

# Growth and Body Development of *Oreochromis niloticus* (Linnaeus, 1758) Fattened in Floating Cages Based on Commercial Feed in Benin

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Received: August 13, 2019      Accepted: September 23, 2019

doi:10.5296/jbls.v11i1.15259      URL: <https://doi.org/10.5296/jbls.v11i1.15259>

## Abstract

This work evaluates the growth and body development of *Oreochromis niloticus* in floating cages in the Toho Lake of Benin. Thus, 6000 juvenile monosex male with an average initial weight of  $8.87 \pm 4.89$  g and average initial total length of  $7.87 \pm 1.43$  cm were randomly distributed in two floating cages ( $5 \times 5 \times 2.5$  m<sup>3</sup>) at the stocking density of 3000 fish/cage. The fish were hand-fed to apparent satiation, three times daily, using 45-32% crude protein commercial pelleted floating feed Skretting®. The physico-chemical parameters of lake water recorded every 72 hours during the experiment were within the suitable ranges for fish culture and were as follows: temperature ( $27.78 \pm 0.41$  °C), pH ( $7.55 \pm 0.22$ ), dissolved oxygen ( $4.03 \pm 0.96$  mg/l), ammonium ( $0.31 \pm 0.18$  mg/l), nitrite ( $0.29 \pm 0.07$  mg/l) and nitrate ( $0.27 \pm 0.12$  mg/l). The variables studied at the end of the 215 days of rearing were as follows: final mean total length ( $26.61 \pm 2.99$  cm), final mean standard length ( $22.40 \pm 2.74$  cm), final mean predorsal length ( $6.93 \pm 0.94$  cm), final mean head length ( $3.45 \pm 0.58$  cm), final mean dorsal fin base length ( $13.55 \pm 2.96$  cm), final mean inter-orbital width ( $2.97 \pm 0.37$  cm), final mean body height ( $8.57 \pm 1.56$  cm) and final mean caudal peduncle height ( $3.27 \pm 0.39$  cm). The zootechnical growth parameters evaluated were as follows: survival rate (91.5%), final mean body weight ( $402.18 \pm 137.05$  g), average daily weight gain ( $1.83 \pm 0.08$  g), specific growth rate ( $0.77 \pm 0.03\%$ /day), feed conversion ratio ( $1.74 \pm 0.09\%$ ) and protein efficiency ratio ( $1.62 \pm 0.06$ ). These results compared to the literature indicate interesting growth and body development and it would be important to promote in-cage farming of *Oreochromis niloticus*.

**Keywords:** *Oreochromis niloticus*, breeding, growth, cage, commercial feed

## 1. Introduction

There are about 80 species of tilapia, mostly from the African continent and, beyond the Suez Canal, from the region of Israel and Jordan among which, only some of the *Oreochromis* genus have the qualities required for aquaculture (Legros, 1995). The zootechnical characteristics of *Oreochromis niloticus* or tilapia (the ease with which they can breed, their relatively fast growth, their high tolerance to extreme rearing and harsh environmental conditions (high stocking density, low oxygen levels, etc.), resistance to handling, resistance to disease, good consumer acceptance) make this species, the most interesting and the basis of the freshwater fish farming in the intertropical belt of the globe (Legros, 1995; Arrignon, 1998; Lazard, 2007). According to its diet, *Oreochromis niloticus* can reach a market size of 400 g in 8 months (Lazard, 2007) and its commercial production generally requires the use of male monosex populations because they grow about 30% faster than females (Macintosh *et al.*, 1985; Smith and Phelps, 2001; Ridha, 2011). In view of all the above, one of the possibilities for optimizing the production of *Oreochromis niloticus* or Nile tilapia could be its cage culture as it presents more advantages over other farming methods, such as culture ponds or raceways (Care, 2000; Gupta and Acosta, 2004). Cage culture is commonly used in water bodies that cannot be drained, such as lakes, estuaries, reservoirs or coastal marsh areas. Cage culture practices have numerous advantages over other culture systems. By integrating the cage culture system into the aquatic ecosystem the carrying capacity per unit area is optimized because the free flow of

current brings in water and removes metabolic wastes, excess feed and faecal matter (Beveridge, 1984). In addition, cage-culturing requires low investment costs, easy management, easy and low cost of harvesting, opportunities for close observation of feeding and health status of fish (McGinty and Rakocy, 2005). Cages can be floating surface or standing surface cages, and the material by which they are constructed should be durable, lightweight, and cheap, such as a galvanized and plastic coated welded wire mesh, plastic netting and nylon mesh (Fitzsimmons, 2004). According to Beveridge (1996), cage aquaculture is an old practice. It dates back to early 10<sup>th</sup> century when Chinese fishermen used to fatten fry in cage made with bamboo stick. Similar farming practices have been reported in both freshwater and marine environments, including open ocean, estuaries, lakes, reservoirs, ponds and river (Eng and Tech, 2002). However, the knowledge of the behavior of cultured species is crucial for the construction of an appropriate cage (McGinty and Rakocy, 2005). In the case of *Oreochromis niloticus*, it is less active and sometimes territorial in habitat, the shape of the cage does not affect its mobility, however, for easy assemblage and management rectangular cage is appropriate (Fitzsimmons, 2004). However, this farming practice is still embryonic in Benin, where national aquaculture production is still struggling to meet the ever-increasing demand. The present study aims to evaluate the growth performance and body development of *Oreochromis niloticus*, in floating cage based on imported commercial feed, with a view to translating the results into a diffusion technological package.

## 2. Materials and Methods

### 2.1 Study Area, Animal Descriptions, Study Design and Assessment of Growth and Body Development

The trial was conducted for a 215 days period (from September 27, 2015 to May 18, 2016) at the Aquaculture Incubation Centre of Toho, a private fish farm located in Pahou in the municipality of Ouidah (6 °22' 00" NORTH, 2 °05' 00" EAST). A total of 6000 *O. niloticus* juvenile monosex male (Initial mean body weight IMBW:  $8.87 \pm 4.89$  g; initial mean total length IMTL:  $7.87 \pm 1.43$  cm) were collected from the Aquaculture Research and Incubation Center of Benin, weighed and stocked in two (02) square floating net cages (size of each cage: 5m x 5m x 2.5m) (Figure 1) in the Toho Lake at a stocking density of 3000 fish/cage. This stocking density used, i.e. 48 fish/m<sup>3</sup>, is close to the optimal value of 50 fish/m<sup>3</sup> recommended by Moniruzzaman *et al.* (2015).

The fish were hand-fed to apparent satiation, three times daily at 9.00am, 1.00pm and 5.00pm, using 45-32% crude protein commercial pelleted floating feed Skretting®. The fish progressively received 2 mm, 3 mm and 4.5 mm pellets from the beginning to the end of the trial. Water quality parameters such as temperature, pH, dissolved oxygen, ammonium, nitrite and nitrate were monitored at 72-hour intervals throughout the experimental period. Temperature and pH were recorded using a portable digital thermo-pH meter (pHep 3); test kits were used for the other parameters, namely *Vunique V-Color 9750* for ammonium, *Vunique V-Color 9780* for dissolved oxygen and *API FRESHWATER MASTER TEST KIT* for nitrite and nitrate.

Sampling was done at the end of the experimental period to access the growth performance and body development of the fish. Then, random samples of 1300 fish from each cage were caught.

The measurable morphometric characters of the fish as described by Stiasny *et al.* (2007), recorded at the beginning and the end of the trial were as follows: Total Body Length (TL), Standard Length (SL), Predorsal Length (PL), Head Length (HL), Dorsal Fin Base Length (DFBL), Interorbital Width (IOW), Body Height (BH) and Caudal Peduncle Height (CPH) (Figure 2). The Body Weight (BW) was also recorded during the trial. Weight was measured with a digital electronic scale (SH & A: SHS: SUPER HYBRID SENSOR; max range: 2200 g; accuracy: 0.01 g) for small and medium sized fish and another digital electronic scale (UWE; max capacity: 30 kg; accuracy: 5 g) to weigh large specimens. The morphometric parameters of the fish were measured using an ichthyometer (Total length: 1m; graduated in cm) for the large fish, and a Vernier caliper (graduated in cm) used for small specimens. To determine the growth response of the experimental fish, several parameters were calculated (Table 3): Final Mean Body Weight (FMBW, g), Average Daily Weight Gain (ADWG, g), Specific Growth Rate (SGR, %/day), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER). The Survival Rate (%) of the fish was also evaluated at the end of the experiment.



Figure 1. *O. niloticus* breeding device: floating cages in Toho Lake of Benin

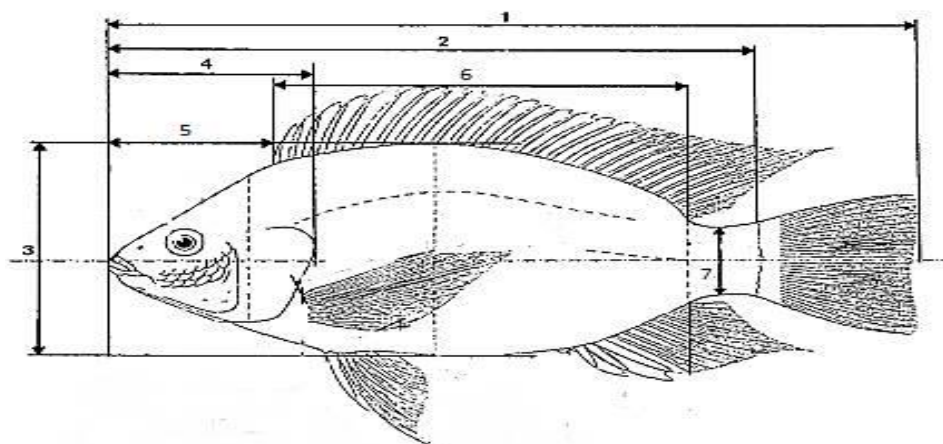


Figure 2. Principal measurements taken on *O. niloticus* (Fermon, 2011)

Legend: 1- Total length (TL), 2- Standard length (SL), 3- Body height (BH), 4- Head length (HL), Interorbital width (IOW), 5- Predorsal length (PL), 6- Dorsal fin base length (DFBL), 7- Caudal peduncle height (CPH).

## 2.2 Statistical Analysis

Data relating to growth and body development parameters (TL, SL, BH, HL, IOW, PL, DFBL, CPH and BW) and also physico-chemical parameters of the water (Temperature ( °C); pH; O<sub>2</sub> (mg/l); NH<sub>3</sub>/NH<sub>4</sub> (mg/l); NO<sub>2</sub> (mg/l); NO<sub>3</sub> (mg/l)) were subjected to a descriptive statistical analysis, using Statistical Analysis System (SAS, 2008). The different rates such as SR, SGR, FCR, PER and the ADWG were calculated from the raw data.

Data on the total body length (TL) and body weight (BW) were recorded from each sampled fish. The parameters *a* and *b* of the length-weight relationship were estimated by logarithmic transformation of the equation  $BW = a \times TL^b$ , in which *BW* is the body weight (g); *TL* is the total body length (cm); *a* is the intercept; and *b* is the slope. Length-weight relationships were used to provide the condition of fish and determine whether growth is isometric (*b* = 3) or allometric (negative allometric: *b* < 3, or positive allometric: *b* > 3). When *b* = 3, there is a good distribution in the body development of the fish (Pauly, 1983). However, *b* < 3 indicates a better growth in length than in weight, while *b* > 3 means a better growth in weight than in length (Micha, 1973; Ricker, 1973; Weatherley and Gill, 1987).

## 3. Results

### 3.1 Water Quality

Table 1. Water quality parameters recorded in male monosex *O. niloticus* floating cages during the study period (values are expressed as mean ± SE).

Physico-chemical parameters	Mean ± SE
Temperature ( °C)	27.78 ± 0.41
pH	7.55 ± 0.22
O <sub>2</sub> (mg/l)	4.03 ± 0.96
NH <sub>3</sub> -N (mg/l)	0.31 ± 0.18
NO <sub>2</sub> (mg/l)	0.29 ± 0.07
NO <sub>3</sub> (mg/l)	0.27 ± 0.12

Data in Table 1 represents the mean values of the rearing water quality parameters. The results showed that physico-chemical parameters remained within the optimum gaps for tilapias, evidenced by the survival rate of 91.5% obtained.

### 3.2 Morphometric Parameters and Body Weight of Fish

Table 2. Morphometric parameters and body weight of male monosex *O. niloticus* at stocking and 215<sup>th</sup> day of breeding in floating cages (values are expressed as mean  $\pm$  SE).

Morphometric parameters (cm) and Body weight (g)									
	TL	SL	PL	HL	DFBL	IOW	BH	CPH	BW
<b>Phases</b>									
At stocking	7.87 $\pm 1.43$	6.41 $\pm 1.23$	1.96 $\pm 0.62$	0.99 $\pm 0.35$	3.51 $\pm 0.74$	0.79 $\pm 0.21$	2.13 $\pm 0.47$	0.85 $\pm 0.20$	8.87 $\pm 4.89$
At harvesting	26.61 $\pm 2.99$	22.40 $\pm 2.74$	6.93 $\pm 0.94$	3.45 $\pm 0.58$	13.55 $\pm 2.96$	2.97 $\pm 0.37$	8.57 $\pm 1.56$	3.27 $\pm 0.39$	402.18 $\pm 137.05$

The mean values of morphometric parameters of fish (TL, SL, PL, HL, DFBL, IOW, BH, CPH) and body weight (BW) obtained at the end of the trial period are presented in Table 2. The results revealed good adaptation and growth of *Oreochromis niloticus* in cages.

### 3.3 Zootechnical Parameters of Fish

Table 3. Zootechnical parameters of monosex male *O. niloticus* after 215 days breeding period in floating cages in Toho Lake of Benin (values are expressed as mean  $\pm$  SE)

Parameters	Overall average
Initial mean body weight (g)	8.87 $\pm$ 4.89
Rearing duration (days)	215
Stocking density (fish /m <sup>3</sup> )	48
Final mean body weight (g)	402.18 $\pm$ 137.05
Average daily body weight gain ADWG (g)	1.83 $\pm$ 0.08
$ADWG = \frac{\text{Final mean weight} - \text{Initial mean weight}}{\text{rearing duration (days)}}$	
Specific growth rate (SGR : %/day)	0.77 $\pm$ 0.03
$SGR = 100 * \frac{\ln \text{ final mean weight} - \ln \text{ initial mean weight}}{\text{rearing duration (days)}}$	
Feed conversion ratio (FCR)	1.74 $\pm$ 0.09
$FCR = \frac{\text{Dry feed intake}}{\text{Final biomass} - \text{initial biomass}}$	
Protein efficiency ratio (PER)	1.62 $\pm$ 0.06
$CEP = \frac{\text{final biomass} - \text{initial biomass}}{\text{Crude protein intake}}$	
Survival rate (SR : %)	91.5%
$TS = 100 * \frac{\text{Fish stocked}}{\text{Fish harvested}}$	

Table 3 presents the zootechnical parameters of the fish. The results revealed good feed use, protein efficiency, specific growth rate and encouraging ADWG.

### 3.4 Length-Weight Relationship

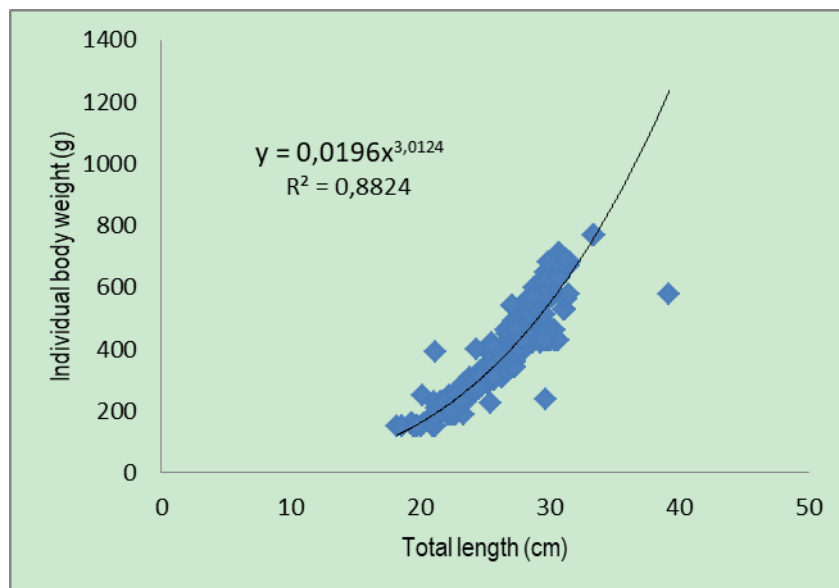


Figure 3. Length-weight relationship of growing-finishing monosex male *O. niloticus* in cage- farming system

The length-weight relationship equation of male monosex *O. niloticus* at the end of the trial was as follows:  $BW = 0.019 \times TL^{3.0124}$ , ( $R^2 = 0.8824$ ) (Figure 3). The value of slope b in the equation was equal to 3.0124. This value being relatively equal to 3, then revealed an isometric growth of the fish; indicate a good distribution in the growth and body development.

## 4. Discussion

### 4.1 Physico-Chemical Parameters of Water

The water quality parameters monitored throughout this study meet the standards required for the breeding of the Nile tilapia *Oreochromis niloticus* such as: 22-29 °C for temperature (Sarig, 1969; Morgan, 1972; Caulton, 1982; Mires, 1995); 6.5-9 for pH (Hepher and Pruginin, 1981); dissolved oxygen content of the water > 3 mg/l (Ross, 2000); nitrite content < 0.3 mg/l (Boyd, 1998); 0.2 - 10 mg/l for nitrate (Boyd, 1998). The importance of water quality in aquaculture was highlighted by some authors (Arulampalam *et al.*, 1998; Thirupathaiah *et al.*, 2012) and would justify a major role in the well-being of the fish, as evidenced by the analysis of the breeding water quality in this study.

### 4.2 Zootechnical Parameters

Generally, fish growth is dependent on several factors which, according to their nature, can be grouped as follows: farming environment, farming management and intrinsic factors related to the animal. Environmental factors include the availability of food resources in the environment and the physico-chemical quality of the species habitat (temperature, dissolved oxygen concentration, luminosity, etc.) (Ezenwaji and Ikusemiju, 1981; De Merona *et al.*, 1988; Panfili *et al.*, 2002; Fontaine and Le Bail, 2004), the device or medium of breeding (Coche, 1978). For



example, cage culture of tilapia species such as *O. niloticus* (Coche, 1978; Cavailles *et al.*, 1981) and *Sarotherodon melanotheron* Rüppell 1852 (Ouattara *et al.*, 2003) improves production and the rearing of mixed-sex populations without recruitment and stunting problems, which are important constraints in traditional culture systems. Concerning the factors related to fish farming management, they include: composition and quality of feeds (Moraes *et al.*, 2009 ; Ashraf *et al.*, 2011; Slawski *et al.*, 2011), stocking density (Araujo *et al.*, 2010), feeding methods (Ridha, 2011), feeding frequency (Yager and Summerfelt, 1993; Davies *et al.*, 2006; Garcia and Villarroel, 2009), availability of food resources in ponds or cages, and feeding rate (Diana *et al.*, 1991; Ng *et al.*, 2000; Mihelakakis *et al.*, 2002; Kestemont *et al.*, 2003), fish rearing duration (Fermon, 2011; Silva *et al.*, 2015). According to Shugunan (1997), higher stocking density reduces the growth and survival rates during fish culture. Increasing stocking density results in stress (Leatherland and Cho, 1985) which leads to enhanced energy requirements causing reduced growth and food utilization (Hengsawat *et al.*, 1997). On the other hand, competition for food is a limiting factor for growth of young fish. Competition and aggressive behaviour increase under situations of food shortage (Symmons, 1971; Essa, 1996). Finally, the intrinsic factors related to the animal include: strain (Dey and Gupta, 2000), genetic background of the fish (Conover, 1992), species (Amoussou *et al.*, 2016), difference between the initial weights (Abdel-Hakim *et al.*, 2008), sexual dimorphism (Bwanika *et al.*, 2007; Ridha, 2011; Wadgy *et al.*, 2011; Chakraborty and Benerjee, 2012). It was reported that the discrepancy in the growth performance between male and female tilapia is multi-factorial. It is believed to be related to channeling of energy from somatic growth toward egg production in females (Rakocy and McGinty, 1989; Baroiller and Borel, 1997), anabolic effects of the male sex steroids and growth hormones, genes linked to sex determination and greatly reduced feeding activity of brooding females (Toguyeni *et al.*, 1997a; Toguyeni *et al.*, 2002).

However, the growth influencing factors considered in this study are: feed content and quality, feeding management, stocking density, rearing device, trial duration, rearing water quality; feed intake level of fish, sexual dimorphism, difference in initial weights of fish at stocking, difference in final weights of fish at harvesting, fish strain, genetic background of fish.

#### 4.2.1 Final Mean Body Weight

*O. niloticus* juvenile monosex at the end of the experiment presented a final mean body weight of  $402.18 \pm 137.05$  g, higher than the values of  $255.53 \pm 16.36$ ;  $227.24 \pm 15.05$ ;  $206.36 \pm 14.06$  and  $172.62 \pm 14.89$  g reported for similar populations reared for 120 days and fed with a commercial pelleted floating feed (29% protein) at 3-5% of body weight in cages at densities of 50, 75, 100 and 125 fish/m<sup>3</sup> respectively (Moniruzzaman *et al.*, 2015). The disparity of results could be attribute to the difference in the protein content of fish feed, the stocking density, and the trial duration. It is also observed that an increase in stocking density results in lower body weight of fish. On the other hand, lower final mean body weight values of  $200.08 \pm 0.8$  and  $123.4 \pm 0.76$  g were also reported respectively for juvenile monosex male and mixed sex populations of the same species after 6 months of pond culture (3 fish/m<sup>2</sup>) using 28% crude protein diet twice daily at 4% body weight (Githukia *et al.*, 2015). An average weight of 217.90 g has also been reported for *O. niloticus* grown in floating cages (135 fish/m<sup>3</sup>) on the Niger

River after 225 days of rearing, based on a diet containing 31% of proteins, 1/3 of which are of animal origin (Lazard and Legendre, 1994). Disparity between authors' results may be due to variation in diet protein quality and content; difference in stocking density, rearing device, trial duration; and sex-specific difference. Indeed, number of study has reported a faster growth rate in male monosex when compared to mixed sex *O. niloticus* (Mair *et al.*, 1995; Dan and Little, 2000; Little *et al.*, 2003; Chakraborty *et al.*, 2011). Due to their sexual dimorphism, males grow significantly larger and are more uniform in size than females (Ponzoni *et al.*, 2005; Nguyen *et al.*, 2007). Dagne *et al.* (2013) highlighted that lack of energy expenditure in egg production and mouth brooding by females and lower energy expenditure on courtship are some of the reasons behind faster growth rate in male monosex tilapia. According to de Oliveira *et al.* (2012), stocking density is the concentration that fish are stocked into a system. It directly influences fish growth, feed utilization, survival and fish health (Lovell, 1989; Wocher *et al.*, 2011). Rearing fish at inappropriate stocking densities may impair growth and reduce immune competence due to factors such as social interactions and deterioration of water quality, that negatively affect the feed conversion efficiency and growth of the fish (Ellis *et al.*, 2002).

#### 4.2.2 Average Daily Weight Gain

The ADWG of *O. niloticus* monosex in this study after 215 days trial at a stocking density of 48 fish/m<sup>3</sup> is of 1.83 ± 0.08 g. It is greater than the value of 1.05 g reported for juvenile male monosex after 6 months of pond culture (3 fish/m<sup>2</sup>) using 28% crude protein diet twice daily at 4% body weight (Githukia *et al.*, 2015). On the other hand, an ADWG of 0.62 g was presented by a mixed sex juvenile of the same species, reared in ponds (Githukia *et al.*, 2015). The influence of density is also highlighted because Moniruzzaman *et al.* (2015) under cage-culturing system reported ADWG values of 2.01 g; 1.76; 1.59 and 1.31 g for *O. niloticus* juvenile male reared at densities of 50 ; 75 ; 100 and 125 fish/m<sup>3</sup> respectively. With higher density, authors obtained lower ADWG compared to our study. This result corroborates the observations of Lovell (1989) and Wocher *et al.* (2011) who reported that stocking density directly influences fish growth and feed utilization. Rearing fish at inappropriate stocking densities may impair its growth (Ellis *et al.*, 2002). Only all males bred at a stocking density of 50 fish/m<sup>3</sup> performed relatively better than that of our study. This disparity could be due to difference in fish strain (GIFT strain) and initial mean weight of fish (15.20 ± 0.15 g) used by Moniruzzaman *et al.* (2015), compared to that of our study (initial mean weight: 8.87 ± 4.89 g). Lower ADWG (0.81 g) than that of our study was reported by Lazard and Legendre (1994), for *O. niloticus* reared in cage at a density of 135 fish/m<sup>3</sup>. Nevertheless, higher growth has been reported for male monosex of Nile tilapia raised at a density of 83 fish/m<sup>3</sup> in circular cages (Silva *et al.*, 2015). Using males and females of a genetically improved strain (GIFT) of *O. niloticus* cultured in recirculating tanks, the values of 3.19 ± 0.08 g and 1.93 ± 0.04 g were respectively reported while males and females of unimproved strains exhibited ADWG of 2.16 ± 0.22 and 1.18 ± 0.08 g respectively in the same rearing system (Ridha, 2011). It is understood that fish strain has significant influence on its growth.

#### 4.2.3 Specific Growth Rate

The SGR obtained in this study (0.77 ± 0.03 %/day) is lower compared to the values of 1.83 ±

0.15%/day and  $1.47 \pm 0.18\%$ /day reported respectively for pond raised *O. niloticus* monosex male and mixed sex (Githukia *et al.*, 2015). The SGR of this study is also lower than the rates of 2.35; 2.25; 2.17 and 2.02%/day reported by Moniruzzaman *et al.* (2015) in floating cage culture for the monosex male of the same species at the stocking densities of 50; 75; 100 and 125 fish/m<sup>3</sup> respectively. This disparity could be attributed to difference in stocking density, fish strain, rearing device, and fish feeding management. In recirculating tanks culture system, genetically improved strain (GIFT) of *O. niloticus* showed higher SGR (male:  $1.03 \pm 0.01$  %/day; female:  $0.86 \pm 0.03$  %/day) versus unimproved strain SGR (male:  $0.86 \pm 0.03$  %/day; female:  $0.72 \pm 0.04\%$ /day) (Ridha, 2011). All monosex male Nile tilapia in this study showed better SGR than unimproved female strain. This could be attributed to fish strain and sexual dimorphism of the fish.

#### 4.2.4 Feed Conversion Ratio

FCR is considered as an important indicator of the quality of fish feed and lower FCR indicates better utilization of the fish feed (Mugo-Bundi *et al.*, 2013). This study showed lower FCR ( $1.74 \pm 0.09$ ) compared to 1.81; 1.92; 1.97, and 2.05 reported by Moniruzzaman *et al.* (2015) for juvenile monosex male tilapia raised in floating cages at densities of 50; 75; 100 and 125 fish/m<sup>3</sup>. This performance could be due to the quality of the feed used in this study and the feeding management. On the other hand, the FCR of juvenile monosex tilapia in this study is respectively lower than that of  $1.92 \pm 0.03$  reported for mixed sex tilapia in pond culture (Githukia *et al.*, 2015), and 3.0 reported by Lazard and Legendre (1994) in floating cage culture in Niger. According to Ellis *et al.* (2002) rearing fish at inappropriate stocking densities may impair growth and reduce immune competence due to factors such as social interactions and deterioration of water quality, that negatively affect the feed conversion efficiency and growth of the fish.

#### 4.2.5 Protein Efficiency Ratio

Protein is the main constituent of the fish body thus sufficient dietary supply is needed for optimum growth (Pillay, 1990). Protein efficiency ratio (PER) is based on the weight gain of a test subject divided by its intake of a particular food protein during the test period (Buamah and Singsen, 1975). According to Bahnasawy *et al.* (2009), fish growth is significantly affected by diet protein level. The PER of this study ( $1.62 \pm 0.06$ ) is in the interval from 1.25 to 1.98 reported by Khattab *et al.* (2000) for Nile tilapia in pond culture. It is also between the range of 1.34 to 1.85 reported for *O. niloticus* reared in recirculating water system, using feed containing respectively 35% and 20% crude protein content at a stocking density of 60 fish/m<sup>3</sup> (Bahnasawy *et al.*, 2009). Ahmad *et al.* (2004) found PER of 1.92; 1.58 and 1.98 for tilapia fingerlings (20.3 g) reared in concrete tanks using a recirculating system and a diet containing 25; 35 and 45% crude protein respectively. The disparity between results could be due to difference in: the diet protein content, feed quality, feeding management, the feed intake level of fish, the final weight of fish, the breeding water source and the breeding device indirectly. Indeed, Ghozlan *et al.* (2018) reported a significant influence of water sources on PER. According to the authors, PER is significantly improved with each increase in pond sizes and decrease in stocking density. Ellis *et al.* (2002) also reported that rearing fish at inappropriate

stocking density may lead to water quality deterioration and affect negatively the feed conversion efficiency. However, cage farming in a water body offers the advantage of automatic or natural water renewal without any kind of energy.

#### 4.2.6 Survival Rate

Male monosex tilapia in this study showed a good SR value of 91.5%. In comparison to the literature which highlights the effect of density on survival, higher SR values (96.8 and 92.6%) were reported by Moniruzzaman *et al.* (2015) for monosex tilapia reared under cage culture system at densities of 50 and 75 fish / m<sup>3</sup> respectively. On the other hand, respectively similar (91.2%) and lower (83.1%) survival rate were reported by the same authors for monosex tilapia bred at stocking densities of 100 and 125 fish/m<sup>3</sup> under the same culture system. In addition, a similar survival rate (90.70%) to that of our study was reported for *O. niloticus* monosex reared in floating cage at a stocking density of 135 fish/m<sup>3</sup> (Lazard and Legendre, 1994). That performance, despite the high density applied by these authors could be favored mainly by the higher initial mean weight (35.70 g) of the fish.

#### 4.3 Body Development of Fish

At the end of the study, the fish showed significant increase in the recorded eight morphometric parameters. Indeed, the length gain (cm) obtained was of 18.74 for TL; 15.99 for SL; 4.97 for PL; 2.46 for HL; 10.04 for DFBL; 2.18 for IOW; 6.44 for BH and 2.42 for CPH. The daily body development (cm) of this species is therefore of 0.087 for TL; 0.074 for SL; 0.023 for PL; 0.011 for HL; 0.047 for DFBL; 0.010 for IOW; 0.030 for BH and 0.011 for CPH.

The comparative growth performance of male monosex and mixed sex Nile tilapia (*Oreochromis niloticus*) (Initial mean weight: 12.2 g; initial mean TL: 7.6 cm) reared in earthen ponds was performed by Githukia *et al.* (2015). Daily length gain values of 0.08 cm and 0.06 cm were showed respectively by the monosex male and mixed sex at a stocking density of 3 fish/m<sup>2</sup>. A relatively better result (0.087 cm) was obtained in this study after 215 days of trial using floating cages at a stocking density of 48 fish/m<sup>3</sup> or 120 fish/m<sup>2</sup>. These performances could be attributed to the difference between rearing devices, duration of breeding, crude protein content of feed and feeding management.

Kebede (2011) studied for 6 months the effect of food quality (22 to 24.28% CP) on the growth performance of mixed sex *O. niloticus* raised in floating cages. The characteristics of the fish at the beginning of rearing were of 42.80 - 43.51 g for weight, 11.93 - 12.5 cm for TL and the stocking density was 100 fish/m<sup>3</sup>. The daily length gain (0.087 cm for TL) recorded in the males of *O. niloticus* in our study was higher, compared to the values reported for mixed sex cohorts ranging from 0.026 to 0.034 cm/day. This difference observed in body development could be attributed to the high stocking density, sex dimorphism, rearing duration, and lower crude protein content of the diet used by this author.

The effect of stocking density on growth of monosex tilapia (*O. niloticus*) (initial mean weight: 15.20 g; initial mean total length: 9.16 cm) under cage culture in Kaptai Lake of Bangladesh was performed by Moniruzzaman *et al.* (2015). Daily length gain values of 0.116; 0.106; 0.10 and 0.078 cm were reported after 120 days of rearing, respectively at stocking densities of 50;

75; 100 and 125 fish/m<sup>3</sup>. In spite of the lower crude protein content of the pelleted feed (28.76%) distributed, *O. niloticus* showed better growth compared to the one obtained in our study except for the cohort reared at the density of 125 fish/m<sup>3</sup>. This high performance could mainly be attributed to the genetically improved strain used by these authors, and also to the difference in the initial mean body weight of the fish. At the end of 180 days of rearing at similar stocking density (49 fish/m<sup>3</sup>) in floating cages, *O. mossambicus* fed on natural resources showed a daily length gain (0.084 cm) similar to that obtained in our study, while higher growth (0.103 cm) has been reported for the same species when fed with commercial pellet (Balkhande, 2019). The effect of stocking density on the production of Nile tilapia (*O. niloticus*) (Akosombo strain) (initial mean body weight: 2.09 - 2.15 g; initial standard length: 3.97 - 4.09 cm) was also studied in floating cages on the Volta Lake by Asase (2013) at the stocking densities of 50; 100 and 150 fish/m<sup>3</sup>. At the end of 177 days of rearing test, the daily length gain values for SL showed by the fish in increasing order of the densities were as follows: 0.075; 0.072 and 0.069 cm. Except for the fish raised at a density of 150 fish/m<sup>3</sup>, the results showed by *O. niloticus* are similar to those obtained at the end of our study. However, a decline in body development is observed with an increase in density.

#### 4.4 Length-Weight Relationship

The length-weight relationship of *O. niloticus* monosex was established, based on the equation  $BW = 0.0196 TL^{3.0124}$  ( $R^2 = 0.8824$ ) (Figure 2). Indeed, the value of the coefficient b (3.0124) is not significantly different from 3, thus revealing an isometric growth of the fish considering the scale of Ricker (1973). There is, therefore, a good distribution in length and weight of the body development. This observation is in line with that reported by Silva *et al.* (2015) in juvenile monosex male Nile tilapia (initial mean weight =  $28.6 \pm 4.16$  g) raised in circular cages (12 m<sup>3</sup> each). The good distribution of growth in this population could be attributed to: the absence of females, whose early maturity and reproduction usually contribute to overpopulation and stunting, leading therefore to poor quality and small size fish (Lazard, 2009).

## 5. Conclusion

The results of the present study revealed good adaptation and good growth performance and body development of male monosex *Oreochromis niloticus* in-cage farming system. This breeding structure has enabled an automatic and natural renewal of water, thus maintaining a suitable quality for fish growth. In addition, the stocking density adopted (50 fish/m<sup>3</sup>) in accordance with the recommendations of the literature has contributed to obtaining a good fish survival and a good use of the feed distributed. All these factors allowed for a better expression of the performances of the species. Promoting the growing-finishing of male monosex Nile tilapia in cage culture system could therefore be recommended to farmers to improve their production so that they could make more effective contribution to achieving food security and improving their profits.

## Acknowledgement

The authors wish to acknowledge Mr. Gilbert Cossi Tonon, Mr. Hermes Tonon, and Mr. Christian Guidibi of Tonon Foundation for their assistance. They would also like to thank the staff of Benin Aquaculture Incubation and Research Centre and Toho Aquaculture Incubation Centre for their collaboration.

## References

- Abdel-Hakim, N. F., Ammar, A. A., & Salah, A. A. (2008). Effect of initial stocking size and production cycle on growth performance of monosex tilapia reared in earthen ponds. *8<sup>th</sup> International Symposium on Tilapia in Aquaculture*, 255-269.
- Ahmad, M. H., Abdel-Tawwab, M., & Khattab, Y. (2004). Effect of dietary protein levels on growth performance and protein utilization in Nile tilapia (*Oreochromis niloticus*) with different initial body weight. Sixth international symposium on tilapia in aquaculture, Manila, Philippine, 249-263.
- Amoussou, T. O., Toguyeni, A., Imorou, T. I., Chikou, A., & Youssao, A. K. I. (2016). Caractéristiques biologiques et zootechniques des tilapias africains *Oreochromis niloticus* (Linnaeus, 1758) et *Sarotherodon melanotheron* Rüppell, 1852 : une revue. *Int. J. Biol. Chem. Sci.* 10(4).1869-1887. <https://doi.org/10.4314/ijbcs.v10i4.35>
- Araujo, G. S., Rodrigues, J. A. G., Da Silva, J. W. A., & Farias, W. R. L. (2010). Cultivo da tilápia do Nilo em tanques-rede circulares em diferentes densidades de estocagem. *Bioscience Journal*, 26, 428-434.
- Arrignon, J. (1988). Aménagement piscicole des eaux douces 5<sup>ème</sup> éditions, Lavoisier, Paris. p. 589.
- Arulampalam, P., Yusoff, F. M., Law, A. T., & Rao, P. S. S. (1998). Water quality and bacterial populations in a tropical marine cage culture farm. *Aquaculture Research*, 29, 617-624. <https://doi.org/10.1046/j.1365-2109.1998.00248.x>
- Asase, A. (2013). Effect of stocking density on the production of Nile tilapia (*Oreochromis niloticus*) in floating net cages on Volta Lake. A thesis submitted in partial fulfillment of the requirement for the Award of MPHIL Fisheries Science Degree. University of Ghana, Legon. p.111.
- Ashraf, M. Zafar, A., Rauf, A., Mehboob, S., & Qureshi, N. A. (2011). Nutritional values of wild and cultivated silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*). *Int. J. Agric. Biol.*, 13, 210-214.
- Bahnasawy, M. H., El-Ghobashy, A., & Abdel-Hakim, N. F. (2009). Culture of the Nile tilapia (*Oreochromis niloticus*) in a recirculating water system using different protein levels. *Egyptian Journal of Aquatic Biology and Fisheries*, 13(2), 1-15. <https://doi.org/10.21608/ejabf.2009.2029>
- Balkhande, J. V. (2019). Cage culture of *Oreochromis Mossambicus* (Tilapia) in back water

of river Godavari, Nanded, Maharashtra India. *MOJ Ecology and Environmental Sciences*, 4(3), 100-105. <https://doi.org/10.15406/mojes.2019.04.00140>

Baroiller, J. F., & Borel, F. (1997). Growth/reproduction interactions in *Oreochromis niloticus*. Proceedings of the Fourth International Symposium on Tilapia in Aquaculture, Florida, USA. p. 272.

Beveridge, M. C. (1984). Cage and pen fish farming. Carrying capacity model and environmental impacts. FAO Fisheries technical paper 255. FAO Rome. p.131.

Beveridge, M. C. M. (1996). Cage aquaculture. Second Edition. Oxford: Fishing News Books. p. 346.

Boyd, C. E. (1998). Water quality for pond aquaculture. Research and Development Series No.43. *International center for Aquaculture and Aquatic Environments*, Alabama Agricultural Experiment Station, Auburn University, Alabama, 1-7.

Buamah, T. F., & Singsen, E. P. (1975). Studies on the Protein Efficiency Ratio Method for Evaluation of Poultry Feed Supplements. Modifications associated with choice of dietary protein level for assay. *The Journal of Nutrition*, 105(6), 688-700. <https://doi.org/10.1093/jn/105.6.688>

Bwanika, G. N., Murie, D. J., & Chapman, L. J. (2007). Comparative age and growth of Nile tilapia (*Oreochromis niloticus* L.) in lakes Nabugabo and Wamala, Uganda. *Hydrobiologia*. 589. 287-301. <https://doi.org/10.1007/s10750-007-0746-y>

Care, (2000). Successful Cage Aquaculture-Low input cage culture in Bangladesh. Care Bangladesh, 3-28.

Caulton, M. S. (1982). Feeding, metabolism and growth of tilapias- some quantitative considerations. In: Pullin R.S.V. and Lowe-McConnell R.H. (eds), *The Biology and Culture of Tilapia* (pp. 157-184). ICLARM, Manila, the Philippines.

Cavaillès, M., Konan, K., & Doudet, T. (1981). Essai d'élevage de poissons en cage flottante en eaux continentales. C.T.F.T., Division de Recherches en Pisciculture, Bouaké, Côte d'Ivoire. p. 28.

Chakraborty, S. B., & Banerjee, S. (2012). Comparative growth performance of mixed-sex and monosex Nile tilapia at various stocking densities during cage culture. *Recent Research in Science and Technology*, 4, 46-50.

Chakraborty, S. B., Mazumdar, D., Chatterji, U., & Banerjee, S. (2011). Growth of mixed-sex and mono-sex Nile Tilapia in different culture systems. *Turkish Journal of Fisheries and Aquatic Science*, 11, 131-138. <https://doi.org/10.4194/trjfas.2011.0117>

Coche, A. G. (1978). Revue des pratiques d'élevage de poissons en cage dans les eaux continentales. *Aquaculture*, 13, 157-189. [https://doi.org/10.1016/0044-8486\(78\)90109-6](https://doi.org/10.1016/0044-8486(78)90109-6)

Conover, D. O. (1992). Seasonality and scheduling of life history at different latitudes. *Journal of Fish Biology*, 41, 161-178. <https://doi.org/10.1111/j.1095-8649.1992.tb03876.x>

- Dagne, A., Degefu, F., & Lakew, A. (2013): Comparative growth performance of mono-sex and mixed-sex Nile tilapia (*Oreochromis niloticus* L.) in pond culture system at Sebeta, Ethiopia. *International Journal of Aquaculture*, 3, 30-34.
- Dan, N. C., & Little, D. C. (2000). The culture performance of monosex and mixed-sex new-season and overwintered fry in three strains of Nile tilapia (*Oreochromis niloticus*) in northern Vietnam. *Aquaculture*, 184, 221-231.  
[https://doi.org/10.1016/S0044-8486\(99\)00329-4](https://doi.org/10.1016/S0044-8486(99)00329-4)
- Davies, O. A., Inko-Tariah, M. B., & Amachree, D. (2006). Growth response and survival of *Heterobranchus longifilis* fingerlings fed at different feeding frequencies. *African Journal of Biotechnology*, 5, 778-787.
- De Merona, B., Hecht, T. & Moreau, J. (1988). Croissance des poissons d'eau douce africains. In C. L'évêque, M. N. Bruton & G. W. Ssentongo (eds), *Biologie et Ecologie des Poissons d'Eau Douce Africains* (pp. 191-219). Travaux et Documents de l'ORSTOM.
- de Oliveira, E. G., Pinheiro, A. B., de Oliveira, V. Q., da Silva Júnior A. R. M., de Moraes, M. G., Rocha, I. R. C. B., de Sousa, R. R. & Costa F. H. F. (2012). Effects of stocking density on the performance of juvenile pirarucu (*Arapaima gigas*) in cages. *Aquaculture*, 370-371, 96-101. <https://doi.org/10.1016/j.aquaculture.2012.09.027>
- Dey, M. M., & Gupta, M. V. (2000). Socioeconomics of disseminating genetically improved Nile tilapia in Asia: an introduction. *Aquaculture Economics and Management*, 4, 5-11.  
<https://doi.org/10.1080/13657300009380257>
- Diana, J. S., Lin, C. K., & Schneeberger, P. J. (1991). Relationships among nutrient inputs, water nutrient concentrations, primary production, and yield of *Oreochromis niloticus* in ponds. *Aquaculture*, 92, 323-341. [https://doi.org/10.1016/0044-8486\(91\)90038-9](https://doi.org/10.1016/0044-8486(91)90038-9)
- Ellis, T., North, B., Scott, A. P., Bromage, N. R., Porter, M., & Gadd, D. (2002). The relationships between stocking density and welfare in farmed rainbow trout. *Journal of Fish Biology*, 61, 493-531. <https://doi.org/10.1111/j.1095-8649.2002.tb00893.x>
- Eng, C. T., & Tech, E. (2002). History of cage culture. In P. T. K. Woo (Eds), *Disease and disorders of finfish in cage culture*, 138. CABI publishing.
- Essa, M. A. (1996). The effect of fish density and feeding frequency on both *O. niloticus* and *Mugil cephalus* fish reared as mixed culture on floating eages. *Bull. Nat. Inst. Oceanogr, and Fish. ARE*, 22, 181-197.
- Ezenwaji, B. I. O., & Ikusemiju, K. (1981). Age and growth determinations in the catfish *Chrysichthys nigrodigiralis* (Lacépède) by use of the dorsal spine. *Journal of Fish Biology*. 19, 345-351. <https://doi.org/10.1111/j.1095-8649.1981.tb05837.x>
- Fermon, Y. (2011). La pisciculture de subsistance en étangs en Afrique : manuel technique. Action contre la faim. ACF-International Network, Paris, 276.
- Fitzisimmons, K. (2004). Development of new products and markets for the global tilapia



trade. In R. Bolivar, G. Mair and K. Fitzsimmons (Eds.), *Proceeding of the 6<sup>th</sup> International Symposium on Tilapia in Aquaculture* (pp. 624-633). Manila. Philippines.

Fontaine, P., & Le Bail, P. Y. (2004). Domestication et croissance chez les poissons. *INRA Prod. Anim.*, 17(3), 217-225.

Garcia, J. A., & Villarroel, M. (2009). Effect of feed type and feeding frequency on macrophage functions in tilapia (*Oreochromis niloticus*). *Fish Shellfish immune*, 27(2), 325-329. <https://doi.org/10.1016/j.fsi.2009.05.018>

Ghozlan, A. A., Zaki, M. M., Gaber, M. M., & Nour, A. (2018). Effect of different water sources on survival rate (%), growth performance, feed utilization, fish yield, and economic evaluation on Nile tilapia (*Oreochromis niloticus*) monosex reared in earthen ponds. *Oceanogr, Fish Open Access J.*, 6(1), 1-7. <https://doi.org/10.19080/OFOAJ.2018.05.555676>

Githukia, C. M., Ogello, E. O., Kembenya, E. M., Achieng, A. O., Obiero, K. O., & Munguti, J. M. (2015). Comparative growth performance of male monosex and mixed sex Nile tilapia (*Oreochromis niloticus* L.) reared in earthen ponds. *Croatian Journal of Fisheries*, 73, 20-25. <https://doi.org/10.14798/73.1.788>

Gupta, M. V., & Acosta, B. O. (2004). A review of global tilapia farming practices. *Aquaculture Asia Magazine*, 9, 7-12.

Hengsawat, K., Ward, F. J., & Jaruratjamorn, P. (1997). The effect of stocking density on yield, growth and mortality of African catfish (*Clarias gariepinus* Burchell 1822) cultured in cages. *Aquaculture*, 152, 67-76. [https://doi.org/10.1016/S0044-8486\(97\)00008-2](https://doi.org/10.1016/S0044-8486(97)00008-2)

Hepher, B., & Pruginin, Y. (1981). Commercial fish farming. Wiley-Interscience Publication, New York. p. 261.

Kebede, A. A. (2011). Effect of feed quality on growth performance and water quality in cage culture system for production of Nile tilapia [*Oreochromis niloticus*, (Linnaeus, 1758)] in Lake Hora-Arsedi, Ethiopia. Addis Ababa University, School of graduate studies, Faculty of Life Sciences. Thesis presented in partial fulfillment of the requirement for the Degree of Master of Science in Biology, Ethiopia. p. 87.

Kestemont, P., Jourdan, S., Houbart, M., Mardard, C., Paspatis, M., Fontaine, P., Cuvier-Peres, A., Kentouri, M., & Baras, E. (2003). Size heterogeneity, cannibalism and competition in cultured predatory fish larvae: biotic and abiotic influences. *Aquaculture*, 227, 333-356. [https://doi.org/10.1016/S0044-8486\(03\)00513-1](https://doi.org/10.1016/S0044-8486(03)00513-1)

Khattab, Y. A. E., Ahmad, M. H., Shalaby, A. M. E., & Abdel-Tawwab, M. (2000). Response of Nile tilapia (*Oreochromis niloticus* L.) from different locations to different dietary protein levels. *Egyptian Journal of Aquatic Biology & Fisheries*, 4(4), 295-311.

Lazard, J. (2007). Aquaculture et espèces introduites: Exemple de la domestication ex situ des tilapias. *Cahiers Agricultures*, 16(2), 123-124. <https://doi.org/10.1684/agr.2007.0085>

Lazard, J. (2009). La pisciculture des tilapias. *Cahiers Agricultures*, 18(2-3). 393-401.

<https://doi.org/10.1684/agr.2009.0305>

Lazard, J., & Legendre, M. (1994). La pisciculture africaine: enjeux et problèmes de recherche. Synthèse. *Cahiers Agricultures*, 3, 83-92.

Leatherland, J. F., & Cho, C. Y. (1985). Effect of rearing density on thyroid and internal gland activity and plasma hepatic metabolite levels in rainbow trout, *Salmo gairdneri*, Richardson, *J. Fish. Biol.*, 27, 583-592. <https://doi.org/10.1111/j.1095-8649.1985.tb03203.x>

Legros, D. (1995). Guide technique pour l'élevage du tilapia. CDI, Bruxelles, 1ère édition. p. 45.

Little, D. C., Bhujel, R. C., & Pham, T. A. (2003). Advanced nursing of mixed-sex and mono-sex tilapia (*Oreochromis niloticus*) fry, and its impact on subsequent growth in fertilized ponds. *Aquaculture*, 221, 265–276. [https://doi.org/10.1016/S0044-8486\(03\)00008-5](https://doi.org/10.1016/S0044-8486(03)00008-5)

Lovell, T. (1989). Nutrition and feeding of fish. An AVI Book- Van Nostrand Reinhold, New York, NY, USA. p. 260. <https://doi.org/10.1007/978-1-4757-1174-5>

Macintosh, D. J., Varghese, T. J., & Satyanarayana, G. P. (1985). Hormonal sex reversal of wild spawned tilapia in India. *Journal of Fish Biology*, 26, 87-94. <https://doi.org/10.1111/j.1095-8649.1985.tb04245.x>

Mair, G. C., Abucay, J. S., Beardmore, J. A., & Skibinski, D. O. F. (1995). Growth performance trials of genetically male tilapia (GMT) derived from YY-males in *Oreochromis niloticus* L.: On station comparisons with mixed sex and sex reversed male populations. *Aquaculture*, 137, 313-322. [https://doi.org/10.1016/0044-8486\(95\)01110-2](https://doi.org/10.1016/0044-8486(95)01110-2)

McGinty, A., & Rakocy, J. (2005). Cage culture. Southern Regional Agricultural Center Extension. Service. USA, 4.

Micha, J. C. (1973). Etude des populations piscicoles de l'Oubangui et tentatives de sélection et d'adaptation de quelques espèces à l'étang de pisciculture *ED.C.T.F.T.*, Paris. p. 110.

Mihelakakis, A., Tsolkas, C., & Yoshimatsu, T. (2002). Optimization of feeding rate for hatchery produced juvenile gilthead sea bream *Sparus aurata*. *Journal of World Aquaculture Society*, 33, 169-175. <https://doi.org/10.1111/j.1749-7345.2002.tb00491.x>

Mires, D. (1995). The tilapias. In C. E. Nash and A. J. Novotony (Eds.), *Production of Aquatic Animals: Fishes* (pp.133-152). Elsevier, New York.

Moniruzzaman, M., Uddin, K. B., Basak, S., Mahmud, Y., Zaher, M., & Bai, S. C. (2015). Effects of Stocking Density on Growth, Body Composition, Yield and Economic Returns of Monosex Tilapia (*Oreochromis niloticus* L.) under Cage Culture System in Kaptai Lake of Bangladesh. *Journal of Aquaculture Research and Development*, 6(8), 1-7. <https://doi.org/10.4172/2155-9546.1000357>

Moraes, A. M., Seiffert, W. Q., Tavares, F., & Fracalossi, D. M. (2009). Desempenho zootécnico de tilápia do Nilo, *Oreochromis niloticus*, em tanques-rede, com diferentes raças comerciais. *Revista Ciência Agronômica*, 40, 388-395.

- Morgan, P. R. (1972). Causes of mortality in the endemic Tilapia of Lake Chilwa (Malawi). *Hydrobiologia*, 40, 101-119. <https://doi.org/10.1007/BF00123596>
- Mugo-Bundi, J., Oyoo-Okoth, E., Ngugi, C. C., Manguya-Lusega, D., Rasowo, J., & Chepkirui, B. V. (2013). Utilization of *Caridina nilotica* (Roux) meal as a protein ingredient in feeds for Nile tilapia (*Oreochromis niloticus*). *Aquaculture Resources*, 2, 1-12. <https://doi.org/10.1111/are.12181>
- Ng, W. K., Lu, K. S., Hashim, R., & Ali, A. (2000). Effects of feeding rate on growth, feed utilization and body composition of tropical bagrid catfish. *Aquaculture International*, 8, 19-29. <https://doi.org/10.1023/A:1009216831360>
- Nguyen, N. H., Khaw, H. L., Ponzoni, R. W., Hamzah, A., & Kamaruzzaman, N. (2007). Can sexual dimorphism and body shape be altered in Nile tilapia by genetic means? *Aquaculture*. 272. S36-S48. <https://doi.org/10.1016/j.aquaculture.2007.08.013>
- Ouattara, N. I., Teugels, G. G., N'Douba, V., & Philippart, J. C. (2003). Aquaculture potential of the black-chinned tilapia, *Sarotherodon melanotheron* (Cichlidae). Comparative study of the effect of stocking density on growth performance of landlocked and natural population under cage culture conditions in Lake Ayame (Côte d'Ivoire). *Aquaculture Research*, 34, 1223-1229. <https://doi.org/10.1046/j.1365-2109.2003.00921.x>
- Panfili, J., De Pontual, H., Troadec, H., & Wright, P. J. (2002). Manuel de Sclérochronologie des Poissons. IFREMER/IRD. p. 464. <https://doi.org/10.4000/books.irdeditions.20901>
- Pauly, D. (1983). Some simple methods for the assessment of tropical fish stocks. *FAO Fisheries Technical Paper No. 234*. FAO, Rome.
- Pillay, T. V. R. (1990). *Aquaculture: principles and practices*. Fishing News Book. Blackwell Scientific Publications, Ltd., Oxford, UK. p. 575.
- Ponzoni, R. W., Hamzah, A., Saadiah, T., & Kamaruzzaman, N. (2005). Genetic parameters and response to selection for live weight in the GIFT strain of Nile tilapia (*Oreochromis niloticus*). *Aquaculture*. 247. 203-210. <https://doi.org/10.1016/j.aquaculture.2005.02.020>
- Rakocy, J. E. & McGinty A. S. (1989). Pond culture of tilapia. Southern Regional Aquaculture Center (SRAC) publication, 280, 1-4.
- Ricker, W. E. (1973). Linear regression in fisheries research. *Journal of the Fisheries Research Board of Canada*, 30, 409-434. <https://doi.org/10.1139/f73-072>
- Ridha, M. T. (2011). Evaluation of monosex culture of GIFT and non-improved strains of Nile tilapia *Oreochromis niloticus* in recirculating tanks. *International Aquatic Resources*, 3, 189-195.
- Ross, L. G. (2000). Environmental physiology and energetics. In M. C. M. Beveridge and B. J. McAndrew (eds.), *Tilapias: Biology and Exploitation* (pp.89-128). Fish and Fisheries Series 25, Kluwer Academic Publishers, Dordrecht, The Netherlands. [https://doi.org/10.1007/978-94-011-4008-9\\_4](https://doi.org/10.1007/978-94-011-4008-9_4)

- Sarig, S. (1969). Winter storage of tilapia. *FAO Fish Culture Bulletin*, 2, 8-9.
- Shugunan, V. V. (1997). Fisheries management of small water bodies in seven countries in Africa, Asia and Latin America. *FAO Fisheries Circular* No. 933, Rome, FAO. p.149.
- Silva, T. S. D. C., dos Santos L. D., da Silva, L. C., Michelato, M., Furuya, V. R. B., & Furuya, W. M. (2015). Length–weight relationship and prediction equations of body composition for growing-finishing cage-farmed Nile tilapia. *Revista Brasileira Zootecnia*, 44(4), 133-137. <https://doi.org/10.1590/S1806-92902015000400001>
- Slawski, H., Adem, H., Tressel, R. P., Wysujack, K., Kotzamanis, Y., & Schulz, C. (2011). Austausch von Fischmehl durch Rapsproteinkonzentrat in Futtermitteln für Steinbutt (*Psetta maxima* L). *Zichtungskunde*, 83, 451-460.
- Smith, E. S., & Phelps, R. P. (2001). Impact of feed storage conditions on growth and efficacy of sex reversal of Nile tilapia. *North American Journal of Aquaculture*, 63, 242-245. [https://doi.org/10.1577/1548-8454\(2001\)063<0242:IOFSCO>2.0.CO;2](https://doi.org/10.1577/1548-8454(2001)063<0242:IOFSCO>2.0.CO;2)
- Stiassny, M. L. J., Teugels, G. G., & Hopkins, C. D. (2007). Poissons d'eaux douces et saumâtres de basse Guinée, ouest de l'Afrique centrale, Vol. I. p. 805.
- Symons, P. E. K. (1971). Behavioural adjustment of population density to available food by juvenile Atlantic salmon. *Journal of Animal Ecology*, 40, 569-587. <https://doi.org/10.2307/3438>
- Thirupathaiyah, M., Samatha, Ch. & Sammaiah, C. (2012). Analysis of water quality using physico-chemical parameters in lower manair reservoir of Karimnagar district, Andhra Pradesh. *International Journal of Environmental Sciences*, 3(1), 172-180.
- Toguyeni, A., Fauconneau, B., Boujard, T., Fostier, A., Kuhn, R. E., Mol, K. A., & Baroiller J. F. (1997a). Feeding behaviour and food utilisation in tilapia, *Oreochromis niloticus*: Effect of sex ratio and relationship with the endocrine status. *Physiology and Behavior*, 62(2), 273-279. [https://doi.org/10.1016/S0031-9384\(97\)00114-5](https://doi.org/10.1016/S0031-9384(97)00114-5)
- Toguyeni, A., Fauconneau, B., Fostier, A., Abucay, A., Mair, G., & Baroiller, J. F. (2002). Influence of sexual phenotype and genotype, and sex ratio on growth performances in tilapia, *Oreochromis niloticus*. *Aquaculture*, 207, 49-261. [https://doi.org/10.1016/S0044-8486\(01\)00747-5](https://doi.org/10.1016/S0044-8486(01)00747-5)
- Wagdy, K. B. K., Wafaa, S. H., Mohamed-Assem, S. M., Hossam, H. A., & Eman, A. Z. (2011). Assessment the impact of 17 $\alpha$ -methyltestosterone hormone on growth, hormone concentration, molecular and histopathological changes in muscles and testis of Nile tilapia; *Oreochromis niloticus*. *Life Science Journal*, 8(3), 329-343.
- Weatherley, A. H., & Gill, H. S. (1987). The biology of fish growth. Academic Press, London.
- Woche, H., Harsányi, A., & Schwarz, F. J. (2011). Husbandry conditions in burbot (*Lota lota* L.): impact of shelter availability and stocking density on growth and behaviour. *Aquaculture*, 315, 340-347. <https://doi.org/10.1016/j.aquaculture.2011.01.051>

---

Yager, T. K., & Summerfelt, R. C. (1993). Effects of fish size and feeding frequency on metabolism of juvenile walleye. *Aquacultural Engineering*, *13*, 257-282.  
[https://doi.org/10.1016/0144-8609\(94\)90015-9](https://doi.org/10.1016/0144-8609(94)90015-9)

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