Review Article

Recent trends on Tilapia Cultivation and Its Major Socioeconomic Impact among Some Developing Nations: A Review

ABSTRACT

Tilapia cultivation has been found to be an effective tool for many developing countries for socio-economic development by addressing some important issues like food-security and employment generation. Adoption of tilapia cultivation has increased over the decades because of easy management practice and versatile farming technologies have been observed worldwide. Tilapia gain popularity because of their excellent breeding capabilities, ~~excellent~~ flesh quality, high growth rate, disease resistance and survival capabilities under different farming systems and environmental conditions. Such features boosting up rapid growth of tilapia producing industries in an impactful way, by involving poor and non-poor farming communities in some of the developing countries of Asian, African and South American continents. However, some problems still exists with cultivation of different tilapia varieties; such as the inadequate availability of quality fry, deterioration in seed quality, limited technical knowledge among farming communities and poor marketing strategies especially in some of these developing countries ~~also~~ depriving its commercial success to some extent. This review ~~should help us to find out~~ present scenario regarding potentialities and difficulties of commercial adaptation of Tilapia cultivation under socio-economically constrained conditions.

Keywords: species varieties; cultivation; production; developing nations; income generation.

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1. Introduction

Aquaculture has been consider to be an important tool to boost up economic and nutritional status globally and now considered as one of the fastest growing food production sector with an export value of 164.1 USD billion in 2018; playing an important role in nation development and poverty reduction globally [1]. Being considered as potential fish, Tilapia play a leading role in addressing malnutrition, food security and income generation from aquaculture especially for developing countries [2]. It is also considered to be the most productive food fish with great aquaculture potentials for about 125 numbers of tropical and subtropical countries because of its fast growth under different environmental conditions and production under different culture systems [3]. Origin of Tilapia has come from Middle Eastern and African region, where about 77 species available under Genus *Coptodon, Sarotherodon*, *Tilapia* and *Oreochromis* of Chichlidae family. As per FAO's prediction, global production of tilapia going to increase twice within 2030 in comparison to its production value of 2010, which making it one of the front liner fish for future aquaculture development [4]. Nile Tilapia (*Oreochormis niloticus*) is considered to be the most important farmed tilapia globally with significant production increment annually, presently it contributes about 75% of the total tilapia production and 8.3% (4525.4 thousand tonnes) among total aquaculture production in 2018 [1, 5, 6]. In 2018, Tilapia secured second position globally among finfish in terms of global production, the production value reached about 6.03 million tonnes where about 75.61% global production come combinedly from China (26.93%), Indonesia (20.27%), Egypt (17.43%), Bangladesh (5.72%) and Brazil (5.26%) [1,6]. Due to limited capacity of growth, survival and reproduction of *O. niloticus* in saline water; its cultivation mainly restricted in freshwater condition [5,7,8]. Depending on different

environmental conditions like cold or high salinity, researcher and farmers also giving efforts either to establish genetically improved *O. niloticus* or standardize cultivation technique of some alternative varieties of *O. niloticus*, such as cultivation of *O. aureus* for colder regions, Red Tilapia hybrids (*Oreochormis spp.*), *O. spilurus* and -*Tilapia guineensis* (Dumeril) and for brackish water regions around the world gaining importance [9,10].

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Last three decades global adoption of Tilapia cultivation and production increased rapidly because of easy farming technique and readily available market. Tilapia farming technologies ranges from rural extensive and semi-intensive pond based practice with low input cost to intensive commercial scale. To manage hungers and requirement of dietary protein tilapia found to be the ultimate fish to ensure food security in several developing countries of Asia, African and Latin America [3, 6, 11, 12]. Various models have been adopted globally on commercial level for productivity enhancement of Tilapia under pond, tanks and reservoirs by maintaining high stocking densities under cages, raceways, re-circulatory and bio-floc systems. Due to richness of protein and minerals Tilapia considered to be an affordable and healthy food item for human consumption especially for developing countries and continuous efforts are also being made worldwide to improve its nutritional value [13].

Researchers found that uncontrolled reproduction of Tilapia in grow-out ponds creates major draw backs during promoting its cultivation in initial days, which mainly hamper the pathway towards sustainable aquaculture development. Several technological attempts are been made to control such unwanted situation, among which cultivation of monosex (only male) Tilapia showed promising results, by adopting several types of production techniques like manual separation of sexes, environmental manipulation, hybridization, hormonal treatments

and genetic manipulation. However, in recent day's aqua-culturists facing difficulties regarding cultivation of Tilapia due to disease and environmental pollution causing factors; as selective breeding, genetic manipulation and other stock improvement related programmes mainly focused towards productivity enhancement and growth performance [14]. Such poor management and genetic erosion made modern varieties of Tilapia genetically inferior in comparison to wild varieties [15]. In recent days during cultivation of such genetically inferior varieties, *Streptococcus* sp. infection found to be a primary cause of economic losses to the aqua-culturists of different countries form Asian, African and American continents [16, 17, 18; 19; 20] Another important issue related to Tilapia cultivation is huge requirement of supplementary feed which not only making the cultivation practice expensive but also in monoculture system huge nutrient loss observed, as water soluble feed nutrients remains unutilized, Such condition creates an unfavorable water quality which required to be address during cultivation to avoid environmental stress and disease outbreak [14, 21]. To combat against such major issues; scientists now focusing towards finding solution through genetic improvements, immunological measures and polyculture of Tilapia with other teleosts and crustaceans for better environmental sustainability and profitability of the farming community [5, 14, 22]. Besides these issues lack of attention given to marketing strategies of Tilapia leading to create a limited level of success on commercially scale especially in some developing countries [9, 23]. Present review mainly focusing on enumeration of the status Tilapia farming technologies, development and constrains, better understanding of which may help us to develop optimal management practices in a sustainable way.

2. Farmed tilapia production status globally

Tilapia cultivation achieved extraordinary growth which was significantly faster and higher than any other aquaculture industries since past two decades. Since 2005, tilapia became the second most farmed finfish when it reached a volume of 2 million tonnes; from 2014 this value exceeded over 5 million tonnes. In 2018, total production of Tilapia globally reached 6.03 million tonnes with an estimated value of 11.2 billion USD and still secured its second highest global position in terms of production and accounted 4.5% share of all globally cultured aquatic animals. In comparison to its global share regarding production of farmed finfish, exponential growth have been observed for tilapia industry from 4.85% in 1998 to 11.11% in 2018 and in terms of export value (USD), however highest peak of 5.2% observed in 2012. Since 1998, average annual production growth of farmed tilapia was found to be 10.1%, the most fastest growth rate have been found from 1999 to 2013 when it reached a level of 11.8%. Since 2014 the growth rate started to decline on about 5% average basis which became much lower in 2018 with only 1.6% level on global scale. Asia always serves as the leading producer of Tilapia since its global commercialization started, in 2018 the production value reached 4.2 million tonnes and the continent account 68.8% share of total world production, however in 1998 the value was 84.4% and significant reduction was primarily happed; because of production increment in Africa from 7.5% in 1998 to 21.8% in 2018 and in America from 8.1% in 1998 to 9.3% in 2018. Globally China remained the largest producer of farmed tilapia with a production value of 1.62 million tonnes in 2018. However, in terms of global production, share of China declined from 52.3% in 1998 to 26.9% in 2018. Since 1998 Indonesia and Egypt secured second and third respective positions in terms of production with a production value of 1.22 million tonnes and 1.05 million tonnes respectively in 2018. However, position of Thailand and

Philippines declined from top four to sixth and eight respective positions with global contribution of only 3.5% to 4.6% respectively in 2018. Promising growth have been observed in Bangladesh, whether it secured its position in fourth place with total production of 0.34 million tonnes of Tilapia in 2018 [1,6].

3. Global Types of Farmed Tilapia

Out of 77 different varieties only 23 species till now recorded in aquaculture and at present only ten farmed raised varieties of Tilapia gained commercially important status worldwide [6] Maximum efforts are being made worldwide towards cultivation of Nile Tilapia (*O. niloticus*), global production reached 4.53 million tonnes in 2018 making it the most cultured Tilapia globally. However, its global contribution decreased from 83.4% in 1998 to 75% in 2018 due to increasing cultivation of some other varieties [6]. *O. niloticus* have considered being the most popular species among the aqua-culturists, because of its excellent flesh quality, high resistance against muddy and turbid water condition, its high level of disease tolerance nature and flexibility for cultivation under various farming system and environmental condition. Scientist also found cultivation of male *O. niloticus* variety more profitable as they can grow almost twice faster than female due to superior physiological capabilities and aggressive feeding behavior [12]. Following which the production of tilapia without any species specific information (*Oreochormis sp.*) contributed about 17.1% in the total farmed tilapia production globally with a production quantity of 1,030,004 tonnes in 2018, the value shows sharp increment from 103,564 tonnes production in 1998. Global production of *O. niloticus* × *O. aureus* hybrid considered to be the third most important variety of farmed tilapia with total production of 406,048 tonnes in 2018 accounted for 6.7% of total farmed tilapia production worldwide.

However, according to [24]; data regarding *O. niloticus* production were inaccurately represented, as hybrid varieties have been cultivated in many countries. According to [25], *O. niloticus* has taken the lead as the principle species for cultivation worldwide, while *O. aureus* considered being the principle species utilized particularly for hybrid variety production. Significant increase of *O. mossambicus* and *O. aureus* production also observed globally from 40,652 tonnes and 844 tonnes in 1998 to 53,754 and 3,182 tonnes in 2018 respectively.

O. aureus showed feasibility for cultivation in colder regions with water temperature ranges between 8-9° C, and suitable for countries with rapid seasonal and climatic changes during cultivation. Due to its delayed sexual maturity, seasonal water body based cultivation becoming its additional advantage [9]. In case of *O. mossambicus* pure strains showing low potentialities for aquaculture purpose due to its lower growth rate for both male and female. Aqua-culturist avoid to introduce it in polyculture system because of its early maturation and prolific breeding nature hamper growth performances of other fish species and also enhance chances of growth rate reduction due to inbreeding depression [24]. However, due to its high salinity tolerance nature under brackish water condition, among some developing countries rural farmers continues its cultivation at extensive and low cost culture system [8, 27]. Hybridization of *O. mossambicus* has been suggested by several researches for better aquaculture prospects [9, 28, 29]. In Taiwan Hybridization of *O. mossambicus* × *O. niloticus* resulted to produce Red Tilapia hybrids, it has been considered to be the third generation of tilapias due to its uniquely red colouration [30]. Such advantageous phenotypical characteristics and salinity tolerance features made it a preferred fish specially for brackish water cultivation and alternative of some economically important marine fish like Red Snapper and Sea Bream

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[31]. Some recent evidences also showed that low input farming system also possible for Red Tilapia, showing potentialities for rural farmers as well [32].

Other important varieties of Tilapia includes *Oreochromis shiranus, Coptodon rendalli, Oreochromis macrochir*, *Oreochromis andersonii* and *Oreochromis tanganicae,* together accounted less than 1% share in terms total global farmed raised tilapia production in 2018 [6].

4. Socio-economic impact on developing countries

To alleviate poverty through industrialization an aquaculture based model now considered to be an effective tool through continuous modernization and up-gradation for the purpose of productivity enhancement and to provide the food security to the nation. Apart from its protein rich food value now aquaculture also considered to be a source of employment and an important component for rural development and livelihood generation [3, 11]. Recent development of Tilapia farming sector also got attention as an attractive investment activity for rural farmers of many developing countries. Egypt was the first country from where aquaculture has been started for about 4000 years ago by cultivating tilapia [11] and till date technological up-gradation continuously enhancing its productivity, profitability and sustainability. Although on global scale tilapia cultivation widely been reported especially for developing countries but few data available regarding its socio-economic impact especially on developing countries.

4.1. Egypt

In several African countries aquaculture serves as an important resource for livelihood generation, economic development and food security [33]. In 1957 the first modern commercial tilapia farm was built by the Egyptian government for earthen pond based

polyculture of Nile tilapia, Common Carp and Flathead Grey Mullet [34]. At present in Egypt, earthen pond based semi-intensive monoculture of sex reversed male *O. niloticus* is the most important farming system in the country. However, in some parts of the country semi-intensive polyculture of *O. niloticus* with *Mugil cephalus, Liza ramada Cyprinus carpio*; *Ctenopharyngodon idella*; *Hypophthalmichthys nobilis;* and *Hypophthalmichthys molitrix* are reared semi-intensively in a polyculture system in earthen ponds. Cage based Monosex Nile Tilapia cultivation industries showed outstanding growth in Egypt in last few decades in the Domiat (Damietta) and Rashid branches of the Nile River. As a result, cage-based Tilapia production increased from 32,000 tonnes in 2003 to 2,49,385 tonnes in 2012. However, cage culture in Egypt has been practised by the private sector exclusively, while pond based monoculture and polyculture systems have been adopted by commercial, urban and rural farmers. All leading Tilapia farming system appeared to be cost-effective and profitable in this country. However, Benefit Cost Ratio (BCR) ranged from 1.3 to 1.5 for polyculture system which was much lower than the BCR value of intensive commercial culture systems, because investment of private and government sectors was much higher for intensive cultivation. Here active involvement of family members from the age group of 21 to 60 years has been observed among Tilapia farming communities. Such kinds of attempts enhanced the dependence of family labours in fish farming instead of hiring external labours. As per [35] in Egypt full-time employment per 100 tonnes of fish produced from fish ponds was 13.8. Commercial tilapia production also found to greatly improve the livelihoods of the poor, mainly by generating employment opportunities through the value chain and by providing affordable high-quality edible animal protein [36, 37]. Tilapia contributed about 62% among the total aquaculture production value here and because

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of tilapia the annual per capita consumption of fish increased from 9.5 kg in 1995 to 19.1 kg in 2011 [11].

4.2. Ghana

In Ghana, cage and pond culture system have been adopted for tilapia production. Establishment of tilapia farm in Ghana found to be expensive and partially depended on foreign investment. Instead of pure variety, Ghana mainly rely on the improved strain (Akosombo) of *O. niloticus* developed by the Aquaculture Research and Development Centre with technical assistance from World Fish for cage culture purpose, however farmers continuously giving efforts for further improvement, in pond based cultivation system sex reversed or mix-sex *O. niloticus* both in monoculture and polyculture with *Clarias gariepinus*. Cage culture farming system accounted for over 95% of tilapia aquaculture production in Ghana [11]. WorldFish (2011) found fisheries production value in Ghana equal to nearly 20% of the country's agricultural GDP (Gross Domestic Product) and 7% of its total GDP and ranked sixth in overall fisheries dependency (combining nutritional, macroeconomic and employment dependence) and third on nutritional dependency in global point of view [38]. Fish is considered to be the prime source of dietary protein in Ghana, where tilapia serves the leading position, Asmah (2008) reported that about 90% household in this country consume tilapia on regular basis or occasionally, with a per capita consumption rate 9.0 to 20.5 kg per year[11]. Average demand of tilapia in this country was about 60,000-120,000 tonnes which again enhances its commercial importance in Ghana. Tilapia cultivation found to improve socio-economic and nutritional status of Ghana in an exponential way; however poor people cultivate tilapia for food security mainly, because intensification and commercialisation of tilapia was costly in Ghana [11]. Due

to huge expenditure for tilapia production, Ghana imported tilapia from Asian countries for so many years (e.g. China and Thailand) [11]. Fisheries sector in Ghana estimated to create employment opportunity for about 10% of total countries population, with active involvement of women farmers (almost 10% of total farming community) created an achievable socioeconomic change [11]. About 100000 numbers of people employed in fish farming activity in Ghana and majority of them utilize tilapia farming as an alternative income generation source. Most promising results reported at Ashanti region of Ghana, where both poor and non-poor farmers gained about 8% of total family income from Tilapia farming. But, still some major disadvantages like improper profit distribution among rich and poor, theft and vandalism along with non-availability of quality seed found to be major coexisting drawbacks of this country [11].

4.3. Nigeria

Tilapia aquaculture increased in Nigeria from about 1600 tonnes in 1999 to over 21000 tonnes in 2013 and considered to be the second most important aquaculture fish type after catfish with a share of about 7% of country's total aquaculture production. In sub-Saharan Africa Nigeria considered being the one of largest farmed tilapia producer after Uganda and Ghana. Here, mainly pond based Tilapia production system has been established in extensive and semi-intensive system from monoculture to polyculture with *Clarias* spp., *Heterobranchus* spp., *Cyprinus carpio* or *Heterotis niloticus* [11]. Recently efforts are made by government and private sectors to encourage tilapia farming; because of relatively high profitability and acceptance. Last few decades demand of Tilapia increased in the country and about 10000 tonnes of frozen Tilapia were imported into Nigeria in 2011. In Nigeria about 40% of dietary animal protein came

from fish and it has been considered to be the cheapest source of protein and preferred food for rural areas. Tilapia has contributed significantly to the livelihood needs and sustenance of many Nigerians in terms of employment and economic development. Jobs are created along the tilapia value chain, including construction of ponds, tanks or cages, production of feed, production of seed (wild collection or hatchery production), nursing and outgrowing, processing and value addition, marketing and sales, and so on. In Nigeria, more women are involved in tilapia processing, value addition and marketing than men, except for northern regions. While in the south, more than 70% of fish processors were women. Retail shops providing fresh, smoked or grilled Tilapia and stews or soup with Tilapia, have been served as a livelihood option for women here. There are some major factors that constrained the development of tilapia farming in the country include low input technology (extensive culture system), poor skills of farmers, unintended propagation in ponds hampering ideal yield and prices [11].

4.4. Uganda

In Uganda, tilapia is considered to be the most suitable farmed fish owing to its omnivorous feeding habits. Aquaculture production systems used in Uganda include earthen ponds, cages in reservoirs and tanks. The use of earthen ponds dominated production of Tilapia and because of cheaper operational cost. Cage culture system also showed rapid growth in commercial scale by targeting lakes, water reservoirs and dams [11]. Rapid growth of tilapia cultivation from 600 tonnes in 2000 to about 50000 tonnes in the early 2010, dominated by production *O. niloticus* and redbelly tilapia (*Tilapia zillii*) [11]. Fish is one of the most important animal protein sources in Uganda, with almost 30% dependency in terms of country's dietary protein. Tilapia is low in fat and calories and a source of fatty acids, which makes it an important meal for mothers and

growing children here. Due to increasing demand and growth of tilapia industry now Ugandan Government giving extra attention to establish regulatory and policy related frame works here to mitigate some important constrains faced by tilapia farmers, such as limited technical knowledge, high cost and availability of quality seed and feed [11].

4.5. Brazil

Among the Latin American countries in Brazil tilapia has been the largest aquaculture item, contributed to nearly half of the country's aquaculture production in 2017, the country also considered to be one of the fastest growing aquaculture powerhouse of Latin American continent with an average annual growth rate of 14% and regarding tilapia production it secure it position in fifth globally [1]. *Tilapia rendalli* was first introduced in Brazil since 1950s for reservoir based capture fisheries purpose. Since 1970s several other staring also introduced here, such as *O. niloticus*, *O. angolensis, O. aureus* and *O. urolepis hornorum*. In recent days, Brazil continuously giving efforts towards development of GIFT strains and monosex farming technology, to produce large size tilapia for better marketability. An *O. niloticus* strain from the Asian Institute of Technology (AIT) in Bangkok, Thailand, was first introduced in Brazil, known as Chitralada, had several favorable traits (e.g. better domesticated, more cold-resistant and higher-fillet yield) and therefore rapidly became widespread [1]. Since the late 1990s, a variety of GIFT strains have been introduced in Brazil by private hatcheries or research institutes, including GIFT, GIFT Supreme, GIFT Spring and GIFT Aquamérica. Nowadays, the GIFT strains and Chitralada have become the major tilapia species farmed in Brazil. Among the cultivation technologies semi-intensive and intensive cultivation of tilapia in pond and cage systems both in monoculture and polyculture mode have been adopted here. Tilapia also enhances per capita

fish consumption in Brazil which was recorded as 9.6 kg/year/capita in 2013. The entire aquaculture value chain in Brazil has created 3.5 million job opportunities, 1 percent of which are jobs in tilapia farming. Instead of huge domestic demand of cultivable tilapia Brazil still manage to enhance its export from 6 tonnes in 2002 to 315 tonnes in 2005; however it then declined gradually to 23 tonnes in 2011. Due to high profitability tilapia farming managed to attract Brazilians attention and as a result country's tilapia aquaculture production has increased more than four times from the early 2000s to the mid-2010s [1]. Now tilapia also considered to be the high quality, economical protein source among rural and urban Barzilians. Huge expansion of tilapia industries has created noticeable effects on regional development by creating employment opportunity which helps the country to mitigate some major issues of rural emigration and rural emptiness besides addressing malnutrition related issue. However, still more attention towards social dimensions of tilapia cultivation have been suggested, especially to develop a road map for developing value chain of tilapia farming in an economically viable, environmentally sustainable and socially responsible way [3].

4.6. Cambodia

In Cambodia, freshwater aquaculture reported to contributes about 160,000 metric tons in 2016 which was about 90% of national aquaculture production. It is dominated by snakehead (*Channa* spp.), which accounts for about 40,000 metric tons per year. In recent years tilapia culture spread within the country due to increasing demand for both Nile tilapia (*O. niloticus*) and Red Tilapia (*O. niloticus* × *O. mossambicus*), cultured in both pond and cages ranges from extensive pond based (yields 1.5-2 kg/m^2) to intensive cage and pond based (yields 38 kg/m^2) commercial farms. Marketing strategies also varies greatly as small scale farms mainly target

local retail market and large scale intensive farms mainly target wholesalers and creating promising livelihood generation opportunity for farmers of various categories. Since 2018, drastic change have been observed in Cambodian tilapia industry due to introduction of GIFT starin which was widely adopted by farmers. It has been predicted by WorldFish that production of GIFT may increase from 12000 mt in 2018 to 35000 by 2024, accounting over 70% of tilapia produced in the country. However, availability of quality seed is one of the main constrain found in Cambodia's tilapia industry and the adoption of GIFT monosex technology by farmers has been predicted to overcome such concerns [32].

5. Conclusion

A few years ago, tilapia mostly consumed locally but with recent technological developments especially genetic improvement enhances market value of tilapia and its global demand. Now countries, besides Africa and Asia greater part of other existing nations also started consuming different varieties of Tilapia. The worldwide escalating demand of Tilapia improve value chain of Tilapia business by direct or indirect employment of communities and creating opportunities for some countries to be benefited from foreign exchange. Due to possible production in low cost extensive condition tilapia consumption rate consciously increases among rural communities of developing countries and found to be one of the most effective tool to address food security and employment issues. Polyculture of tilapia with so many different types of fish species under various culture conditions creating opportunities for farmers to expand their tilapia business along with other high demand crops like carp, catfish, prawns and shrimp by utilizing similar water resources with betterment of environmental and economic viability. However, there are some constrains still exists hampering expansion of tilapia's

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industrialization on global scale and some key issues includes; non-availability of quality seed, deterioration of genetic quality, high operational cost in some countries for commercial scale production and lack of availability of proper marketing strategies.

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