while shrimp prices were determined by the size as shown below;

< 13.3 g shrimp 100 THB kg-1

13.3-18.1 g shrimp 150 THB kg-1

> 18.2 g shrimp 270 THB kg-1

* 40 THB = 1 US $

Discussion: In this study, shrimp feeding was mainly dependent on commercial feed pellets and feed amounts were calculated regarding to shrimps' requirements. Therefore, growth reduction of shrimp with the increasing tilapia stocking might be linked to competition for natural foods grown in the tank. Zooplanktons such as copepods, nauplii and rotifers are reported to be consumed by both shrimp and tilapia (Getachew, 1993; Martinez- Cordova et al., 1998a, 2002). In addition, phytoplanktons such as Navicula, Cymbella, Nitzschia and Oscillatoria serve as natural feed for both shrimp and tilapia (Bombeo-Tuburan et al., 1993; Getachew, 1993; Gamboa-Delgado et al., 2003).

On the other hand, a polyculture farm profitability report has shown that tilapia income is far from keeping the farm profitable when there is a decline in shrimp production (Martinez-Cordero et al. 2004).

3.2.2

Tilapia-Carp: It is a well-known practice and promising results were achieved in tilapia-carp polyculture systems. Their supplementary feeding characteristics, efficient use of water column are considered to be the key factors of success of this system. Moreover, larger-sized carps may serve as a predator on tilapia fry and therefore can reduce the typical excessive reproduction problem of tilapias.

An experiment was carried out by Cukurova University in Turkey. Nile tilapia (O. niloticus) and common carp (Cyprinus carpio) fingerlings were stocked into concrete ponds which have 200 m2 surface area and 1.5 m of depth with different stocking combinations and then growth performances (live weight and length increase) were examined during a period of 134 days.

During trial, same amounts of water were supplied to the ponds and a special attention was paid not to have temperature differences in the ponds. All the ponds were treated with 15 kg of chicken manure in every two weeks.

In first 15 days after stocking fish were not fed, afterwards until first weighing period, they were fed 6% of their live weight. After first weighing process, they were fed respectively; first month;6% of live weight, second month ; 4% of live weight, third month; 3% of live weight and fourth month; 3% of live weight. For feeding, carp pellet feeds with 29% crude protein and 4% fat content were used.

Weighing and length measurement processes were carried out every month and in this respect, 10% of different species of fish were randomly taken from all the ponds

Table 3.8: Stocking ratios of Nile tilapia (O. niloticus) and Carp (C. carpio) (Dikel, 2009)

GROUPS				
	1	2	3	4
O. niloticus	1150	1100	1050	1000
C. carpio	50	100	150	200
Total	1200	1200	1200	1200

Table 3.9: Weight averages of both two species in monthly based weighing (g) (Dikel, 2009)

	Weighing Time				
		15.July	18.August	15.September	15.October
1.Group	Tilapia	17.4±0.2	56.0±0.4	114.5±0.9	151.4±1.0
	Carp	83.8±0.9	312.1±1.5	565.6±3.0	1027.5±3.2
2.Group	Tilapia	16.7±0.2	53.0±0.3	98.9±0.8	143.1±1.0
	Carp	76.3±0.3	192.1±1.8	352.8±2.9	812.8±3.1
3. Group	Tilapia	12.2±0.1	51.0±0.3	94.7±1.1	128.7±0.9
	Carp	62.5±0.4	172.0±1.5	306.6±1.9	573.2±2.4
4. Group	Tilapia	10.7±0.1	42.3±0.2	84.8±0.7	116.8±1.0
	Carp	47.0±0.3	183.1±1.4	204.3±1.8	378.7±1.9

Table 3.10: Length averages of both two species in monthly based measurements (cm) (Dikel, 2009)

	Measurement Time				
		15. July	18. August	15. Sept.	15. Oct.
1.Group	Tilapia	9.6±0.1	14.1±0.3	17.4±0.4	19.3±0.3
	Carp	15.3±0.2	25.1±0.9	27.5±3.0	31.1±0.6
2.Group	Tilapia	9.2±0.1	14.2±0.2	16.5±0.2	18.9±0.3
	Carp	15.5±0.1	20.2±0.7	24.2±0.4	29.2±0.6
3.Group	Tilapia	8.4±0.1	13.7±0.3	15.8±0.3	18.3±0.3
	Carp	13.9±0.1	18.9±0.4	22.5±0.3	26.3±0.6
4. Group	Tilapia	8.1±0.1	12.8±0.2	15.5±0.2	18.1±0.3
	Carp	18.8±0.1	18.9±0.8	19.6±0.4	23.2±0.5

Table 3.11: At the end of trial, total yield and feed conversion ratios (FCR) of two groups (Dikel, 2009)

GROUPS				
	1	2	3	4
Tilapia (kg)	174.1	157.4	135.1	116.8
Carp (kg)	51.4	81.3	86.0	75.7
Total product (kg)	225.5	238.7	221.1	192.5
Total Feed Consumption (kg)	280.6	257.9	233.4	222.2
Feed Conversion Ratio (FCR)	1.24	1.08	1.06	1.50

Results: Due to values obtained during trial, 1.group which consists of 1150 tilapia + 50 carp, were demonstrated a better performance in weight increase and respectively reached 151.4 ± 1.0 g and 1027 ± 3.2 g.

Experiment shows that whilst having the same numbers of fish at total, reduction in numbers of carps and increased numbers of tilapias, result in improved average length and weight values for both two species. Also, carp and tilapia monoculture, 60% carp + 40% tilapia and 40% carp + 60% tilapia polyculture groups in a water recirculating system were compared. Polyculture of these two species had better growth performances than the monoculture systems. For comparison of these two polyculture combinations, 2. group where the tilapias have higher numbers with 60%, showed a better performance although there was only an insignificant difference (Papaoutsoglu et al., 1991).

Consequently, when the higher market price of tilapia is taken into account,1. group has a superiority over all the other groups in frame of economical perspective. In addition, 1. group was showed the best performance in weight increase. On the other hand, 2. group had a better yield than the 1. group with a roughly 13 kg difference of total product. So that, polyculture of tilapias and carps is an applicable practice with the improved performances of both two species, particularly correct stocking ratios (more than 50% of tilapias) are applied. First and second groups are seem to be feasible for commercial production of tilapias and carps in a polyculture system.

Discussion

Data from literatures and results of experiments have indicated that tilapia is a suitable specie both for semi-intensive and intensive culture systems.

In semi-intensive system, as tilapias have a great ability to utilize different available ingredients and not dependent on high quality commercial feeds, an efficient pond fertilization and delayed external feeding seems to be the ideal production strategy as the experiments suggest. However, critical standing crop (CSC) should not be exceeded. Therefore, with the presence of pond fertilization and some local and cheap feed ingredients, semi-intensive tilapia farming may go on expanding in developing countries, particularly in Asia.

In intensive culture system, necessity of high stocking densities makes the process much more complicated. High stocking density is a prerequisite for a feasible production in an intensive system, but this situation induces the risk of water quality deterioration, disease occurrence. Moreover, even if water quality is maintained at optimal levels, it will be costly. In addition, with the increasing total yield, individual fish weight will dramatically decrease. Hence, producer should orient the production due to specific demands in market.

In my opinion, among all the different intensive culture systems, aquaponic system has the biggest potential. Although it is a modified re-circulating system, better efficiency in water reuse and reduced water discharge are the biggest advantages. Getting a second crop from the same production area is the biggest superiority. As it can be seen from the tilapia-lettuce economical analysis, although lettuce was considered to be the secondary product, it was compensated negative return of the tilapia production alone.

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