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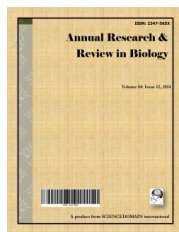
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Tilapia – An Excellent Candidate Species for World Aquaculture: A Review

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This work was carried out in collaboration between all authors. 'Author A' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. 'Author B' and 'Author C' managed the analyses of the study. 'Author C' managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aquaculture is currently playing, and will continue to play, a big part in boosting global fish production and in meeting the rising demand of fishery products. Capture fisheries production has levelled off and is no longer considered capable of sustaining the supply of fisheries products needed to meet the growing global demand. Tilapia is the common name for several species of cichlid fish inhabiting freshwater streams, ponds, rivers and lakes and less commonly in brackish water. Considered as an invasive species, tilapias are now of increasing importance in Aquaculture. Tilapia is the second most farmed fish world-wide and its production has quadrupled over the past decade because of its suitability for aquaculture, marketability and stable market prices. Native to

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Africa and Middle East, tilapias were introduced into over 90 countries for aquaculture and fisheries. Tilapia continued its rapid increase in global production. Recent production figures reported by various sources, our global production estimate for 2015 is 5,576,800 mt. Tilapias are now one of the most widely introduced fish globally that has clearly emerged as a very promising group in aquaculture.

Keywords: *Tilapia; aquaculture; cage; pond; raceway; biofloc*

1. INTRODUCTION

Aquaculture production has increased steadily in recent years and is the fastest growing food production sector and has become a valuable component of national development and poverty reduction plans in many areas of the world (Prabu & Santhiya, 2016). Aquaculture is one of the fastest growing sectors of the global livestock production (FAO, 2010). Approximately 40% of fish from aquaculture is originated from tilapia production (Scorvo-Filho et al., 2010). Aquaculture is currently playing, and will continue to play, a big part in boosting global fish production and in meeting the rising demand of fishery products.

Global inland waters capture production reached 11.6 million tonnes in 2012. Total farmed food fish production has increased from 50 % in 1980 to 63 % in 2012. In the world scenario, 15 countries produced 92.7 % of all farmed food fish in 2012. India, Bangladesh, Egypt, Myanmar and Brazil depend mainly on inland aquaculture of finfish while their potential for mariculture production of finfish remains largely untapped (FAO, 2012).

2. TILAPIA

Capture fisheries production has levelled off and is no longer considered capable of sustaining the supply of fisheries products needed to meet the growing global demand (Subasinghe et al., 2009). Aquaculture, especially of tilapias, has the potential to play a leading role in the fight against food insecurity, malnutrition, and poverty in Africa (Bene et al., 2005). Tilapia is the common name for several species of cichlid fish inhabiting freshwater streams, ponds, rivers and lakes and less commonly in brackish water. Considered as an invasive species, tilapias are now of increasing importance in Aquaculture. Tilapia is the second most farmed fish world-wide and its production has quadrupled over the past decade because of its suitability for aquaculture,

marketability and stable market prices (Wang et al., 2016).

The Nile tilapia, *Oreochromis niloticus* is considered as one of the most important species of fish in tropical and sub-tropical aquaculture (FAO, 2012). It serves as an important sources of animal protein and income throughout the world (Sosa et al., 2005). Tilapia can grow and reproduce facing a wide range of environmental conditions and tolerate stress induced by handling (Siddik et al., 2014). The mono-sex male population of tilapia are well recognized for increased production potential and low management requirements (El-Sayed, 2006). Today, tilapia has become the shining star of aquaculture and also popularly known as 'aquatic chicken' and the rate of consumption has increased across the globe (Fitzsimmons, 2005). Annual global production of cultured tilapia has increased continuously in recent years (Ahsan et al., 2013).

Native to Africa and Middle East, tilapias were introduced into some 90 countries for aquaculture and fisheries, through Pan-African transplants (Courtenay, 1997; Pullin et al., 1991) during the 20th century. Presently, a major part of the global tilapia production is outside the fish's native ranges. Tilapias are now grown commercially in almost 10 countries and have become one of the most important food fishes in the world. It is the second most important farmed fish species after the carps.

Unlike most other finfish species, tilapias are extremely hardy fish equally adaptable to a range of culture systems such as low density pond systems, cage culture systems, raceway systems and super-intensive culture systems under a wide range of environmental conditions. Due to its easiness of breeding and farming, low protein requirement and ability to assimilate plant protein, it became the species of interest among the resource poor especially in rural areas. This fish is also popular and prized in many Asian countries, including the Philippines and Indonesia, where local people adopted it as a

vital part of the national cuisine and as a native species of their country (Costa-Pierce and Rakocy, 1997). During the 1970's, this fish inspired the International Development Agencies to name it as "Aquatic Chicken" and twenty years later as "fish of the 1990's". Presently it is considered as "Food fish of the 21st Century" (Costa-Pierce and Rakocy, 2000; Ramnarine, 2005).

Asian countries are the major producers as well as the consumers of tilapia. World aquaculture production of *Oreochromis niloticus* alone presently stands at nearly 3.2 million tons with china being the major producer, contributing over one third of the total global production. Tilapias are also widely farmed in countries such as Egypt, Indonesia, Thailand, Philippines, Brazil, Bangladesh, Vietnam, Columbia and Malaysia. An international collaborative project to improve the genetic performance of farmed Nile tilapia (*Oreochromis niloticus*) was initiated at the Bureau of Fisheries and Aquatic Resources/Freshwater Aquaculture Center (BFAR/FAC) facilities in Muñoz, Philippines in 1988 (Gjedrem, 2012; Pullin et al., 1991).

3. COMMERCIALLY IMPORTANT SPECIES OF TILAPIA

Thys (1968) described 77 species (besides a number of sub-species) of tilapia, and Jhingran & Gopalakrishnan (1974) listed 22 species that have been used in experimental or production scale fish culture. The major cultivable species of tilapia are *Oreochromis niloticus* (Nile tilapia), *Oreochromis mossambicus*, (Mozambique tilapia), *Oreochromis aureus* (Blue tilapia), *Oreochromis hornorum* (Zanzibar tilapia) and *Oreochromis* hybrids (Red tilapia). Nile tilapia is the predominant cultured species worldwide. More than 90 percent of all commercially farmed tilapia outside Africa are Nile tilapia. The hybrid "red" tilapia has also become increasingly popular for farming because of its similar appearance to the marine red snapper that gives it high market value. The original red tilapias were genetic mutants. Tilapia farming has gained its popularity in China, Bangladesh, Indonesia, Laos, Malaysia, Taiwan, Philippines and Vietnam. People do not treat it as exotic fish, instead regard as very important source of fish quality animal protein and income. The natural distribution of tilapia is restricted to Africa, Jordan, and Israel, where 112 species and subspecies of the genera *Oreochromis*,

Sarotherodon, and *Tilapia* have been identified (El-Sayed, 2006; McAndrew, 2000).

4. AQUACULTURE OF TILAPIA

The farming of tilapias especially *Oreochromis niloticus* (Nile tilapia) in its natural form is believed to have originated more than 4000 years ago from Egypt. From the borders of their native, this versatile group of fish has travelled far, reaching every continent except Antarctica. Tilapias are now being cultured all over the world and in fact they are more common in Asia than in their African home land (Costa-Pierce and Rakocy, 1997). Most of the tilapia-culture practices have been restricted to tropical and sub-tropical regions of the world (El-Sayed, 2002; Altun et al., 2006).

In 1978, Nile tilapia was introduced to China, which leads the world in tilapia production and consistently produced more than half of the global production in every year from 1992 to 2003. The uncontrolled breeding of tilapia in ponds, which led to excessive recruitment, stunting and a low percentage of marketable-sized fish, dampened the initial enthusiasm for tilapia as a food fish. The development of hormonal sex-reversal techniques in the 1970s represented a major breakthrough that resulted in the production of male monosex populations to be raised to uniform, marketable sizes. Historically and from a social standpoint, the most important use of tilapia has been production for home consumption, with millions of small-scale fish farmers in more than 100 countries supplementing their diets with tilapia (Fitzsimmons, 2006).

In monosex culture, males are preferred because they have a faster growth rate than females. In addition, research on nutrition and culture systems, along with market development and processing advances, led to rapid expansion of the industry in the mid-1980s. Several species of tilapia are cultured commercially, but Nile tilapia *Oreochromis niloticus* the predominant cultured species worldwide (FAO, 2012).

5. PREFERENCE OF TILAPIA FOR AQUACULTURE

Tilapia is the second most farmed fish in the world after carps. The Global market for tilapia is growing at the rate of 10 – 12 % per year. More commonly, fresh tilapia also is provided for sale

either at the farm gate or in local markets. However, tilapias have grown in importance from being just a low-cost, high-protein food fish ("aquatic chicken" (Pullin, 1985)) employed by development agencies to feed the poor in the world's rural areas, to a highly-domesticated "livestock" with annual sales amounting to over \$2 billion globally (FAO, 2010; Fitzsimmons, 2006). The major reasons for its popularity among aqua farmers are listed below:

- ✓ Feeding habits (Herbivore / Omnivore, Low trophic level feeder)
- ✓ Algae, bacteria and detritus (bioflocs) are important food sources
- ✓ Prepared feeds are mostly grains and agriculture by-products
- ✓ Fast growth rate
- ✓ Easy adaptability to different conditions including high stocking densities
- ✓ Highly disease resistant and tolerant of poor water quality
- ✓ Antibiotics and chemicals are not needed for commercial farming
- ✓ Prolific breeders, easy breeding in captivity
- ✓ Fry do not pass through a planktonic phase, in its life cycle
- ✓ Fry consume formulated feed immediately after yolk-sac absorption, no live feed such as algae, rotifer and artemia is necessary
- ✓ Low production costs
- ✓ White flesh and meat suitable for a wide variety of value added forms
- ✓ Good market demand and readily acceptable by consumer
- ✓ In terms of economic importance, tilapia surpassed the salmonids in 2004, and they are expected to eventually equal the carps (Fitzsimmons, 2006). The tilapias have been referred to as the "most important global whitefish commodity" (Gjoen, 2001).

6. AQUACULTURE OF TILAPIA IN INDIA

Tilapias are one of the most widely introduced fish globally that has clearly emerged as a very promising group in aquaculture. *Oreochromis mossambicus* was the first tilapia species to be taken up for large scale aquaculture, followed by *Oreochromis niloticus*, *Oreochromis aureus* and *Tilapia rendalli*. Today *Oreochromis niloticus* contributes more than 80% of global tilapia production by aquaculture.

In India, *Oreochromis mossambicus* was introduced from Srilanka in 1952 and thereafter stocked in several reservoirs of southern India for

production enhancement (Sugunan, 1995). Tilapia now forms a part of fish fauna in the Godavari, Krishna, Cauvery, Yamuna and Ganga Rivers (Lakra et al., 2008).

Oreochromis niloticus was probably introduced unofficially in West Bengal in the late 1970s or early 1980s and in Andhra Pradesh during the late 80s. Through it was also popularized in the states of Kerala and Tamil Nadu, the overall experience with the species had not been encouraging as the fish turned out to be a prolific breeder, leading to over population and stunted growth in both aquaculture ponds and reservoirs. Tilapia is also reported to have displaced and virtually eliminated a number of species from some reservoirs of India. Subsequently, the fish was abandoned as candidate species for aquaculture in the country (Eknath et al., 2007).

Today *Oreochromis niloticus* is being cultured in some parts of the country mainly as a live feed for carnivorous fish such as seabass and forms a fishery in a few reservoirs and water bodies of Kerala, Tamil Nadu and Andhra Pradesh. Large quantities of small sized tilapia are also harvested and used as feed for seabass and mud crab aquaculture. Unlike *Oreochromis mossambicus*, growth performance of *Oreochromis niloticus* in the ponds and reservoirs of India is much better. Considering that *Oreochromis niloticus*, is the most widely cultured tilapia species globally and in view of the immense aquaculture possibilities in India and need for enhancing production in freshwater farming systems, the Ministry of Agriculture, Government of India formally issued guidelines for responsible farming of tilapia in India during December 2011.

7. GENETICALLY IMPROVED FARMED TILAPIA STRAIN

The GIFT strain was developed by International Centre for Living Aquatic Resources Management (ICLARM) through several generations of selection from base population involving 8 different strains of Nile tilapia *Oreochromis niloticus* (Eknath et al., 2007).

A ten year collaborative research project (1988 to 1997) widely known as 'Genetic Improvement of Farmed Tilapias (GIFT)' was conducted by the World Fish Center in cooperation with AKVAFORSK (The Institute of Aquaculture Research in Norway), and a number of national research institutions in the Philippines: the

National Freshwater Fisheries Technology Research Center of the Bureau of Fisheries and Aquatic Resources, the freshwater Aquaculture Center of the Central Luzon State University, and the Marine Science Institute of the University of the Philippines. The GIFT project demonstrated the potential of using selective breeding to genetically enhance the production of the GIFT strain was improved by more than 80 percent compared with the base population.

A complete diallel cross experiment with all eight strains was then carried out to study possible heterosis effects on growth performance in seven different farming environments (Bentsen et al., 1998). It was concluded that genotype by environment interactions and non-additive gene effects were of minor importance for growth performance. Consequently, it was decided to form a synthetic population composed of three and four way crossed individuals involving all eight founder strains, and genetic parameters for growth performance in seven different farming environments were estimated (Eknath et al., 2007).

GIFT technology includes a number of different and complementary tools to produce and test tilapia of known ancestry, to statistically analyse collected grow-out data, and finally, to estimate breeding values for each individual, based on the performance of the breeding candidates themselves and their relatives in the population. The GIFT project resulted in a faster-growing, synthetic aquaculture stock of Nile tilapia (Acosta and Gupta, 2010; ADB, 2004; Yosef, 2009) that has later been an important genetic source for a variety of public and private genetic improvement and/or dissemination programs (Eknath and Hulata, 2009; Ponzoni et al., 2010).

Aquaculture must grow rapidly as an alternative to the declining capture fisheries in the world. Genetically improved stock, such as the GIFT Strain, has an important role to play in increasing aquaculture production in developing countries. However, in some cases, the introduction of already improved strains may not be possible or desirable due to health or bio-diversity considerations. In such cases it is important that, as an alternative, the technology for genetic enhancement of fish be transferred and applied to native species.

Several genetic techniques (e.g. selective breeding, cross-breeding, chromosome manipulation, YY – male technology) are

available to enhance the productivity of aquaculture species, including tilapias. However, with the exception of selective breeding, these technologies only result in a once-off gain, and not in continued improvement. A continuous improvement of relevant traits requires a well-designed selective breeding program where the pedigree of brood fish is monitored to increase the accuracy of selection and to restrict inbreeding.

8. TILAPIA CULTURE SYSTEMS

Tilapia farming ranges from a rural subsistence (extensive, low input practices, non-commercial and for household consumption) to a largescale (capital intensive, commercial purpose and market driven) level, depending on the intensity of management employed. The following provide the details of the culture practices used globally.

8.1 Ponds

Most of the pond-based tilapia farmers in Bangladesh, China, Taiwan, Thailand and Vietnam use the polyculture system while in the Philippines, most farmers grow tilapias under the monoculture system. Culture methods followed in these countries vary depending on nature of farmland and farmers' capacity to invest. Pond culture of tilapia is conducted with a variety of inputs such as agricultural by-products (brans, oil cakes, vegetation and manures), inorganic fertilizers and feed. Annual fish yields using tilapia in polyculture with carps, high levels of agricultural by-products and good stock management can reach or exceed 5 tonnes/ha. In monoculture tilapia systems, animal manures provide nutrients that stimulate the growth of protein-rich phytoplankton, which is consumed by filter feeding Nile tilapia. The nutrient content of manures varies. Water 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. Therefore, a combination of manures with inorganic fertilizers is used in low-input production systems. In Thailand, applying chicken manure weekly at 200-250 kg DM (dry matter)/ha and supplementing it with urea and triple super phosphate (TSP) at 28 kg N/ha/week and 7 kg P/ha/week produces a net harvest 3.4-4.5 tonnes/ha in 150 days at a stocking rate of 3 fish/m² or an extrapolated net annual yield of 8-11 tonnes/ha.



Fig. 1. Pond culture of tilapia

8.2 Cages

The culture of Nile tilapia at high densities in floating cages is practiced in large lakes and reservoirs of several countries including China, Indonesia, Mexico, Honduras, Colombia, and Brazil. Mesh size has a significant impact on production and should be 1.9 cm or greater to maintain free circulation of water. Cage culture offers several important advantages. The breeding cycle of tilapia is disrupted in cages, and therefore mixed-sex populations can be reared in cages without the problems of recruitment and stunting. Eggs fall through the cage bottom or do not develop if they are fertilized. Other advantages include:

- ✓ Use of water bodies that cannot be drained or seined and would otherwise not be suitable for aquaculture.
- ✓ Flexibility of management with multiple production units.
- ✓ Ease and low cost of harvesting.
- ✓ Close observation of fish feeding response and health.
- ✓ Relatively low capital investment compared to other culture techniques.

In Asia, the Philippines was the pioneer for cage culture in lakes and reservoirs in the region and practices semi intensive and intensive farming (Guerrero, 2002). It was reported that, the country's cages in 2000 ha of

water produced a total of 33,067mt of *O. niloticus*. The average yield of 540 kg/ 100m² cage is attained with *O. niloticus* (mean weight of 175g each) after 5 months of rearing fingerlings.

8.3 Raceways and Tanks

Tanks and raceways can only be a good alternative to pond or cage culture if sufficient water or land is not available and economics are favourable. Unlike ponds, it is easier to manage the stocks and exert a relatively high degree of environmental control over water quality parameters. However, tank and raceway culture requires higher investment due to increased construction and production costs (complete commercial diet, aeration, recirculating system). The farming of tilapias in tanks/raceways also needs close and constant attention due to higher risk of major fish mortality caused by disease outbreak and mechanical or electrical failure.

In Asia, intensive culture of tilapias in concrete tanks is practiced in Taiwan, Malaysia and Philippines. Taiwan is the pioneer in the region for the intensive culture of tilapia in concrete tanks and produces over 50,000 tons annually, most operations being small to medium level operations (Liao and Chin-Wei 2001). Red tilapias are cultured in 100 m² octagonal tanks with water change and aeration, and with fish weighing 100-200g and densities of 50 -100/m². With 3-4 times of feeding per day using

commercial feeds and automatic feeders, yields of 3-4mt/tank/cycle of 3- 4 months are obtained with fish weighing 600g on the average, survival of 90% or higher and feed conversions of 1.2-1.4 (Guerrero 2002). Although raceways/tank culture of tilapias is not a common practice in Africa, it is also used in some areas.

The maximum tilapia density in raceways ranges from 160-185 kg/m³, and maximum loading ranges from 1.2-1.5 kg/litre/min. A common production level in raceways is 10 kg/m³/month, as water supplies are often insufficient to attain maximum rates. Production levels are considerably lower in tanks with limited water exchange, but water use efficiency is much higher in these systems.

9. BIOFLOC TECHNOLOGY – AN EMERGING TREND IN TILAPIA CULTURE

In intensive aquaculture business, the highest production cost goes to feeding the organisms, further around 60% of it is wasted by the organisms, which causes phosphorus, carbon, nitrogen to prevail in water as suspended matter or dissolved chemicals and are expelled from the system by gasification or water change polluting other natural water bodies and near-by soils producing economic losses to producers (Gutierrez-Wing & Malone, 2006). To reduce the environmental damages caused by aquaculture,

the alternative technology available is to optimize production with the usage of the “Biofloc” Technology (BFT).

Biofloc technology is a technique of enhancing water quality through the addition of extra carbon to the aquaculture system, through an external carbon source or elevated carbon content of the feed (Hargreaves, 2006). Biofloc technology is a novel farming technique that efficiently manages water quality parameters in aquaculture through balancing carbon and nitrogen in the system. Currently, biofloc technology has received considerable attention because of its potential to generate high production, feed protein recycling, water quality management and a possible alternative measure for disease control (Crab et al., 2007; Avnimelech, 2009).

With almost seven billion people on earth, the demand for aquatic food carries on to increase and hence, expansion and intensification of aquaculture production are highly required. The prime goal of aquaculture expansion must be to produce more aquaculture products without significantly increasing the usage of the basic natural resources of water and land (Avnimelech, 2009). The second goal is to develop sustainable aquaculture systems that will not damage the environment (Naylor et al., 2000). The third goal is to build up systems providing an equitable cost/benefit ratio to heterotrophic bacteria occurs much more rapidly because the growth rate and



Fig. 2. Cage culture of tilapia



Fig. 3. Tilapia culture in raceways

microbial biomass yield per unit substrate of heterotrophs are a factor 10 higher than that of nitrifying bacteria (Hargreaves, 2006). The microbial biomass yield per unit substrate of heterotrophic bacteria is about 0.5 g biomass C/g substrate C used (Eding et al., 2006).

Suspended growth in ponds consists of phytoplankton, bacteria, aggregates of living and dead particulate organic matter, and grazers of the bacteria (Hargreaves, 2006). Typical flocs are irregular by shape, have a broad distribution of particle size, are fine, easily compressible, highly porous (up to more than 99% porosity) and are permeable to fluids (Chu and Lee, 2004).

9.1 The use of Bioflocs as a Feed for Aquaculture Species

In addition to the growing demand for seafood for human consumption, the demand for aquatic products used by the industrial sector for conversion into fishmeal and fish oil products also increases (Peron et al., 2010). Fishmeal and fish oil are used as feed for other human food supply systems, such as poultry, pigs and aquaculture. Hitherto, part of the aquaculture production relies on wild fish harvests, as fishmeal and fish oil are essential elements of the diet of many aquaculture species, both carnivorous and herbivorous fish and shrimp. About 5–6 million tonnes of low-value/trash fish are used as direct feed in aquaculture worldwide either provided without processing or as part of

farm-made feeds (FAO, 2009). FAO (2009) reported that the total amount of fishmeal and fish oil used in aquafeeds is estimated to have grown more than threefold between 1992 and 2006, from 0.96 million tonnes to 3.06 million tonnes and from 0.23 million tonnes to 0.78 million tonnes, respectively. For the 10 types of fish most regularly farmed, a mean of 1.9 kg of wild fish is required for every kilogram of fish produced (Naylor et al., 2000). In terms of fishmeal, many intensive and semi-intensive aquaculture systems use 2 to 5 times more fish protein to feed the farmed species than is supplied by the farmed product (Naylor et al., 2000). Therefore, research in recent times has focused on the development of feed substitution strategies with a minimal supply of fishmeal and fish oil, which are then replaced by alternative and cheaper sources of protein such as plant proteins. In contrast to intensive and semi-intensive systems, extensive and traditional systems already use little or no fishmeal, and farmers often supply nutrient-rich materials to the water to enhance growth of algae and other indigenous organisms on which the fish can feed (Naylor et al., 2000). This inspired researchers to develop the biofloc technology, which is also applicable to intensive and semi-intensive systems. With biofloc technology, where nitrogenous waste generated by the cultivated organisms is converted into bacterial biomass (containing protein), in situ feed production is stimulated through the addition of an external carbon source (Schneider et al., 2005).

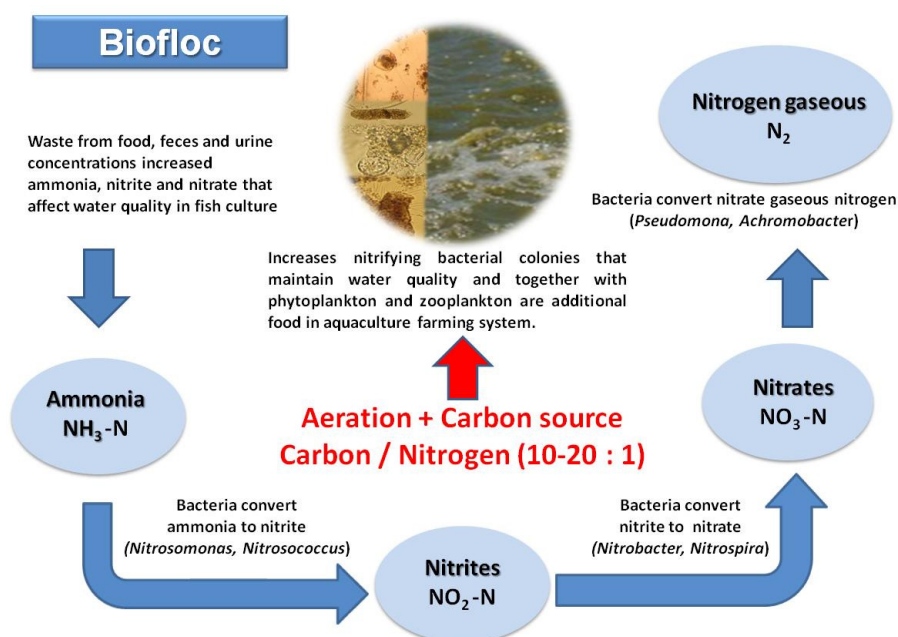


Fig. 4. The biofloc technology

Although bioflocs show an adequate protein, lipid, carbohydrate and ash content for use as an aquaculture feed (Crab et al., 2010), more research is needed on their amino acid and fatty acid composition. Now, fishmeal and fish oil supply essential amino acids (such as lysine and methionine) that are deficient in plant proteins and fatty acids (eicosapentanoic acid and docosahexanoic acid) not found in vegetable oils (Naylor et al., 2000). Herbivorous, omnivorous and carnivorous finfish all necessitate about the same amount of dietary protein per unit weight, but herbivorous and omnivorous species utilize plant-based proteins and oils better and they require minimal quantities of fishmeal to supply essential amino acids (Naylor et al., 2000). However, compound feeds for omnivorous fish often exceed required levels (Naylor et al., 2000). On the other hand, lowering the input of wild fish required for production of farmed carnivorous fish seems not feasible at this time (Naylor et al., 2000). Concomitantly, more research is needed regarding feed replacement strategies such as using vegetable oils, meat byproducts and also biofloc technology. With biofloc technology, one also needs to consider that the choice of cultivated species should take into account their capability of dealing with high suspended solid concentrations, since this negatively affects certain fish species.

Another important factor that is essential for the growth and survival of aquaculture species are

vitamins. Crab (2010) measured vitamin C concentrations in bioflocs ranging from 0 to 54 $\mu\text{g/g}$ dry matter. These values are below the required concentration for fish and shrimp. Besides vitamin C, other vitamins such as thiamine, riboflavin, pyridoxine, pantothenic acid, nicotinic acid, biotin, folic acid, vitamin B12, inositol, choline, vitamin A, vitamin D3, vitamin E and vitamin K, are usually not sufficiently synthesized by the cultured organism either and need to be supplied through the feed. Hence, it needs to be established to what extent bioflocs can contribute to the supply of these essential nutrients. Several studies were performed on the use of bioflocs as an in situ produced feed and they indicate that bioflocs can be taken up by aquaculture species and uptake depends on the species and feeding traits, animal size, floc size and floc density (Avnimelech, 2009; Crab, 2010; Crab et al., 2009). The giant freshwater prawn (*Macrobrachium rosenbergii*), white leg shrimp (*Litopenaeus vannamei*) and tilapia (*Oreochromis niloticus* \times *Oreochromis aureus*) were all able to take up bioflocs and profit from this additional protein source. This indicates that biofloc technology is applicable to both freshwater and seawater systems, both to control water quality and to produce as an additional feed source in situ. The potential feed gain of the application of biofloc technology is estimated to be in the order of 10–20% (De Schryver et al., 2008). With this, production costs will decline considerably since food represents 40–50% of

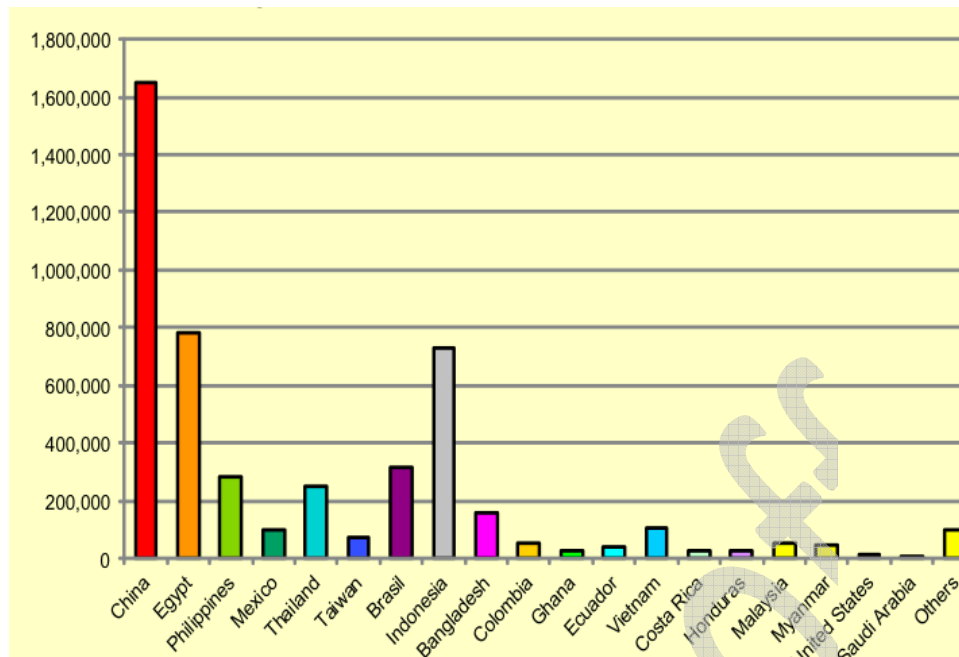


Fig. 5. World Tilapia production in 2015 (Fitzsimmons, 2016)

the total production costs (Craig and Helfrich, 2002).

10. STATUS OF WORLD TILAPIA PRODUCTION

Tilapia continued its rapid increase in global production through into 2015. Indonesia in particular reported a large increase in production. China held relatively steady after low prices held back production in late 2014 and early 2015. In 2014 and 2015 additional expansion with more farms and more productivity in Bangladesh, Mexico, Egypt, and Brasil. With recent production figures reported by various sources, our global production estimate for 2015 is 5,576,800 mt. China continued its position as the single largest producer (1,800,000 mt in 2015). China's exports to the US slowed in 2015, but increased significantly to sub-Saharan Africa and to the Middle Eastern Gulf States. Indonesia moved up to the second biggest producer with over 1,100,000 mt of production. Egypt dropped to the third biggest producer of tilapia in the world, even while increasing production to 800,000 mt in 2015. Indonesia's exports did not increase that much but domestic demand grew significantly. Vietnam increased its production significantly (150,000 mt), much of the growth based on a mix of cage culture, pond production and polyculture systems with marine shrimp to reduce virulence of the AHPNS, White Spot and

various parasites. The ban of American and European seafoods into Russia, led to an increase of exports of tilapia and Pangasius from Vietnam to Russia. Thailand, Myanmar, and the Philippines consumed virtually all the tilapia grown in their countries. Bangladesh continued to increase its production at a tremendous rate. 2015 estimate is for more than 250,000 mt in Bangladesh. Ecuador is the only country expecting production decreases as some tilapia farms have been converted to shrimp to take advantage of the increased shrimp prices. Global prices and demand have been remarkably smooth with only a slight decrease for a few months in late 2014 and early 2015 with large supplies coming from China. As production slacked from China, prices firmed again as demand had increased with the low prices. The diversity of production locations and methods has smoothed supplies and prices as more and more consumers take advantage of the high quality and consistent supply (Fitzsimmons, 2016).

11. DISEASES AND CONTROL MEASURES

Diseases can often be avoided by maintaining a high quality environment and reducing handling stress. The major disease problems affecting Nile tilapia are included in the table below (FAO, 2012).

Table. 1. Please insert caption

Disease	Agent	Type	Syndrome	Measures
Motile Aeromonas Septicaemia (MAS)	<i>Aeromonas hydrophila</i> & related species	Bacteria	Loss of equilibrium; lethargic swimming; gasping at surface; haemorrhaged or inflamed fins & skin; bulging eyes; opaque corneas; swollen abdomen containing cloudy or bloody fluid; chronic with low daily mortality	KMnO ₄ at 2-4 mg/litre indefinite immersion or 4-10 mg/litre for 1 hour; antibiotics (need 'extra-label use permit' in the USA), e.g. Terramycin® in feed at 50 mg/kg fish/d for 12-14 d, 21 d withdrawal
Vibriosis	<i>Vibrio anguillarum</i> & other species	Bacteria	Same as MAS; caused by stress & poor water quality	Antibiotic in feed
Columnaris	<i>Flavobacterium columnare</i>	Bacterium	Frayed fins &/or irregular whitish to grey patches on skin &/or fins; pale, necrotic lesions on gills	KMnO ₄ as with MAS; indefinite immersion with CuSO ₄ at 0.5-3 mg/litre, depending on alkalinity
Edwardsiellosis	<i>Edwardsiella tarda</i>	Bacterium	Few external symptoms; bloody fluid in body cavity; pale, mottled liver; swollen, dark red spleen; swollen, soft kidney	Antibiotic in feed
Streptococcosis	<i>Streptococcus iniae</i> & <i>Enterococcus</i> spp.	Bacteria	Lethargic, erratic swimming; dark skin pigmentation; exophthalmia with opacity & haemorrhage in eye; abdominal distension; diffused haemorrhaging in operculum, around mouth, anus & base of fins; enlarged, nearly black spleen; high mortality.	Antibiotic in feed, e.g. Erythromycin at 50 mg/kg fish/d for 12 d (requires 'extra-label use' permit in the USA)
Saprolegniosis	<i>Saprolegnia parasitica</i>	Fungus	Lethargic swimming; white, grey or brown colonies that resemble tufts of cotton; open lesions in muscle	KMnO ₄ or CuSO ₄ treatments; use 1 mg/litre of CuSO ₄ for every 100 mg/litre alkalinity up to 3.0 mg/litre CuSO ₄ ; formalin at 25 mg/litre indefinite immersion or 150 mg/litre for 1 h
Ciliates	<i>Ichthyophthirius multifiliis</i> ; <i>Trichodina</i> & others	Protozoan parasite	Occurs on gills or skin	KMnO ₄ , CuSO ₄ or formalin treatments
Monogenetic trematodes	<i>Dactylogyrus</i> spp.; <i>Gyrodactylus</i> spp.	Protozoan parasite	Occurs on body surface, fins or gills	Same as for ciliates

12. CONCLUSION

Till a few past years, most of tilapia production was consumed locally, with Africa and Asia as developing countries. Now a day, there has been a growing acceptance and consumption of tilapias in non-traditional countries such as USA, Canada, Europe, Central and South America. Only USA it was reported that importation increased to about 75,000mt (whole fish equivalent), supplying nearly 90% of the country's demand. In view of the growing demand of this commodity, tilapia farming will persist to be an important source of animal protein, foreign exchange and employment opportunities in several countries. Ferdouse (2001) indicated that whether the tilapias that are being produced are for export or for domestic consumption, the quality of the fish and convenience are important factors that will influence the consumer demand, mostly in urban market in Southeast Asia. She claimed that in the well-heeled urban markets in this region (Hong Kong, Malaysia, Singapore and Thailand), good quality fish (without any foul or muddy odour) and expediency food (e.g. fish prepared into skinless fillets) will prolong to assists in tilapia sales for domestic consumption through retail outlets such as supermarkets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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