www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 11: 131-138 (2011) DOI: 10.4194/trjfas.2011.0117

Growth of Mixed-Sex and Monosex Nile Tilapia in Different Culture Systems

Suman Bhusan Chakraborty[1,*], Debasis Mazumdar[2], Urmi Chatterji[3], Samir Banerjee[3]

[1] Serampore College, Dept. of Zoology, West Bengal, India.
[2] Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, India.
[3] University of Calcutta, Dept. of Zoology, West Bengal, India.

* Corresponding Author: Tel.: +91.033 26622322; Fax: +91.033 26623816;
E-mail: sumanbc76@gmail.com

Received 15 April 2010
Accepted 09 January 2011

Abstract

Growth of 17α-methyltestosterone treated monosex Nile tilapia, *Oreochromis niloticus* was compared with hormone untreated mixed-sex fish in four different culture systems. The experiment had 2 X 4 factorial design: the first factor was presence or absence of hormone treatment (monosex and mixed-sex fish), the second factor was related to culture system (cistern, flow-through, pen and pond). Fish were cultured under similar feeding regime and stocking density for six months and different growth parameters such as body weight, length, daily weight gain (DWG), specific growth rate (SGR), proximate body composition and survival rate were analyzed. Monosex tilapia showed significantly higher (P-value <0.05) weight, length, DWG, SGR and protein content than mixed-sex fish. Fish in Pond culture showed significantly higher (P-value <0.05) weight, DWG and protein content than fish in other 3 culture systems. Survival was not significantly different (P>0.05) among mixed-sex and monosex fish and between different culture systems. Monosex tilapia in pond culture system showed the highest weight, DWG and protein content while mixed-sex tilapia in cistern culture system showed the lowest weight, DWG and protein content. Considering the results of this study, culture of monosex tilapia in earthen ponds might be considered the ideal method for tilapia culture in India.

Keywords: *Oreochromis niloticus*, monosex culture, growth in different culture systems.

Monoseks ve Karma Nil Tilapiyasının Farklı Kültür Sistemlerinde Büyümesi

Özet

Dört farklı kültür sisteminde 17 α – metiltestosteron uygulaması yapılan tek cinsiyetli Nil Tilapiyasının, *Oreochromis niloticus* büyümesi ile hormon uygulanması yapılmayan karma cinsiyetli balıklar karşılaştırılmıştır. Deney, 2 X 4 etmensel tasarımdan oluşmaktadır: birinci etmen hormon uygulaması (tek cinsiyet ve karma cinsiyetli balık), ikinci etmen ise kültür sistemidir (rezervuar, tek kullanım sistemi, kafes ve havuz sistemi). Altı ay boyunca balıklar beslenme ve stoklama yoğunluğunun benzer olduğu koşullarda kültüre alınmış; vücut ağırlığı, boy, günlük ağırlık artışı (DWG), spesifik büyüme oranı (SGR), yaklaşık vücut kompozisyonu ve yaşama oranı gibi farklı büyüme parametreleri analiz edilmiştir. Tek cinsiyetli tilapyanın, karma cinsiyetli balıklarla karşılaştırıldığında istatistiksel olarak daha yüksek (P<0,05) ağırlık, boy, DWG, SGR ve protein içeriğine sahip olduğu gösterilmiştir. Havuzda kültüre alının balıklar ise diğer 3 kültür sistemindeki balıklarla karşılaştırıldığında istatistiksel olarak daha yüksek (P<0,05) ağırlık, DWG ve protein içeriğine sahip olduğu gösterilmiştir. Karma cinsiyetli ve tek cinsiyetli balıklar içerisinde ve farklı kültür sistemleri arasında yaşama oranında istatistiksel olarak anlamlı fark bulunmamıştır (P>0,05). Havuz kültür sistemlerindeki tek cinsiyetli tilapiyanın en yüksek ağırlığa, DWG ve protein içeriğine sahip olurken, rezervuar kültür sistemindeki karma cinsiyetli tilapiyanın en düşük ağırlığa, DWG ve protein içeriğine sahip olduğu gösterilmiştir. Bu çalışmanın sonuçları dikkate alındığında tek cinsiyetli tilapiyanın toprak havuzlarda kültüre alınması, Hindistan'da tilapiya kültürü için en ideal yöntem olduğu düşünülebilir.

Anahtar Kelimeler: *Oreochromis niloticus*, monoseks, farklı kültür sistemleri, büyüme.

Introduction

The Nile tilapia, *Oreochromis niloticus* (Linnaeus) is one of the most important species of fish in tropical and sub-tropical aquaculture (FAO, 2007). It provides one of the major sources of animal protein and income throughout the world (Sosa *et al*., 2005). It is currently ranked second only to carps in global production and is likely to be the most important cultured fish in the 21st century (Ridha, 2006). Farmed tilapia production throughout the world increased dramatically in recent years, increasing

from 383,654 mt in 1990 to 2,326,413 mt in 2006 (FAO, 2007). Tilapia grows and reproduces in a wide range of environmental conditions and tolerates stress induced by handling (Tsadik and Bart, 2007). However, this efficiency of reproduction in tilapia has undesirable consequences. Problems common for many tilapia culture systems are the reduction of growth rates at the onset of sexual maturity and precocious and excessive reproduction, leading to various sizes of small fish production (Lèveque, 2002). There are a number of ways to control reproduction in mixed-sex population. One of these is the culture of all-male tilapia (Phelps and Popma, 2000). Moreover, sex-specific differences in growth were significant in *O. niloticus* where males grow significantly faster, larger and more uniform in size than females (Bwanika *et al*., 2007). The desirability of monosex male populations of tilapia is well established for increased production potential and low management requirements (Pillay, 1993; Beardmore *et al*., 2001; El-Sayed, 2006). The development of strategies for generation of monosex populations remains a critical objective for tilapia culture industry.

O. niloticus has an XX/XY chromosome sex determination system (Baroiller *et al*., 2009), but the process of sex differentiation is labile rendering sex reversal possible in the species (Devlin and Nagahama, 2002). Several techniques have been adopted for production of monosex (all-male) tilapia (Phelps and Popma, 2000), and hormonal sex reversal of tilapia has been an active area of research for the past three decades (Pandian and Varadaraj, 1988; Gale *et al*., 1999; Carrasco *et al*., 1999; Afonso *et al.*, 2001). Oral administration of exogenous male sex steroid hormones before the differentiation of primal gonadal cells can cause reversal of phenotypic sex (Smith and Phelps, 2001; Bhandari *et al*., 2006). In an earlier study, almost 100% all-male monosex tilapia population was produced by treating 3 days old fry with a synthetic male hormone 17α-methyltestosterone (17αMT) at a treatment regime of 10 mg kg^{-1} food for 30 days (Chakraborty *et al*., 2007).

The success of the culture methods applied for tilapia farming depends on various factors and determination of the optimal method under a certain condition can be quite complex (Graaf *et al*., 2005). Various traditional and non-traditional tilapia farming methods are adapted in different countries in accordance with the socioeconomic and ecological condition of that place (Lèveque, 2002). It is often cultured in earthen ponds without supplemental feeding (Liti *et al.*, 2005). Pond culture provides an opportunity to balance the use of supplementary feeding in correlation with the natural food availability. Intensive culture of tilapia in tanks has been globally expanding (El-Sayed, 2006). Several factors such as savings in manpower and easier stock management are the main reasons for intensification of fish farming in concrete cisterns in many countries (El-Saidy and Gaber, 2005). Pen culture of tilapia in open waters of lakes is practised in the Philippines on an appreciable scale (Pillay, 1993). Pens have natural earthen substrata as the bottom surface and fish in pen culture are at an advantage that while enclosed they can still procure some natural food and exchange materials. Still, in order to sustain a high biomass within a restricted area, intensive pen culture requires supplementary feeding and maintenance of good water flow. Flow-through technology can be applied in many tropical locations where large volumes of warm flowing water are available (Soderberg, 2006). But construction of such modern intensive culture systems is fairly complex, expensive and requires constant, close monitoring (Lèveque, 2002).

Tilapia has been widely introduced in the shallow and seasonal ponds of eastern region of India. But, its performance in open water ponds of the country has been discouraging over the years (Jhingran, 1991). Increase in yields can result from the development and adoption of new technologies and improved farming operations (Coelli, 1995a). The importance of monosex tilapias has been established in many commercial contexts but there are relatively few published studies comparing the growth performance of androgen treated monosex Nile tilapia with mixed-sex tilapia, under culture, especially from the Indian perspective (Pandian and Varadaraj, 1988; Mair *et al*., 1995). Hence, the propagation potentiality of sex-reversed tilapia under various traditional and nontraditional culture practices must be clearly documented. Thus, the main objective of this study was to establish a sustainable aquaculture method for the production of a major animal protein source by comparing the growth pattern of monosex tilapia with mixed-sex fish under various culture systems.

Materials and Methods

Experimental Design

The experiment had 2x4 factorial design: the first factor was presence or absence of dietary treatment with 17αMT (monosex and mixed-sex tilapia), the second factor was related to culture system (Cistern, Flow-through, pen and pond).

Culture Systems

The growth potentialities of the mixed-sex control and monosex androgen treated tilapia were analyzed in concrete cistern, flow-through system, pen and earthen pond culture systems. The cistern culture system consisted of six 9 m^3 rectangular concrete tanks; the flow-through system consisted of six 9 m^3 rectangular concrete tanks with continuous water flow at a constant rate of 4 L min^{-1} through it; pen culture system consisted of six 9 m^3 fixed

enclosures constructed from bamboo and the pond culture system consisted of six 9 m^3 earthen ponds. The pens were placed in a large natural water body at the Agricultural Field Station, University of Calcutta, West Bengal, India. The experimental ponds were located beside the natural water body. Before starting the experiment, the ponds were completely drained, reshaped and manually cleaned of aquatic vegetation and unwanted fish. Semi-dry pond bottoms were limed with $CaCO_3$ at the rate of 250 kg ha^{-1}. After one week of liming, all ponds were fertilized with semi-decomposed cattle manure at the rate of 1.5 tons ha^{-1}. The ponds were filled with water from the natural water body through a screened inlet pipe after one week of manure application and water level was maintained through weekly additions. Water from the same natural water body was pumped through screened inlet pipes in cisterns and flow-through systems. Water in the cisterns was partially exchanged on a weekly basis. Throughout the entire culture period different water quality parameters like temperature, O_2, free CO_2, pH, total alkalinity and turbidity were regularly monitored using the standard procedures of American Public Health Association (APHA, 1998) and maintained within ideal value limits for all the culture systems. During the experimental period, water temperature was 30.5-31.2°C, pH was 7.3-8.1, turbidity was 27.8-40.6 cm, alkalinity was 122.1-143.6 mg L^{-1}, DO_2 was 4.8-6.3 mg L^{-1} and free CO_2 was 2.8-7.6 mg L^{-1}.

Monosex Tilapia Production

Three days old mixed sex juveniles of Nile tilapia (mean weight 0.02±0.003 g; mean length 0.98±0.02 cm) were collected from the Fish Hatchery at Naihati, West Bengal. The fish were initially reared in 200 litre aerated aquaria at laboratory for one month. In the laboratory, the fish were divided into two equal groups. During these 30 days, one of the groups was fed with 17αMT treated diet with a dose of 10 mg kg^{-1} at a rate of 20% body weight day^{-1} while the other was given hormone untreated control diet at the same feeding rate. Hormone treated diet was prepared by the alcohol evaporation technique (Shelton *et al.*, 1978). Water in all aquaria were replaced weekly and the fish were kept under similar photoperiod (14 L: 10 D), temperature (T=27±2°C) and density (10 fish L^{-1}). The experiment was conducted in triplicate.

Grow-Out Performance Analysis

After one month, 3 tanks, 3 flow-through systems, 3 pens and 3 ponds were stocked with the mixed-sex control fish while the other 3 tanks, 3 flow-through systems, 3 pens and 3 ponds were stocked with the 17αMT treated monosex fish. All the culture systems were stocked with similar density of fish (50 fish m^{-3}). The fish were cultured for another five months. Here, all fish were fed twice daily with an artificial diet (Uno Feeds, India) containing 32% crude protein at a rate of 10% body weight day^{-1} for the first two months and 5% body weight day^{-1} for the rest three months. Hundred fish from each tank, flow-through, pen and pond were randomly sampled every 2 weeks to measure their weight and length. All fish were harvested at the end of culture period, counted, and measured individually for weight and length. Growth parameters such as specific growth rate (SGR), daily weight gain (DWG), food conversion ratio (FCR), protein efficiency ratio (PER), apparent net protein utilization (ANPU), and survival rate were calculated as follows (Pechsiri and Yakupitiyage, 2005):

SGR (% day^{-1}) = [(ln final weight – ln initial weight) / time (days)] X 100

DWG (g day^{-1}) = mean final weight (g) – mean initial weight (g) / days

FCR = total amount of dry feed consumed (g) / wet weight gain of fish (g)

PER = weight gain (g) / protein consumed (g)

ANPU = (total final body protein – total initial body protein) / protein consumed

Survival rate (%) = (final number of fish / initial number of fish) X 100

Five fish from each cistern, flow-through, pen and pond were randomly sampled and frozen at -30°C for whole body composition analysis (% wet weight basis) using standard methods (AOAC, 1984). Crude protein (N x 6.25) was determined using the Kjeldahl nitrogen method. Lipid content was determined gravimetrically following ether extraction. Total ash contents were calculated gravimetrically following ignition of samples in a muffle furnace at 550°C until constant weight. Moisture content was calculated by oven drying at 105°C until constant weight. Secondary sexual characteristics (especially genital papilla) were used to distinguish males from females. Also, the structure of the testes and ovaries were observed by naked eye and examined under light microscopy (Olympus BX50).

Statistical Analysis

The data are expressed in terms of mean ± standard error. All growth parameters were analyzed by two-way ANOVA with 17αMT treatment (with treatment monosex and without treatment mixed-sex) and culture systems (cistern, flow-through, pen, pond) as main factors. The main factor effects means along with interaction means were compared with Fisher's LSD test (at 5%) (Fisher, 1935), if found significant. The statistical works were performed using SPSS 10.0 version for Windows.

Results

After the first month of culture in the laboratory, the weight of the 17αMT treated tilapia was 12.5±0.04 g and that of hormone untreated control tilapia was 5.7±0.03 g. The hormone untreated mixed-sex group had 52±0.4% males while 17αMT treatment produced all-male monosex fish. Effects of 17αMT treatment (monosex and mixed-sex tilapia) and different culture systems (cistern, flow-through, pen, pond), and their interactions on growth parameters of tilapia are given in Table 1. Final weight, length, DWG, SGR, PER and protein content were significantly higher (P<0.05) in 17αMT treated monosex tilapia compared to the untreated mixed-sex fish (Table 1). There was no significant effect (P>0.05) of hormone treatment on survival rate, lipid and ash content of tilapia (Table 1). FCR, ANPU and moisture content of the monosex fish were significantly lower (P<0.05) than those of the mixed-sex fish (Table 1).

Survival of fish for all culture systems was around 91% and culture system had no significant effect on survival rate (Table 1). Final weight, FCR, DWG and protein content were significantly different (P<0.05) for all the culture systems (Table 1). The highest final weight, DWG and protein content were observed in pond culture system, followed by pen, flow-through and cistern culture systems (Table 1). FCR was the highest in pen culture system, followed by pond, flow-through and cistern culture systems (Table 1). Final length of the cistern culture system was significantly lower (P<0.05) than the other three culture systems (Table 1). The highest final length was observed in pond culture system, it was significantly higher (P<0.05) than the final length in flow-through culture system, but not significantly different (P>0.05) from that in pen culture system (Table 1). SGR of cistern culture was the lowest among the culture systems, but it was significantly different (P<0.05) only from pond culture system that showed the highest SGR (Table 1). PER in pen culture was significantly lower (P<0.05) than the other three culture systems (Table 1). The highest PER was observed in cistern culture system and it was significantly higher (P<0.05) than that in pond culture system (Table 1). PER in flow-through culture system was not significantly different (P>0.05) from PER in pond or cistern culture systems (Table 1). ANPU in cistern and flow-through culture systems were significantly higher (P<0.05) than ANPU in pen and pond culture systems (Table 1). Moisture content was the lowest in flow-through culture system but it was not significantly different (P>0.05) from that in pond culture system (Table 1). Moisture content in pen culture was significantly higher (P<0.05) than flow-through and pond culture systems, but it was significantly lower (P<0.05) than that in cistern culture system (Table 1). Lipid contents of pond and flow-through culture systems were significantly higher (P<0.05) than lipid contents of cistern and pen culture systems (Table 1). Ash content of pen culture system was significantly lower (P<0.05) compared to other three culture systems, which had was no significant difference (P>0.05) (Table 1).

Significant interaction effects (P<0.05) of hormone treatment and culture systems were observed for growth parameters such as final weight, DWG, FCR, ANPU, protein and ash content (Tables 1, 2). Within mixed-sex control group, final weight, DWG, FCR and protein content of every culture system were significantly different (P<0.05) from each other

Table 1. Two-way ANOVA comparing growth parameters of tilapia between 17αMT treatment (without treatment mixed-sex control and with treatment monosex) and culture systems (cistern, flow-through, pen and pond)*

Parameters	Treatment category (T)		Culture system (C)				
	Mixed-sex control	Monosex 17α-MT treated	Cistern	Flow-through	Pen	Pond	T X C
Survival rate (%)	90.83±0.4^{x}	91.0±0.3^{x}	91.0±0.5^{a}	91.0±0.5^{a}	90.83±0.4^{a}	90.83±0.5^{a}	NS
Final weight (g)	75.72±1.7^{x}	243.33±5.88^{y}	126.0±14.98^{a}	153.2±17.84^{b}	170.75±20.68^{c}	188.15±23.47^{d}	S
Final length (cm)	16.49±0.3^{x}	22.92±0.2^{y}	18.17±0.7^{a}	19.52±0.8^{b}	20.17±0.8^{bc}	20.97±0.9^{c}	NS
DWG (g day^{-1})	0.42±0.02^{x}	1.35±0.06^{y}	0.7±0.16^{a}	0.85±0.19^{b}	0.96±0.22^{c}	1.05±0.25^{d}	S
SGR (% day $^{-1}$)	4.6±0.05^{x}	5.25±0.04^{y}	4.8±0.1^{a}	4.92±0.09^{ab}	4.97±0.1^{ab}	5.02±0.1^{b}	NS
FCR	3.6±0.02^{y}	3.46±0.03^{x}	3.44±0.04^{a}	3.51±0.03^{b}	3.63±0.02^{d}	3.54±0.03^{c}	S
PER	0.92±0.01^{x}	0.97±0.01^{y}	0.97±0.01^{c}	0.96±0.01^{bc}	0.92±0.01^{a}	0.95±0.02^{b}	NS
ANPU	0.138±0.003^{y}	0.063±0.003^{x}	0.103±0.01^{b}	0.108±0.02^{b}	0.094±0.02^{a}	0.095±0.02^{a}	S
Protein (% wet weight)	12.63±0.25^{x}	15.33±0.12^{y}	11.73±0.61^{a}	13.88±0.33^{b}	14.08±0.32^{c}	14.42±0.28^{d}	S
Moisture (% wet weight)	78.0±0.59^{y}	75.03±0.62^{x}	80.46±0.64^{c}	74.76±0.47^{a}	77.86±0.88^{b}	74.99±0.82^{a}	NS
Lipid (% wet weight)	5.14±0.38^{x}	5.1±0.15^{x}	3.73±0.3^{a}	6.35±0.28^{b}	4.53±0.62^{a}	5.91±0.38^{b}	NS
Ash (% wet weight)	3.69±0.1^{x}	3.76±0.26^{x}	3.79±0.2^{b}	4.08±0.1^{b}	3.17±0.18^{a}	3.82±0.26^{b}	S

*Notations x and y are to compare between the means of hormone treatment category, and notations a, b, c and d are to compare between the means of culture systems. Values with different superscripts are significantly different (P<0.05). NS: Not significant. S: Significant. Initial mean weight of fish for all treatment was 0.02±0.003 g.

Table 2. Final weight, DWG, FCR, ANPU, protein and ash content of 17αMT treated monosex and untreated mixed-sex control tilapia in different culture systems*

Treatment category	Culture system	Parameters					
		Final weight (g)	DWG (g day^{-1})	FCR	ANPU	Protein (% wet weight)	Ash (% wet weight)
Mixed-sex control	Cistern	60.8±1.6^{a}	0.33±0.006^{a}	3.54±0.009^{d}	0.13±0.004^{c}	10.3±0.05^{a}	4.29±0.1^{e}
	Flow-through	75.5±1.6^{b}	0.43±0.006^{b}	3.58±0.009^{e}	0.148±0.005^{d}	13.1±0.06^{b}	3.79±0.04^{d}
	Pen	80.7±1.7^{c}	0.46±0.003^{c}	3.68±0.003^{g}	0.138± 0.005^{cd}	13.38±0.06^{c}	3.39±0.23^{cd}
	Pond	85.9±1.7^{d}	0.48±0.009^{d}	3.62±0.003^{f}	0.135± 0.003^{c}	13.76±0.05^{d}	3.3±0.23^{bc}
Monosex 17α-MT treated	Cistern	191.2±0.13^{e}	1.07±0.003^{e}	3.35±0.009^{a}	0.075± 0.003^{b}	14.58±0.05^{e}	2.8±0.04^{ab}
	Flow-through	230.9±0.1^{f}	1.27±0.003^{f}	3.44±0.003^{b}	0.068± 0.003^{b}	15.43±0.08^{f}	4.7±0.05^{ef}
	Pen	260.8±0.13^{g}	1.46±0.007^{g}	3.58±0.007^{e}	0.053± 0.003^{a}	15.58±0.1^{fg}	2.7±0.09^{a}
	Pond	290.4±0.16^{h}	1.61±0.003^{h}	3.47±0.003^{c}	0.055± 0.003^{a}	15.73±0.09^{g}	4.8 0.05^{f}

*Notations a, b, c, d, e, f, g and h are to compare among the means of different culture systems for mixed-sex control and 17αMT treated monosex tilapia within the same column. Values with different superscripts are significantly different (P<0.05). Initial mean weight of fish for all treatment was 0.02±0.003 g.

(Table 2). The highest final weight, DWG and protein content were observed in pond culture system followed by pen, flow-through and cistern culture systems (Table 2). FCR was the highest in pen culture system, followed by pond, flow-through and cistern culture cystems (Table 2). Similar observations were found for final weight, DWG and FCR in monosex fish (Table 2). In monosex fish, protein content in pond culture system was significantly higher (P<0.05) than those in flow-through and cistern culture systems, but showed no significant difference (P>0.05) from that in pen culture system (Table 2). In mixed-sex fish, ANPU in cistern and pond culture systems were significantly lower (P<0.05) than that in flow-through culture system (Table 2), while ANPU for pen culture system was not significantly different (P>0.05) from any other culture systems (Table 2). In monosex fish, ANPU for pond and pen culture systems were significantly lower (P<0.05) than those in cistern and flow-through culture systems (Table 2). In mixed-sex fish, the highest ash content was observed in cistern culture system, while in monosex fish, pond culture showed the highest ash content (Table 2). In all 4 culture systems final weight, DWG and protein content were significantly higher (P<0.05), while FCR and ANPU were significantly lower (P<0.05) in monosex tilapia than those in mixed-sex fish (Figure 1, Table 2). In cistern and pen culture systems, ash content of mixed-sex fish was significantly higher (P<0.05) than monosex tilapia; but in flow-through and pond culture systems, ash content of monosex fish were found significantly higher (P<0.05) than mixed-sex tilapia (Table 2).

Discussion

17αMT treatment was reported to have no effect on survival of tilapia (Vera Cruz and Mair, 1994). In this study also, similar survival rates were observed in both mixed-sex and monosex fish. Hormone treated monosex tilapia achieved greater mean individual weight and length than mixed-sex fish (Tables 1, 2 and Figure 1). Increase in individual growth of Nile tilapia during monosex culture was observed in different studies (Mair *et al.*, 1995; Dan and Little, 2000; Little *et al.*, 2003). Faster growth of monosex tilapia has been related to the lack of energy expenditure in egg production and mouth brooding by females and lower energy expenditure on courtship by males (Dan and Little, 2000; Tran-Duy *et al*., 2008). However, no spawning was observed in mixed-sex fish under any culture system in the present study. During sexing of fish at harvest, many females from all the culture systems were found to possess ovaries filled with eggs and further lengthening of culture duration might have resulted in subsequent spawning. Growth increase in androgen treated fish was also reported in *Oreochromis mossambicus* (Kuwaye *et al.*, 1993), *Oncorhynchus kisutch* and *Cyprinus carpio* (Pandian and Sheela, 1995). Shepherd *et al*. (1997) suggested that the growth-promoting actions of 17αMT in tilapia were linked to elevations in growth hormone (GH) metabolism and consequently to insulin-like growth factors (IGFs). Several studies are in agreement that testosterone produces muscle hypertrophy by increasing muscle protein synthesis (Bhasin *et al.*, 2001). The increased growth performance and greater protein content of the androgen treated monosex tilapia compared to the mixed-sex control fish for every respective culture system might have been analyzed considering this knowledge. But, many workers have reported no significant difference in growth between 17αMT treated, sex-reversed males and genetic males in tilapia (Phelps and Popma, 2000). Thus, the anabolic effect resulting from the use of 17αMT to sex reverse tilapia is difficult to identify and further analysis with genetic males and YY males are needed in this regard.

There was a general decrease in FCR and increase in PER for monosex fish compared to the mixed-sex fish. Such observation may be related to the fact that FCR decreases while PER increases with increased feeding rate (Pechsiri and Yakupitiyage, 2005). It has been observed that for a given food

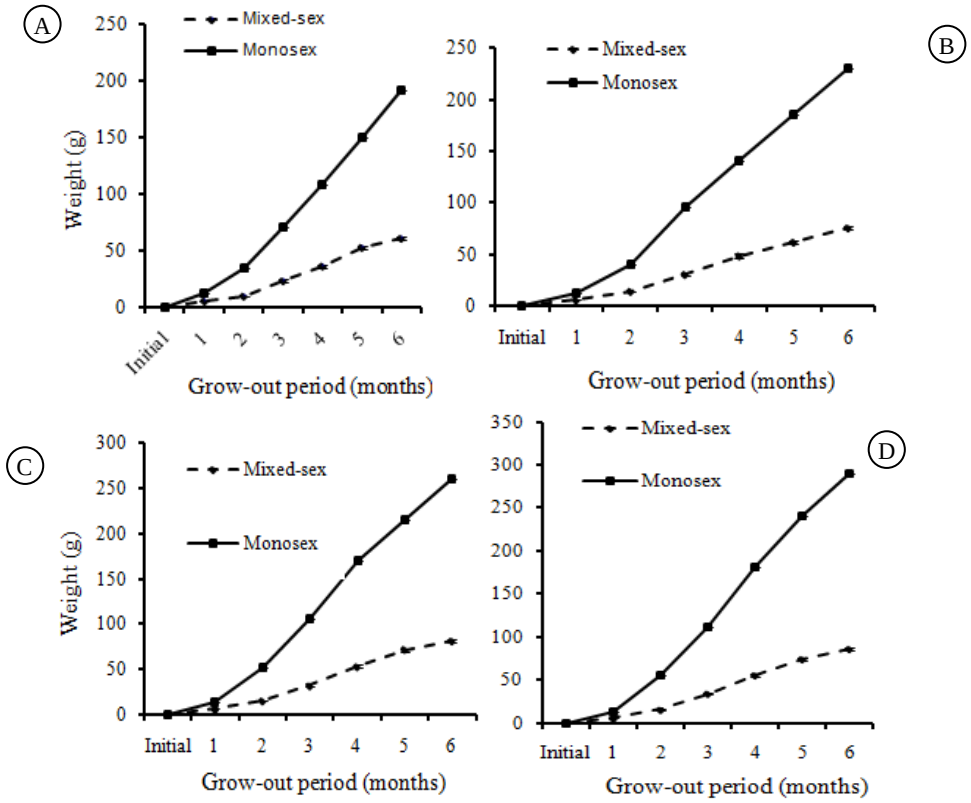

Figure 1. Growth rate of mixed-sex control and monosex 17αMT treated Nile tilapia in (A) cistern, (B) flow-through, (C) pen and (D) pond culture systems.

composition, the body protein percentage on a wet weight basis is mainly affected by the body weight in salmonids (Shearer, 1994). Similar observations have been noticed in Nile tilapia also where body protein content increases with increasing wet weight (Pouomogne and Mbongblang, 1993; Abdelghany and Mohammed, 2002). This explains the higher protein content of the monosex fish than the corresponding mixed-sex fish. The moisture content in monosex tilapia was significantly lower ($P<0.05$) than the mixed-sex fish. But, Killian and Kohler (1991) recorded significant increase in moisture content in 17αMT treated coho salmon.

The better growth of fish in pond culture system compared to the other three culture methods can be facilitated by the additional availability of relatively energy-rich natural food materials that may confer an energetic advantage for increased growth (El-Sayed, 2002, Bwanika *et al.*, 2007). Fish in pen culture system might also have access to natural food materials, but to lesser extent than fertilized ponds. Availability of natural food in pond and pen culture systems might have resulted in less consumption of supplemented food, leading to comparatively poorer feed utilization efficiency but better growth in these two culture systems compared to cistern and flow-through culture systems. Absence of water circulation in cistern culture system might have resulted in waste build-up, resulting in fish stress and reduction in growth compared to other culture systems. Continuous exchange of water in flow-through system might have sustained a better general environment for fish growth than in cistern culture system. But, at a very high water flow rate, fish spend a substantial amount of dietary energy for continuous swimming, leading to reduced growth and increased mortality (El-Sayed, 2006). In this study, no significant difference ($P>0.05$) was observed in survival rate between the culture systems. However, further research on impact of water flow rate during flow-through culture system is to be carried out. Fish in cistern culture system showed the highest moisture content and lowest lipid content, while fish in flow-through culture system showed the lowest moisture content and highest lipid content (Table 1). Such inverse relation between moisture and lipid content in fish was also reported in FAO (1999).

The main objectives of fishery sector in India are to increase fish production, improve export earnings, provide more animal protein and expand employment opportunities. In view of the relatively wide regional distribution of tilapia in India and its acceptability by the consumers, high priority must be placed on the modification and improvements of the techniques for its culture. Culture of tilapia as a cash crop has two basic options: mixed-sex culture without sex separation and the culture of monosex male populations. Mixed-sex culture has often failed in the past because of the "wild spawning" of tilapia that produces a large number of fry which stunt the entire

population. Culture of monosex male tilapia resolves this problem. Moreover, the monosex all-male tilapia has been found to grow bigger than fish in mixed-sex culture. Hence, additional advantages of larger fish and higher yields are gained through culture of such monosex tilapia. However, further research with genetic males and YY males is required to provide greater insight into the potential role of 17αMT in tilapia growth induction. In this study, the maximum growth of tilapia was obtained in pond culture system. Moreover, tilapia culture in India is mainly practiced in small scales by rural people who do not have the infrastructure facilities required for cistern or flow-through culture systems. Thus, under the socioeconomic condition of India, where a large number of freshwater impoundments are available for aquaculture, rearing of androgen treated monosex tilapia in earthen ponds may be considered as the ideal method of choice for a sustainable fish production. But, further research is required to increase the feed utilization efficiency during such culture.

Acknowledgements

This work is financed by the University Grants Commission (Minor Research Project, No.F. PSW – 032/07-08). We thank the Principal of Serampore College to grant permission for conducting the works.

References

Abdelghany, A.E. and Mohammed, H.A. 2002. Effects of feeding rates on growth and production of Nile tilapia, common carp and silver carp polycultured in fertilized ponds. Aquaculture Research, 33: 415-423.

Afonso, L.O., Wassermann, G.J. and Terezinha de Oliveira, R. 2001. Sex reversal in Nile tilapia (*Oreochromis niloticus*) using a nonsteroidal aromatase inhibitor. Journal of Experimental Zoology, 290(2): 177-181.

AOAC. 1984. Official methods of the Association of Official Analytical Chemists, 14th edition, Association of Official Analytical Chemists, Arlington, VA, USA., 1298 pp.

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition, APHA (American Public Health Association), Washington, USA.

Baroiller, J.F., D'Cotta, H., Bezault, E., Wessels, S. and Hoerstgen-Schwark, G. 2009. Tilapia sex determination: Where temperature and genetics meet. Comparative Biochemistry and Physiology Part A, 153: 30–38.

Beardmore, J.A., Mair, G.C. and Lewis, R.I. 2001. Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects. Aquaculture, 197: 283–301.

Bhandari, R.K., Nakamura, M., Kobayashi, T. and Nagahama, Y. 2006. Suppression of steroidogenic enzyme expression during androgen-induced sex reversal in Nile tilapia (*Oreochromis niloticus*). General and Comparative Endocrinology, 145: 20–24.

Bhasin, S., Woodhouse, L. and Storer, T.W. 2001. Proof of the effect of testosterone on skeletal muscle. Journal of Endocrinology, 170: 27-38.

Bwanika, G.N., Murie, D.J. and Chapman, L.J. 2007. Comparative age and growth of Nile tilapia (*Oreochromis niloticus* L.) in lakes Nabugabo and Wamala, Uganda. Hydrobiologia, 589: 287-301.

Carrasco, L.A., Penman, D.J., Villalobos, S.A. and Bromage, N. 1999. The effects of oral administration with 17 alpha-methyltestosterone on chromosomal synapsis in *Oreochromis niloticus* (Pisces, Cichlidae). Mutation Research, 430(1): 87-98.

Chakraborty, S.B., Sarbajna, A., Mazumdar, D. and Banerjee, S. 2007. Effects of differential dose and duration of 17-methyltestosterone treatment on sex reversal of Nile tilapia, *Oreochromis niloticus* at different age groups under Indian perspective. Asian Journal of Microbiology, Biotechnology & Environmental Science, 9(3): 705-710.

Coelli, T.J. 1995a. Recent development in frontier modeling and efficiency measurement. Australian Journal of Agricultural Economics, 39: 215-245.

Dan, N.C. and 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.

Devlin, R.H. and Nagahama, Y. 2002. Sex determination and sex differentiation in fish: an overview of genetic, physiological, and environmental influences. Aquaculture, 208: 191–364.

El-Saidy, D.M.S.D. and Gaber, M.M.A. 2005. Effect of dietary protein levels and feeding rates on growth performance, production traits and body composition of Nile tilapia, *Oreochromis niloticus* (L.) cultured in concrete tanks. Aquaculture Research, 36: 163-171.

El-Sayed, A-F.M. 2002. Effect of stocking density and feeding levels on growth and feed efficiency of Nile tilapia (*Oreochromis niloticus* L.) fry. Auaculture Research, 33: 621-626.

El-Sayed, A-F.M. 2006. Tilapia Culture. CABI Publishing, CAB Internnational, Wallingford, Oxfordshire, UK, 277 pp.

Fisher, R.A. 1935. The design of experiments. Oliver and Boyd, London, UK.

Food and Agriculture Organization of the United Nations (FAO). 1999. The State of World Fisheries and Aquaculture 1998. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). 2007. FAO FishStat plus Aquaculture Production 1970-2002. Rome, Italy.

Gale, W.L., Fitzpatrick, M.S., Lucero, M., Contreras-Sanchez, W.M. and Schreck, C.B. 1999. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in androgens. Aquaculture, 58: 215-226.

Graaf, G.J., Dekker, P.J., Huisman, B. and Verreth, J.A.J. 2005. Simulation of Nile tilapia (*Oreochromis niloticus niloticus* L.) culture in ponds, through individual-based modeling, using a population dynamic approach. Aquaculture Research, 36: 455-471.

Jhingran, A.G. 1991. Performance of tilapia in Indian waters and its possible impact on the native ichthyofauna. The IPFC Proceedings, Bogor, Indonesia. FAO Fisheries Report No. 458. FAO, Rome: 143-161.

Killian, H.S. and Kohler, C.C. 1991. Influence of 17 α-methyltestosterone one on Red Tilapia under two thermal regime. Journal of World Aquaculture Society 22(2): 83-94.

Kuwaye, T.T., Okimoto, D.K., Shimoda, S.S., Howerton, R.D., Lin, H.-R., Pang, P.K.T. and Grau, E.G. 1993. Effect of 17α-methyltestosterone on the growth of the euryhaline tilapia, *Oreochromis mossambicus*, in fresh water and in seawater. Aquaculture, 113: 136–152.

Lèveque, C. 2002. Out of Africa: the success story of tilapias. Environmental Biology of Fishes, 64: 461-464.

Liti, D.M., Fulanda, B., Munguti, J.M., Straif, M., Waidbacher, H. and Winkler, G. 2005. Effects of open-pond density and caged biomass of Nile tilapia (*Oreochromis niloticus* L.) on growth, feed utilization, economic returns and water quality in fertilized ponds. Aquaculture Research, 36: 1535-1543.

Little, D.C., Bhujel, R.C. and 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.

Mair, G.C., Abucay, J.S., Beardmore, J.A. and 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.

Pandian, T.J. and Sheela, S.G. 1995. Hormonal induction of sex reversal in fish. Aquaculture, 138: l-22

Pandian, T.J. and Varadaraj, K. 1988. Techniques for producing all-male and all-triploid *Oreochromis mossambicus*. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. Maclean (Eds.), The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 15. Department of Fisheries, Bangkock, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines: 243-249.

Pechsiri, J. and Yakupitiyage, A. 2005. A comparative study of growth and feed utilization efficiency of sex-reversed diploid and triploid Nile tilapia, *Oreochromis niloticus* L. Aquaculture Research, 36: 45-51.

Phelps, R.P. and Popma, T.J. 2000. Sex reversal of tilapia. In: B.A. Costa-Pierce, J.E. Rakocy (Eds.), Tilapia Aquaculture in the Americas, Vol. 2. The World Aquaculture Society, Baton Rouge, Louisiana, USA: 34-59.

Pillay, T.V.R. 1993. Aquaculture. Principles and Practices. Blackwell, Oxford, 575 pp.

Pouomogne, V. and Mbongblang, J. 1993. effect of feeding rate on the growth of tilapia (*Oreochromis niloticus*) in earthen ponds. The Israeli Journal of Aquaculture – Bamideh, 45: 147-153.

Ridha, M.T. 2006. Comparative study of growth performance of three strains of Nile tilapia, *Oreochromis niloticus*, L. at two stocking densities. Aquaculture Research, 37: 172-179.

Shearer, K.D. 1994. Factors affecting the proximate composition of cultured fishes with emphasis on salmonids. Aquaculture, 119: 63-88.

Shelton, W.L., Hopkins, K.D. and Jensen, G.L. 1978. Use of hormones to produce monosex tilapia for aquaculture. In: R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. Maclean (Eds.), The Second International Symposium on Tilapia in Aquaculture. ICLARM Conference Proceedings 15, Department of Fisheries, Bangkok, Thailand, and International Center for Living Aquatic Resources Management, Manila, Philippines: 10-33.

Shepherd, B.S., Ron, B., Burch, A., Sparks, R., Richman, N.H.III, Shimoda, S.K., Stetson, M.H., Lim, C. and Grau, E.G. 1997. Effects of salinity, dietary level of protein and 17α-methyltestosterone on growth hormone (GH) and prolactin (tPRL177 and tPRL188) levels in the tilapia, *Oreochromis mossambicus*. Fish Physiology and Biochemistry, 17: 279–288.

Smith, E.S. and 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(3): 242-245.

Soderberg, R.W. 2006. Culture in Flowing Water. C. Lim, C.D. Webster (Eds.), Tilapia: Biology, Culture, and Nutrition, Haworth Press, Binghamton, NY, USA: 289-312.

Sosa, I.D.L.A.B., Adillo, M.D.L.J., Ibanez, A.L. and Figueroa, J.L.I.A. 2005. Variability of tilapia (*Oreochromis* spp.) introduced in Mexico: Morphometric, meristic and genetic characters. Journal of Applied Ichthyology, 20: 7–10.

Tran-Duy, A., Schrama, J.W., van Dam, A.A. and Verreth, J.A.J. 2008. Effects of oxygen concentration and body weight on maximum feed intake, growth and hematological parameters of Nile tilapia, *Oreochromis niloticus*. Aquaculture, 275: 152-162.

Tsadik, G.G. and Bart, A.N. 2007. Effects of feeding, stocking density and water-flow rate on fecundity, spawning frequency and egg quality of Nile tilapia, *Oreochromis niloticus* (L.). Aquaculture, 272: 380-388.

Vera Cruz, E.M. and Mair, G.C. 1994. Conditions for effective androgen sex reversal in *Oreochromis niloticus*(L). Aquaculture, 122: 237-248.