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The Main Factors Affecting Growth Performance of *Oreochromis niloticus L.* (1758) in Aquaculture System

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Abstract

Aquaculture is a practice of cultivating aquatic animals and plants under artificial environmental conditions in controlled or semi-controlled conditions. It is one of the fastest food production sectors in the world due to high animal protein demand and, plays a significant role in contributing food security and reducing employment rate of the rising world population. Despite the enormous potential for aquaculture production in Ethiopia, it remains more potential than actual practice. This review is under taken with recent available articles to assess the main factors affecting growth performance of *Oreochromis niloticus* in aquaculture. The major factors affecting growth performance of *O. niloticus* in aquaculture are genetic variation, feeding rate and frequency, stocking density, feed composition and water quality. These factors can affect feed conversion ratio, weight gain, feeding efficiency, reproduction and health of *O. niloticus*. Water quality also influences feeding, growth, disease burdens, and survival rates. The most important water quality parameters in aquaculture are pH, temperature, ammonia, dissolved oxygen and salinity. For a better growth performance of *O. niloticus* in culture system, the feed should constitute protein, lipid, carbohydrate, vitamin and minerals with an optimum quantity. Generally, better growth performance of *O. niloticus* can be achieved in aquaculture through adjusting the optimum quantity of feed with adequate feeding rate and frequency, increase genetic variability, keeping biological density in a good proportion and monitoring of water quality in a regular manner.

Keywords: Nile tilapia; Growth performance; Stocking density; Aquaculture

Introduction

Aquaculture, also known as aqua farming, is the farming of aquatic animals and plants under controlled or semi-controlled environment [1]. Similarly, Li and Fu (2001) [2] and Asfaw and Abebe (2011) [3] also defined aquaculture as a form of agriculture that involves the propagation, cultivation, and marketing of aquatic plants and animals on land or water based system in a more-or less controlled environment. Aquaculture systems can be land-based or water-based and due to the nature of their site, they can be either flow-through or recirculating. System design and choice depend on production intensity (extensive, semi-intensive, intensive or super intensive); environmental conditions (water quality, temperature, oxygen) and on food requirements (carnivorous, omnivorous and herbivorous) of stocked fish [4, 5].

Aquaculture has sustained a global growth and can fill the shortage in aquatic food products due to decline in capture fisheries [6]. Fish has long been valued as a highly nutritious food source for humans. Increasing production capacity of aqua cultural resources through intensification seems to be the way forward to meet the ever increasing demand for fish. World human population increases dramatically and leads food insecurity. Therefore, aquaculture is an alternative method to increase food production for people in a reasonable cost, produce diversified food items and promote agro-industrial development.

Tilapia belongs to fresh water cichlid family and based on morphometric, meristic and genetic variation has three economically important genera. These are Tilapia, Oreochromis and Sarotherodon [7]. Tilapia is the second most important cultured fish species next to carp around the world [8]. Nile tilapia is one of the most common cultured fish species in tropical and subtropical fresh water aquaculture and accounted for 90% of the total tilapia and cichlid finfish production world-wide in 2014 [9]. It has been reported that tilapia is native to Africa, but has been introduced almost in all parts of the world [10]. Its adaptability to a wide range of environments has resulted in a rapid expansion of tilapia farming and introduction of these fish into many subtropical and temperate regions of the world [11].

Ofori reported that, Nile tilapia first gained popularity as an easily farmed fish that could supply cheap but high-quality animal protein and its mild flavor with few intra-muscular bones of flesh. Tilapias are a target for artisanal and commercial fisheries because of its good source of protein [12]. Even though, it is native to Africa, tilapia have been introduced around the globe and its farming is growing rapidly more in Asia because of their fast growth, ease breeding and accept a wide range of feeds including planktons from natural sources, high fecundity, high disease-resistance, tolerate to poor water quality and low dissolved oxygen levels. These fish have high reproductive and growth rates and are relatively disease free. Tilapia grows and reproduces in a wide range of environmental conditions and tolerates stress induced by handling [13]. The success of the culture methods applied for tilapia farming depend on various factors under a certain conditions such as feed quality, stocking density, genetic variation, environmental condition, feeding rate and feeding frequency [14]. The common problem for Nile tilapia in aquaculture systems are the reduction of growth rates due to environmental, biological as well as physiological factors [15]. The aim of this paper is to review and assess the major factors that affect the growth performance of *O. niloticus* in aquaculture system.

Aquaculture

World aquaculture: The global aquaculture industry has grown

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radically and developed as a major industry in the last half a century but the Corona virus Disease Pandemic (COVID-19) has affected the world, with severe impacts on the global economy and the food production industry and distribution sector, including aquaculture and fisheries. About 424 aquatic species are cultivated globally, benefiting millions through the provision of nutrition, food security and sustainable livelihood, and poverty reduction [16]. Economic and food security interest of global population push farmers to consider production systems with highest intensities that initiated the development of modern intensive aquaculture technologies which are able to use less water, provide highest return and minimize waste release to the Environment [4]. More than 120 million people throughout the world are estimated to depend on fish for all or part of their income [17]. Due to continuous increase in world's population, increasing demands for more proteins and the decline of production through capture fisheries, aquaculture production is increasing steadily worldwide [18].

World's tilapia production potential has augmented to increase dramatically and drastically with the passage of time [19]. The contribution of world aquaculture to global fish production reached 46.0% in 2018, up from 25.7% in 2000 [20]. The aquaculture industry, which accounted for 46% of the total production and 52% of fish for human consumption, is the fastest-growing food-producing sector now. World aquaculture production of farmed aquatic animals has been dominated by Asia, with an 89% share in the last two decades. Among major producing countries; China, India, Indonesia, Viet Nam, Bangladesh, Egypt, Norway and Chile have consolidated their share in world production over the past two decades.

According to FAO (2020), from the total fish production in 2016 (166.1 million metric tonnes), 76.5 million metric tonnes were from aquaculture and 89.6 million metric tonnes were produced from capture fisheries. Global fish production in 2017 was 172.7 million metric tonnes of which aquaculture accounted 79.5 million metric tonnes while capture fisheries was 93.1 million metric tonnes. In 2018, world total fish production reached to 178.5 million metric tonnes of which 82.1 and 96.4 million metric tonnes were produced from aquaculture and capture fisheries respectively as shown in Figure 1. Most of the production came from extensive /semi-intensive systems in developing countries, particularly Asia, rearing mostly organisms low on the feed chain such as omnivores and herbivores.

Aquaculture in africa: The African contribution to world aquaculture production is still insignificant (~ 2.7%) [21] and significantly increasing with larger-scale investments in Egypt, Nigeria, Uganda and Ghana producing substantial quantities of fish [22]. Total aquaculture production increased from 7.2 to 11.9 million tonnes from 2000 to 2017 shown in Figure 2 [20]. The growth of aquaculture production was due to the advent and intensification by the contribution of the private sector [23].

Most of the production (99%) is from the inland freshwater systems and is mostly dominated by the culture of indigenous and abundant species of tilapia and African catfish while mariculture only contributes approximately to 1% to the total production quantity, although it is an emerging and promising subsector [24,25]. New aquaculture production systems such as tanks and cages were introduced as well as the improvement of current production systems [26] and top aquaculture producers in Africa are Egypt, Nigeria, Uganda, Ghana, Tunisia, Kenya, Zambia, Madagascar, Malawi and South Africa. The aquaculture sector employs about 6.2 million people in Africa, with a large share of the employees being women that are engaged in large scale commercial farms [23]. The aquaculture sector, therefore, has the potential to significantly contribute to food security, reduce unemployment rates and economic development in Africa.

Aquaculture in ethiopia: Aquaculture activities in Ethiopia have started around 1970`s with establishing pond cultures for different indigenous and non-indigenous fish species for experimental purposes by the National Fisheries and Other Aquatic Resources Research Center [27]. Despite the potential of aquaculture to alleviate food insecurity and other economic issues, the production of aquaculture in Ethiopia is still insignificant which is rather potential than actual practice [28]. Zenebe Tadesse (2012) [29] has reported that even if there are enormous water resources and diversified agro-ecologies in the country, aquaculture is relatively new to Ethiopia and has been limited to stocking of water bodies with fingerlings. Growth performance of cultured fish is an important consideration in pond and other culture systems to increase the production of the farmed fish

Annual aquaculture production in Ethiopia during 2017 was 126 metric tonnes while capture fishery account 56,001 metrics tonnes and in 2018 the total aquaculture and capture fisheries were 165 and 57,166 metric tonnes respectively [20] (Figure 3). Fish production in Ethiopia both by capture and culture is dominated by tilapia which account for about 50% followed by African cat fish and common carp [30]. Domestic supply is fulfilled entirely by capture fisheries, and fishery resources are assessed as underexploited overall [31]. Fisheries contribute to food security in Ethiopia at a very low level and thus Ethiopia is not benefited from this sector. This shows that aquaculture sector is not get due attention in the society as well as at the government level. Researches should have been carried out on these

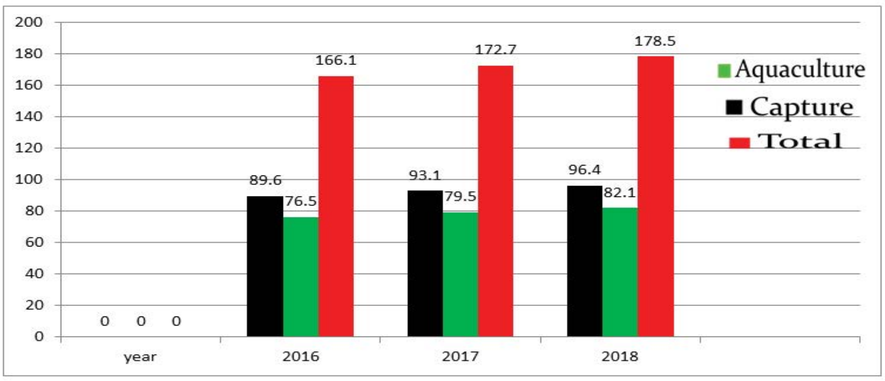

Figure 1: World fish production from both aquaculture and capture fisheries in million metric tonnes (FAO, 2020).

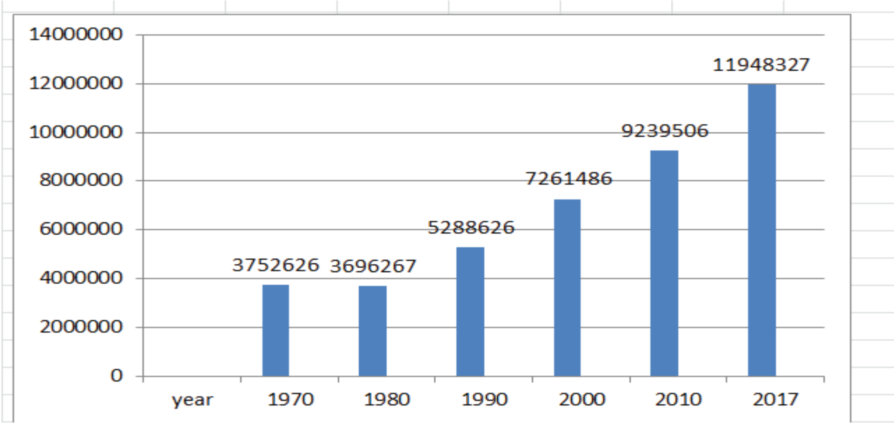

Figure 2: Africa fish production in metric tonnes (FAO, 2018).

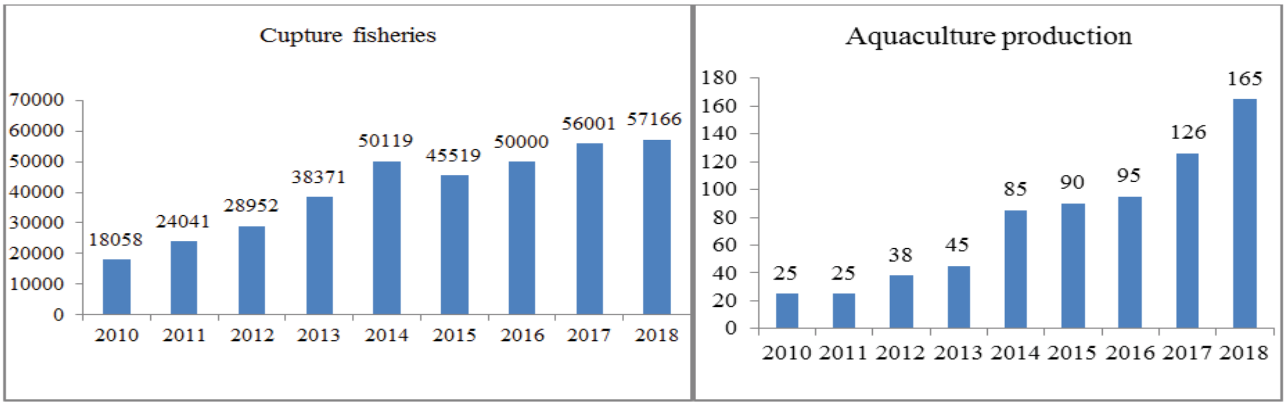

Figure 3: Ethiopia fish production in metric tonnes (FAO, 2018).

economically important fish species particularly tilapia. Aspects on growth performance including factors associated with growth has to be given importance.

Kassaye Balkew (2012) [32], Asfaw Alemayehu and Abebe Getahun (2011) [3] and Abelneh Yimer (2015) [33] have evaluated the growth performance of *O. niloticus* strains under different conditions from different water bodies of Ethiopia in pond culture system. *O. niloticus* is indigenous to the country which comprises the highest number in fish production from culture and captures fisheries and has high socio-economic demand. This might probably show the limitations in assessing those factors affecting growth experiments of the particular species as these studies cannot be sufficient for a country with large number of water bodies containing their respective *O. niloticus* strains.

Nile tilapia culture

Tilapia, a group of species in the family *Cichlidae*, is currently ranked second next to carps in global production and is likely to be the most important cultured fish in the 21st century [34]. Thus, tilapia and other cichlids totally contribute about 5.6% of total aquaculture production in the world [35]. Nile tilapia, locally known in Ethiopia by different names but most commonly it is called as 'Korosso'.

Tilapia production reports impressive growth, after salmon and shrimp, making it as one of the most successful aquaculture products entering in international trade. Tilapias are hardy and omnivorous, feeding at a low trophic level. This makes them relatively inexpensive to feed within extensive systems and suitable for farming under less optimal environmental conditions [36]. *Oreochromis niloticus* remains the farmed species because of its several advantages not only fast growth but also its tolerance to environmental changes and the advantages of several genetic improvements it has undergone and also Nile tilapia is the second most widely cultivated freshwater fish species worldwide and the most available species in the market [20].

The Nile tilapia is preferred due to its fast growth, efficient conversion of food, high fecundity, tolerance to a wide range of environmental conditions and good product quality [37]. Tilapia can tolerate a wider range of environmental conditions such as salinity, Dissolved Oxygen (DO), temperature, pH, and ammonia levels than other cultured freshwater fishes [38].

Growth performance of nile tilapia: Growth can be defined as change in magnitudes. The change can be in size (length or weight or both) and body compositions. Growth is a complex biological process affected by several factors such as physiological, behavioral, nutritional, genetic and environmental conditions. The genetic factor (indigenous factor) of the target fish, providing sufficient amount of balanced diets, feeding rate and feeding frequency, stocking density and optimum environmental conditions (exogenous factors) are important to achieve maximum growth of the cultured fish. Chakraborty (2011) [15] approved that sex, age and production system can affect the growth performance of Nile tilapia. They tested the growth rate in mono sex and mixed-sex tilapia fish in, flow-through, pen and pond systems. They found that, Mono sex tilapia showed significantly higher weight, length, Daily Weight Gain (DWG), specific growth rate and protein content than mixed-sex fish. Fish in Pond culture showed significantly higher weight, daily weight gain and protein content than fish in other three culture systems. This is due to easy management of pond culture system and not vulnerable to pollution compared to other culture systems.

Feed utilization efficiency of nile tilapia: *O. niloticus* is capable of using a wide range of food materials from tiny plankton (phytoplankton and zooplankton) to macrophytes but grows well on artificial feeds. In semi-intensive farming systems, supplementary feeds are needed as a supplement to natural fish food. At high stocking rate, the contribution of natural food decreases and more nutritionally complete feeds are needed. Nutritionally well-balanced diets are the most important requisites for better growth of *O. niloticus* [39].

Factors affecting growth of nile tilapia

Nile Tilapia can be cultured under extensive, semi-intensive and intensive pond culture systems. The major factors in Nile tilapia culture are nutrient composition of fish feed quality (nutritional composition), genetic variation, stocking density, feeding rate, feeding frequency and water quality such as temperature, dissolved oxygen, pH, salinity and ammonia [3]. The negative impact of low water quality and unavailability of quality feed prevalent in the culture of *O. niloticus* explain why constant monitoring is necessary. Therefore, monitoring of water quality parameters and feeding of well-balanced diet in aquaculture systems are important as they affect the physiological processes of fish. Nutrition is one of the most important factors influencing performance of cultured fish, and influenced by factors such as behavior of fish, stocking density, quality of feed, daily ration, feeding frequency and water temperature.

Feed constitutes a major factor in intensive rearing of fishes. This is because the growth of fish depends strongly on the quality of feeds provided. In tilapia, it has been evident from several studies [40,41] that feeding rate and feeding frequency can influence the production performance of tilapia. Feeding rate (allowance) in practical feeding of fish involves either feeding to satiation or feeding with restricted ration. A study with Nile tilapia showed that best growth can be achieved near satiation feeding rate [40]. Fish diet should contain nutrients and energy sources which are essential for maintaining normal growth and health. A well prepared and carefully formulated fish feed plays a significant role in fish culture.

Stocking density: Stocking density is considered as another important factor affecting fish growth, feed utilization and gross fish yield. Stocking density is the amount of fish stocked into a system [42]. High stocking density is a potential source of stress that may limit growth and be harmful for fish welfare when physiological and spatial needs are not adequately met with [43]. Stoking density directly influence survival, growth, behavior, water quality and feeding. Fish culture on a small-scale basis has often failed due to inadequate knowledge regarding on vital biological factors like stocking density of fish [44].

Mridha (2014) [45] examined the effects of stocking density on the growth and production of all-male *O. niloticus* in a rain-fed rice-fish ecosystem for a period of 120 days. Fish were stocked at the rate of 4000, 5000, and 6000 ha^{-1} in three treatments. Significantly, higher growth was observed in first treatment as compared to the second treatment and third treatments. Specific growth rate ranged from 1.26 to 1.51, in the first treatment producing the highest survival.

Mainar (2011) [46] have tested the viability of the use of low-volume cages ($1m^{-3}$) placed in farm ponds and evaluated the productivity of Thailand and red tilapia under different stocking densities (200, 250 and 300 fish m^{-3}) They found that, the stocking density tested in the experiments did not affect the growth of tilapia ($P > 0.05$) and this may be due to the intensive management practice during the experimentation. Emmanuel (2013) [47] explained that, when fish are crowded, stressed and executed, water quality can deteriorate rapidly.

Abdel Hakim (2001) [48] evaluated the growth performance of Nile tilapia fingerlings weighing 30g in 16 floating cages each with water volume of $1m^{-3}$. The 16 cages represented four stocking densities (80; 100; 120 and 140 fish m^{-3}). Results obtained revealed an inverse relationship of increasing stocking density with body weight and length. Similarly, Araujo evaluated the effect of stocking density on the weight growth of *O. niloticus* cultured in 3.14 m^{-3} round net cages with stocking densities of 100, 150 and 200 fish m^{-3}. Data analyzed showed a significantly higher weight growth for the density of 100 fish m^{-3}, which demonstrate a better development of Nile tilapia in circular net cages using low stocking densities.

Klanian and Adam (2013) [49] also evaluated the performance of Nile tilapia fingerlings in a recirculation aquaculture system with a stocking density of 400, 500 and 600 fish m^{-2} in which the first two stocking densities were significantly higher than the last one.

Generally, stocking density highly influence the growth of *O. niloticus* and thus optimum stocking density ensures sustainable aquaculture providing proper utilization of feed, maximum production, sound environment and health.

Feeding rate and frequency: In tilapia fish culture, it is important to consider the factors that influence its production such as feed type, ration size, various feeding frequencies and how they may influence on growth and feed utilization. Feeding frequency is important to ensure a maximal food conversion ratio and weight of cultured organisms [50]. Higher feeding frequencies may resulting the faster growth and uniformity in size. Feeding frequency is important to ensure best feed conversion ratio and weight gain of cultured organism [51]. Moreover, feeding frequency can affect growth performance, survival, body composition [52]. In other hand, higher frequency may lead to water quality deterioration.

Jegede and Olorunfemi (2013) [53] studied the effects of feeding frequency on growth and nutrient utilization of *O. niloticus* fingerlings. A 58-day feeding trial was conducted in concrete tanks to determine the effects of O. *niloticus* at four different feeding frequencies (once, twice, three and four times daily). The results showed a significant increase in body weight and lower feed conversion ratio ($P < 0.05$) at feeding frequency of three times daily than the other feeding frequencies. Asfaw and Abebe (2017) [3] also studied the growth performance and survival rate of Nile tilapia at different feeding frequencies (once, twice, three and four times daily). The mean Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Feed Conversion Efficiency (FCE) were higher at a feeding frequency of three and four times daily than one and two times.

Added to the above, Emranul (2009) [51] determined the effect of feeding frequency on the growth and production performance of *O. niloticus* (34.4 g) fed with a commercial diet once, twice, three, or five times a day for 29 days. No significant differences in growth, feed efficiency, or protein utilization were detected among the fish fed two, three, or five times daily but all were significantly better than in fish fed only once daily. Abdul Malik Daudpota (2016) [54] carried out an experiment of two feeding frequencies (2 and 3 meals/day) and five feeding rates (2, 4, 6, 8, and 10% body weight per day) for about 70 days. The results suggested that a feeding rate of 6% body weight per day with a feeding frequency of 2 meals/day was the most favorable protocol for the growth and physiological balance of Genetically Improved Farmed Tilapia (GIFT) during the fry phase. Similar experiments were conducted on Feeding strategies of tilapia cultivated in Bio-Floc technology (BFT) for about 56 days under four different feeding frequencies (one, two, three and four times a day) and three feeding rates (50%, 75% and 100%) consumption was carried out. The result showed that better efficiency of protein utilization at 75% feeding rate with twice/daily feeding frequency was optimum for Nile tilapia fingerlings [55].

Young Nile tilapias were stocked at a density of 5 fish/liter aquaria by fed pellet and un-pelleted crumbles at various daily feeding rates of 15, 30, 45 and 60%. Results showed that prior pelleting of the formulated diet for the tilapia fry given at 30% and 45% feeding rate by fish biomass ensured high survival, fast growth and efficient feed conversion [56].

In conclusion, growth performance and net yield increased with increased feeding frequency, so frequent feeding was recommended for optimum result of *O. niloticus*, and feeding rates will vary with fish size and water temperature. The appropriate amount is measured as a percent of the average body weight. When fish weight increases, the requirement of feeding rate decreases therefore the daily feed ration must be adjusted to compensate for growth.

Genetic variation: Growth performance of tilapia strain affected by the genetic material and varies in different geographical location [57]. Eknath (1993) [58] compared the growth performance of eight different strains of Nile tilapia reared in different farm environments. The strains include four African strains collected from Egypt (E1 & E2), Ghana, Kenya and Senegal, and four established Asian farmed strains known as Israel, Singapore, Taiwan and Thailand. They found that, the African strains performed the same as or better than the Asian strains and the fast growth was obtained from Egypt strain, while the lowest one was obtained from the Ghana strain. They attributed this difference to strain-specific effects of reproduction on growth. The expected genetic differences between groups of fish have been widely used for efficient selection of the optimum strain that could be utilized for the improvement of fish culture and breeding programs. Brood stocks of Nile tilapia, *O.niloticus* were collected from Lakes Nasser (Aswan), Manzalah, Maryut, and Abbassa fishponds and fingerlings of each strain were reared for 90 days. The results showed that Aswan strain was superior to other tilapia strains in growth performance [59].

To realize the potential of Nile tilapia culture, development of adapted farm races of *O. niloticus* species should be part of the genetic improvement programs [60]. The first step of genetic improvement is characterizing the available strains and subsequently select one or more strains to form a base population for genetic improvement [61], and thus an increasing in productivity through the application of genetic techniques [62]. Therefore, determination of genetic variation on the growth performance of different *O. niloticus* strains is very important for breeding program.

Genotype by environment interaction is another factor that can be affects the productivity of tilapia strains, in which different strains may have different rank in different production environments.

Nutritional composition of feds: Proper nutrition is considered as a critical issue that plays important role in maintaining normal growth rate, survival rate and health of fish. Good nutrition can help mitigate the effects of stress, decrease the susceptibility to disease, and serve as a primary method of boosting the immune system [63]. Tilapia exhibits the best growth rate when it is fed a balanced diet that provides a proper mix of protein, carbohydrates, vitamins, minerals and lipids. Nutritional requirements of fish differ for different species and more importantly vary with life stage. At early stage, fish requires more nutrients with high protein content but decrease as their age increases.

Protein: Protein is the most expensive dietary component that can represent around 40-70% of the total feed cost in aquaculture [64]. Fish require the 20 essential and non-essential amino acids that make up proteins [39]. The ten amino acids listed in Table 1 that cannot be synthesized are the essential amino acids that must be provided in proper amounts in their diet. Moreover, it is difficult to set a level of protein that is best for all situations as there are many factors that affect the dietary protein requirements; such as water temperature, feed allowance, amount of non-protein energy in the diet, protein quality, natural food available and management practices [65].

Tilapia brood stocks require 30-40% dietary protein for optimum reproduction, spawning efficiency, growth and survival [65]. The protein requirements of tilapia range from 40-45% crude protein for brood stock, 40-50% crude protein for fry/fingerlings and 28-32% crude protein for grow-out fish [59]. El-Sayed (2006) [64] has been reported that protein requirements of larval, juvenile and adult stage tilapia ranges between 35-40, 30-35 and 25-30%, respectively. According to Bahnasawy (2009) [66], Nile tilapia fingerlings fed on 35% protein diet attained highest growth than fingerlings fed on 30% protein diet. Reports of FAO (2016) [24] also stated that protein requirement of Nile tilapia during first feeding larval stages is high and ranges from 45 to 50%, but decreases with increasing fish size. Tilapia fry and fingerlings require high protein percentage while adult tilapia requires less dietary proteins for optimum performance.

Lipid: Lipids are essential nutrients in fish diets because they liberate approximately 9.4 kcal of gross energy g^{-1} which makes them the best sources of energy in terms of kcal/g compared with carbohydrates (4.1 kcal/g) and proteins (5.6 kcal of/g) [39].

Adult tilapia fish seem to cope with higher dietary fibre content, a maximum of 8-10% [67], than younger ones at about 6-8% [64]. El-Kasheif (2011) [68] have reported that *O. niloticus* fingerlings fed on diet containing 9% supplemented lipid attained maximum final weight and show better feed utilization efficiency. In another experiment, Jauncey (2000) [67] has suggested that to maximize protein utilization, dietary

Essential amino acid	% Inclusion (Fagbenro, 2000)	% inclusion (NRC, 2011)
Arginine	4.1	1.2
Histidine	1.5	1.0
Isoleucine	2.6	1.0
Leucine	4.3	1.9
Lysine	-	1.6
Methionine	1.3	0.7
Phenylalanine	3.2	1.1
Threonine	3.3	1.1
Tryptophan	0.6	0.3
Valine	3.0	1.5

Table1: Essential amino acids (EAA) require for *O. niloticus.*

lipid concentration should be between 8% and 12% for tilapia up to 25g, and 6% to 8% for larger fish. This is within the range reported by FAO (2016) [24] where dietary crude lipid requirement of *O. niloticus* ranges between 6-13% for fry and fingerling and 4-12% for adult. In general, suggested dietary lipid levels for tilapias range from 8% to 12%.

Carbohydrate: Carbohydrates are the most economical source of energy available in abundant quantities at low prices and have a protein-sparing effect in some low-protein diets. Many fish appear to be able to utilize simple carbohydrates, such as sugars, more effectively than complex starches. However, warm-water species like tilapia have been reported to utilize complex sugars (starch) more efficiently than disaccharides and monosaccharides [64,65]. Starch which is richly found in cereals is less digested than fats and proteins, unless it is passed through heat and moisture involved treatments. Metabolizable energy (Metabolizable energy = food intake gross energy - faecal energy - energy in gaseous products of digestion - gill energy - urinary energy) that can be provided to fish from fats, proteins and carbohydrates is estimated to be 8.5, 4.5 and 1.2-2.0 kcal/g, respectively [39]. Lipid and to a lesser extent, carbohydrate can be used in diets of fish to 'spare' protein for growth. Higher levels of lipid and carbohydrate enable a reduction in the protein level necessary for optimum growth [65]. FAO (2016) [24] recommends greater than 25% carbohydrate concentration for all stages of *O. niloticus*. Wang (2017) [69] have suggested that 20% dietary starch is enough for normal growth of *O. niloticus*. This is within the range reported by Amirkolaie (2006) [70] where improved growth was observed in *O. niloticus* fed on diets with 10%-40% inclusion of starch. Carbohydrates usually represent less than 25% of the diet for fry and increases to 25-30% for fish greater than 1.0 g up to harvest [71]. This implies that Fry and fingerlings (20-25%) require diets with lower carbohydrates requirement than adult fish (> 25%).

Water quality: The optimal performances of cultured fish depend not only on the provision of a balanced diet but also depending on culturing environment [29]. The appearance of good water quality in the fish pond is necessary for their survival and proper growth of fish. Excessive feed and faecal wastes may lead to water deterioration resulting in significant changes in ecosystem structure and functioning. Water quality in fish culture influences feeding, growth, disease burdens, and survival rates. The most important water quality parameters that affect growth of *O. niloticus* are dissolved oxygen, temperature, pH, ammonia and salinity [72].

The water quality should be monitored regularly and can be tested using test kits. Management of physico-chemical parameters in aquaculture system is important since it affects both cultured organisms and the availability of nutrients in the system as well.

pH: It is an important factor for the growth, development and survival of fish. The pH of water is a measure of hydrogen ion that causes acidity and alkalinity on a scale of 0-14 with 7 being the neutral state [73]. pH fluctuations in water causes ionic imbalance which may leads to death. Sophin (2001) [74] has been reported that the optimum range of 6.5-9.0 of pH is recommended for warm water fish culture. It is in the range to Rakocy (2006) [75] mostly tilapia fish often prefer pH ranging from about 6 to 9.

Tilapia can tolerate a pH range of 3.7 to 11, but best growth rates are achieved between 7 to 9. El-Sherif and El-Feky (2009) have studied the performance of Nile Tilapia (*O. niloticus*) fingerlings in different pH levels (6, 7, 8 and 9) and the result showed that growth performance was significantly ($P < 0.05$) decreased at pH 6 and pH 9, while the optimum growth was observed at pH 7 and 8. No mortality occurred during the whole experiment. Feed conversion ratio increased at pH 6 and 9.

According to COche (1982) [76] better growth of *O. niloticus* were observed at pH level of 6.8 to 8. Tomaz (2016) [77] has investigated the suitable range of water pH for culture of *O. niloticus* in eutrophic water ranged from 5.5-9.0 is suitable for the growth of *O. niloticus*. Several studies revealed that *O. niloticus* shows better growth performance , feed utilization and survival rate with in PH range from about 6-9.

Dissolved oxygen: Low Dissolved Oxygen (DO) concentration is recognized as a major cause of stress, poor appetite, increase feed conversion ratio, slow growth, disease susceptibility and mortality in aquaculture animals [78]. It is generally accepted that the minimum daily dissolved oxygen concentration in aquaculture systems is of greatest concern.

Mjoun (2010) [38] reported that Tilapia is highly tolerant of low dissolved oxygen concentration but optimum growth is obtained at concentrations greater than 3 mg L^{-1}. The minimum dissolved oxygen requirements of tilapia species is 5mg L^{-1} and if the concentration of dissolved oxygen decreases respiration and feeding activities also decrease.

According to Adamneh Dagne (2013) [79] dissolved oxygen level for acceptable growth of *O. niloticus* ranges from 6.0 to 9.0 mg L^{-1}. The level of dissolved oxygen between 5 to 8 mg/l has positive effect on growth of *O. niloticus*, while DO values < 3.5mg/L could adversely affect its growth and feed utilization [80]. As mentioned by Kassaye (2012) [81] better growth and feed utilization of *O.niloticus* were observed in the range of dissolved oxygen concentrations from 5.7 to 6.7 mg/L. Bahnasawy (2003) [82] also confirmed that dissolved oxygen concentration ranged from 6.1 to 8.4 mg/L were suitable for optimum growth performance and feed utilization efficiency of *O. niloticus*. At dissolved oxygen levels between 3-5mg/L, feeding should be reduced, and feeding should be stopped at dissolved oxygen levels below 3 mg/L. De Long (2009) mentioned that, operating levels of dissolved oxygen for tilapia in tanks culture between 5.0 and 7.5 mg/L are recommended. In conclusion, growth and feed conversion will be affected by chronically when dissolved oxygen concentrations below 3 mg/L.

Temperature: Nile tilapia growth can be seriously influenced by the physical and biological composition of their environment [83]. Because the environment in aquaculture system is complex, water quality parameters such as temperature must be monitored. Of all the abiotic factors, a change in ambient water temperature has the largest effect on physiological properties in fish. Growth performance and feed utilization efficiency of juvenile *O. niloticus* are temperature dependent and thus, it is crucial to select the right water temperature for a specific fish species to a particular culturing area [32].

Mirea (2013) [84] reported that the growth performance, survival rate and biochemical composition of Nile tilapia were affected by temperature. The fish were stocked at 20, 24, 30 and 28°C (control) water temperature for 30 days. Results showed that growth performance was not significantly ($P > 0.05$) decreased at 20 and 24°C. Survival rate was the same for the treatments. It has showed that the thermal range 20-30°C was suitable for intensive culture of Nile tilapia regarding the optimum growth performance and survival rate.

Nehemia (2012) mention that, optimal temperature for growth of tilapia ranges from 29°C to 31°C. Growth declines greatly with decreasing temperature and at 20° to 22°C. The lethal minimum temperature for most species of tilapia is 10°C or 11°C, while at 37-38°C stress and diseases tend to attack most of them.

According to Kassaye (2012) [32] Growth performance and feed utilization efficiency of juvenile *O. niloticus* reared at different water temperature treatments (24, 26, 28 30, 32 and 34°C). The highest growth of *O. niloticus* was achieved from 28-32°C water temperature but lower growth rate at 24°C and 34°C water temperature and also the maximum feed conversion ratio observed at 28 and 32°C while lower fed conversion ratio was at 24°C.

Pandit and Nakaura (2010) have been reported that growth performance of juvenile *O. niloticus* reared at different water temperature increased as water temperature increased until 30°C to 32°C and declined when it exceeded. As mentioned by Azaza (2008) [85], juvenile *O. niloticus* reared at 26°C and 30°C water temperature has higher body weight than reared at 22°C and 34°C water temperature. Therefore, better growth rate and feed utilization of *O.niloticus* can be achieved in an optimum temperature range. According to the different studies the optimum water temperature for the growth performance of Nile tilapia in aquaculture ranged from 26°C to 32°C.

Ammonia: Ammonia is a nitrogenous compound excreted by fish through gills and faeces. It is a production limiting factor in the aquaculture media affecting fish production. In water ammonia is present in two forms: the high toxic Un-ionized Ammonia (NH_3) and the non-toxic Ionized Ammonium (NH_4^+). The main negative consequences of the elevated ammonia in Tilapia culture are the sharp decrease in body growth rate, change in hematological traits, increased cortisol and glucose in the blood to cope with ammonia toxic effects [86]. The sum of NH_3 and NH_4^+ is called total nitrogen ammonia [46]. Chronic ammonia exposures affect Nile tilapia in several ways. For instance it causes gill and kidney damage, decreased brain monoamines, decreased ATPase level, reduce growth rates and increased brain glutamine [87].

Generally at pH7 only less than 1% of the total ammonia is in the toxic unionized form, at pH8 about to 9%, at pH9 about 30 to 50%, while at pH 10 is about 80-90%. The first mortality from prolonged exposure to toxic ammonia begin at concentration as low as 0.2mg/L and this un-ionized form of ammonia begin to depress appetite of tilapia at concentration as low as 0.08 mg/L. Thus, the concentration of NH_3 should be maintained below 0.1mg/L to achieve a normal growth performance of the fish [88]. The lower concentration of ammonia was also reported in the water recirculating system used for cultivation of Nile tilapia by Effendi (2017) [89] which ranged from 0.004 to 0.04 mg/l and to achieve an optimum growth in *O. niloticus*, the concentration of NH_3 should not exceed 0.05-0.1 mg/L.

Ali (2006) [90] study the effects of stocking density (10, 15, 50 and 75 fish in 65 liter per tank) and ammonia excretion on the growth of Nile tilapia. The result show that, increasing stocking density of *O. niloticus* from 15 fish/tank resulted in associated increase in ammonia level (1.48 ± 0.87 mg/liter to 26.44 ± 11.4 mg/liter) and significantly lower growth rates and better feed conversion ratios were found for fish reared at lower (15 fish/tank) stocking densities compared to higher (75 fish/tank) stocking densities. Ammonia is the most important factor that affects the growth performance and feed consumption of farmed fish and thus should be monitored regularly during culture period.

Salinity: Growth rate of *O. niloticus* is greatly influenced by different salinity levels [91]. Salt tolerance of *O. niloticus* is depends on strains, size and prevailing environmental factors [92]. This have been reported that better growth of *O. niloticus* was observed in a salinity level up to 7 ppt. Similar result has also been reported by Popma and Masser (1999) [93]. *O. niloticus* can grow at salinities up to 15 ppt, performing better below 5 ppt. Furthermore, this report has also been supported by Likongwe (1996) [94] where *O. niloticus* can grow at salinities up to 16 ppt with optimum salinity level of 8 ppt. Nile tilapias are among the least tolerant to high salinity and typically tolerate up to 15 g/L [93].

The best performance of *O. niloticus* cultivated in lower water-salinity levels can be related to the energy cost for the ionic regulation, which is lower when the fish is kept in an isotonic environment and this energy can be directed towards growth. *O. niloticus* shows better growth in water- salinity up to 8 ppt. Besides osmoregulation, the effect of water salinity on the performance of *O. niloticus* might be explained by its action upon digestive enzymes, where the exposure to different salinities might modify the water ingestion, altering the salinity of the intestinal content and affecting the activity of digestive enzymes [94-100].

Conclusion and Recommendation

Aquaculture is rearing of aquatic organisms under controlled or semi-controlled water environment. Global aquaculture fish production is increasing considerably while capture fisheries is declining.

Nile tilapia can be selected as a good candidate for aquaculture due to its high density stocking ratio, disease resistance, occupy different trophic level, low production cost, tolerate low level of dissolved oxygen, easily reproduction in captive condition and tolerate high ammonia concentration.

Growth performance of Nile tilapia is highly affected by genetic materials, food quality, stocking density, feeding rate and frequency and environmental factors (water quality such as temperature, dissolved oxygen, pH, salinity and ammonia).

Therefore, increasing genetic variation of the target fish, providing sufficient amount of balanced diets, good proportion of feeding rate and feeding frequency, good stocking density and optimum environmental conditions are important to achieve maximum growth of the cultured fish.

Further research on factors affecting the growth performance of different tilapia strains other than *O.niloticus* is strongly recommended.

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