J. Fish. Sci. Tech. 5(1), 59~63, 2002

JOURNAL OF
FISHERIES SCIENCE
AND TECHNOLOGY

Growth of Sex Reversed Nile Tilapia, *Oreochromis niloticus* In a Closed Recirculating Culture System

Gil Ha Yoon*, Jae-Yoon Jo[1], Youhee Kim[2] and In-Bae Kim[1]

**Chongpyong Inland Fisheries Institute, NFRDI, Gyongki 477-810, Korea*
[1]Department of Aquaculture, Pukyong National University, Busan 608-737, Korea
[2]Department of Marine Biotechonolgy, Gangwon Provincial University, Gangnung 210-804, Korea

(Received November 2001, Accepted March 2002)

Swim up fry of the Nile tilapia, *Oreochromis niloticus*, were fed 0 or 60 mg 17-methyltestosterone (MT) per kg feed for 30 days. Fish that had been fed 0 or 60 ppm MT for the first 30 days were subsequently fed a commercial diet for 56 weeks to evaluate growth, survival, sex ratio, body composition, gonadosomatic index and the total edible portion. Mean body weight of MT treated group and untreated group were 1.7 g and 1.1 g, respectively at the end of the treatment for 30 days ($P<0.05$). The experiment was terminated after a total of 60 weeks, the mean body weight of the MT treated population was 1,016 g and that of the untreated population was 762 g ($P<0.05$). However, the final mean body weight of untreated males (1, 086 g) was not significantly different from treated males (1,016 g), but the mean body weight of the female group was 512 g. Therefore, the reason for the lower mean body weight of the untreated group was entirely due to stunted females. The percentage fillet yield of MT treated fish (34.6%) was not significantly different from that of the untreated males (34.4%), but the untreated females were lower than those of both treated and untreated male groups (32.4%) ($P<0.05$). There were no significant differences in the percentage of the all edible portion (AP) between MT treated and untreated males, but females were lower than males. Females are smaller fish in size and the gonads are larger in proportion which were discarded along with the intestine this explains the observed difference. Total biomass of the two groups were 134.8 kg and 104.5 kg per m^3, respectively. The proportion of fish reaching a marketable size of over 800 g in body weight within 14 months were 78% in the MT treated group and 41% in the untreated group.

Key words: Tilapia, Sex reversal, 17-methyltestosterone, Recirculating culture system, Edible portion

Introduction

Tilapia are one of the most popular cultured fish species in the world, growing well at high density and able to withstand poor water quality. Nile tilapia, *Oreochromis niloticus* are favored by aquaculturists because this species represents one of the biggest and fast-growing species among the cichlidae (Pullin and Capili, 1988).

In Korea, there are long and cold winters and so closed recirculating culture systems with heating facilities are used for tilapia culture. Usually Korean and Japanese consumers require fish exceeding 800 g in size for sliced raw fish (*Hoe*) rather than 150 ~300 g sized fish required by many other countries (Kim, 1992).

However, uncontrolled reproduction and high breeding rate result in overcrowding and a large biomass of stunted fish under marketable size (Guerrero, 1982; Torrans et al., 1988). Culturists have to grade fish frequently to select out the stunted fish and also because of the different growth rates between males and females. Stunted fish waste culture space, labor and feed, etc.

The androgenic hormone treatment of swim up

*Corresponding author: yoon12@momaf.go.kr

fry now represents the most commonly used method to produce all-male populations of tilapia (Tayamen and Shelton, 1978). All-male populations of tilapia removes the problem of uncontrolled reproduction, prevents overcrowding and increases productivity (Nakamura, 1981; Phelps et al., 1992). Several researchers (Guerrero, 1975; Billy and Liley, 1985; Macintosh et al., 1985; McGeachin et al., 1987; Jo et al., 1988; Varadaraj, 1990; Ellis et al., 1993; Varadaraj et al., 1994) have reported that androgen hormones were very affective for tilapia species when treated orally or by bath treatment. Most of them, however, focused on part of the lifecycle, and especially sex-reversal of fish in early life. Therefore, the objectives of the present study were to test and determine the growth rate, survival rate, sex-ratio and the total edible portion of two tilapia populations on a commercial scale in a closed recirculating culture system.

Materials and Methods

The two populations of tilapia were cultivated until one group reached an mean fish weight of 1 kg. The experiment was conducted on a commercial scale in a closed recirculating culture system at PKNU (Pukyong National University).

The fish, two day old swim up fry, used for this study were collected from 6 incubating jars in which the fry from 6 of the 9 broodstock fish had hatched at the same time.

Hormone-treated feed was prepared with 17-methyltestosterone (MT) at a rate of 60 ppm of rainbow trout feed protein 47%. Hormone was added into 95% ethanol and mixed with the feed. The control feed was mixed in the same way, omitting the addition of MT. Mixed feeds were dried in the shade at room temperature for 3 days and then kept at −30℃ until required.

Swim up fry were randomly divided into 2 groups. One group was given the hormone treated feed, the other was supplied with untreated feed from 07:00 to 19:00 at 1 hour intervals for 30 days. Fish were fed until satiation. Each treatment had 4 replicates. Mean temperature was 30 ± 2℃, dissolved oxygen was 3.5 ± 0.5 mg/L during the experimental period. After 30 days both were fed a commercial feed until termination of the experiment.

As the fish grew, they were transferred to appropriately sized glass tanks. After 13 weeks, the fish were moved into 4 m^3 concrete tanks for the remaining 47 weeks.

Fish were weighed every 2 weeks when they were in the glass aquarium and then every 4 weeks after being transferred to the concrete tanks to monitor growth and survival rates. From week 36, fish were also checked for sex ratio and growth rate differences between males and females. Sex of the fish was determined by external examination using differences in papilla structure. Unclassified fish were identified by abdominal pressure and resultant release of sexual products.

At the end of the growing period, 10 fish were randomly sampled from each replicate for fillet yield, all edible portion (AP) and gonadosomatic index (GSI). The calculations were as follow:

Gonadosomatic index (GSI)
= (Gonad weight/body weight) × 100
Fillet yield
= (Muscle weight/body weight) × 100
Skin percentage
= (Skin weight/body weight) × 100
Intestine percentage
= (Intestine weight/body weight) × 100
All edible portion = [Body weight − (skin + intestine)]/body weight × 100

Sex ratios were subjected to the Chi-Square test. Growth rates differences between the treated group and the untreated group were subjected to Duncan's multiple range test. Growth rate of the sex-reversal period, fillet yield, AP and GSI were performed using student t-tests to the 5% significance level.

Results and Discussion

The data obtained from the sex reversal period for 30 days is given in Table 1. After the sex reversal period, the mean weight of the hormone treated group (1.67 g) was heavier than the untreated group (1.14 g) and the daily growth rate of MT treated group was higher than the untreated group. This suggested that MT had an anabolic effect. Similar observations were reported by Guerrero (1975), Macintosh et al. (1985) and Jo et al. (1988). Jo

Table 1. Effects of dietary 17-methyltestosterone on the growth of Nile tilapia, *O. niloticus* fry at the end of the sex reversal period of 30 days

Group	Stocking			Harvesting			Survival (%)	Daily growth rate (%)
	Number of fish	Total wt. (g)	Mean wt. (g)	Number of fish	Total wt. (g)	Mean wt. (g)		
Treated	1994	99.7	0.05	1551	2590	1.67	77.8	12.4
Control	1994	99.7	0.05	1660	1890	1.14	83.3	11.0

Table 2. Percentage of male and female fish of sex reversed (treated) and normal (control) Nile tilapia, *O. niloticus* at the end of the rearing period of 60 weeks

Group	Male (%)	Female (%)
Treated	100	0
Control	43.5	56.5

(1988a) observed that the growth rate of 60 mg MT/kg treated fish was 16.4% higher than 0 mg treated fish and that growth rate was positively correlated to hormone concentration.

Survival rate was not significantly different between the two groups. This result suggests that survival was not affected by the androgen.

When harvested after 60 weeks, the total production of the MT treated population was 134.8 kg/m^3 and that of the control group was 104.5 kg/m^3. Mean weights were 1,016 g and 762 g, respectively (Table 3). The percentage of fish over 1 kg was 54.0% in the MT treated group and 28.8% in the control group. Marketable sized fish over 800 g in the hormone treated group was 78% and in the untreated group 40.9%. In the control group, 97% of males were over 800 g and only 2 female fish were over 1 kg. A comparison of the males in both groups found that although there was no significant difference, the mean body weight of the untreated males was slightly heavier than that of the treated group. According to Jo (1988c) the mean body weights of 10, 15 and 20 mg MT treated males were less than untreated males. This phenomenon was assumed to occur as similar sized fish competed with each other for feed in the treated group. In the control group, however, males were twice the size of females, such that males gained an advantage over females for feeding.

Mean portion of fillet yield, all edible parts and GSI are shown in Table 4. The mean fillet yield of untreated males was 34.4%, this was similar to the treated group (34.6%), although this was less than 32.4% in the females. GSI in untreated females was 2.98%, this being 5 times as high as treated and untreated males. It is assumed that the AP of females was less than that of both male groups as a result of females having propotionately larger gonads. Ali and Rao (1989) showed that the GSI of 300 mg and 400 mg MT treated carp was less than the control group. Gonads of treated groups did not develop as normal and therefore increased the edible portion. Jo (1988b) demonstrated that the GSI of *Tilapia aurea* was negatively correlated to the amount of hormone. These same results have shown that MT arrested development of the ovary and increased the edible portion.

In conclusion, the mean body weight of treated fish was 1,016 g, this was 33% heavier than the untreated fish, 762 g. Weight of untreated males was 1,086 g and females was 512 g. The difference in the mean weight between two groups was due to stunted females in the control group. Total productivity per unit in the treated group was 29% higher than the

Table 3. Growth and survival of sex reversed (treated) and normal (control) Nile tilapia, *O. niloticus* after 60 weeks rearing period

Group	Stocking			Harvesting			Survival (%)	Feed coefficient	Daily growth rate (%)
	Number of fish	Total wt. (g)	Mean wt. (g)	Number of fish	Total wt. (g)	Mean wt. (g)			
Treated	620	1.04	1.67	530	538.4	1,015.8	85.5	1.16	3.0
Control	620	0.71	1.14	549	418.2	761.9	88.5	1.19	3.1

Table 4. Mean portion (%) of fillet yield, edible parts for soup, intestine, skin and GSI of sex reversed (treated) and normal (control) Nile tilapia, *O. niloticus* at the end of experimental period (n=20)

Group	Muscle	Soup*	Intestine	Skin	Gonad	All edible
Treated	34.6 ± 2.6	49.5 ± 2.1	7.1 ± 1.4	6.2 ± 0.4	0.6 ± 0.4	84.1 ± 5.3
Control						
(Male)	34.4 ± 3.1	49.8 ± 3.1	6.8 ± 2.2	7.5 ± 1.2	0.6 ± 0.5	84.1 ± 5.5
(Female)	32.4 ± 2.5	49.2 ± 2.8	9.4 ± 2.8	6.4 ± 0.8	2.9 ± 2.0	81.5 ± 7.8

*Total weight−(Muscle+Intestine+Skin)

control group. All edible portion in the treated group was slightly higher than the untreated group as a result of the larger gonad in female fish. It is assumed that the percentage of reaching marketable size within 18 months in the treated group could be 93%, compared to 59% in the untreated group.

The above benefits show that mono sex culture of tilapia using MT could reduce the rearing period, labour and culture space and increase total productivity.

However, it will be necessary to compare MT treated tilapia, hybrid male and males using super male (YY) considering not only productivity but also the economical benefits in the same environmental culture system in a future study.

Acknowledgements

For their highly skilled assistance with various aspects of this work, we gratefully acknowledge Jin-Dug Jang and all the students at the Fish Farming Research Station at Pukyong National University, Pusan, Korea.

References

Ali, P.K.M.M. and G.P.S. Rao. 1989. Growth improvement in carp, *Cyprinus carpio* (L.), sterilised with 17-methyltestosterone. Aquaculture, 76, 157~167.

Billy, A.J. and N.R. Liley. 1985. The effects of early and late androgen treatments on the behaviour of *Sarotherodon mossambicus* (Pisces: Cichlidae). Hormone Behav., 19, 311~330.

Ellis, S.C., W.O. Watanabe and W.D. Head. 1993. Effect of initial age variation on production of Florida red tilapia fry under intensive, brackish water tank culture. Aquac. Fish. Manag., 24, 465~471.

Guerrero, R.D. 1975. Use of androgens for the production of all male *Tilapia aurea* (Steindachner). Trans. Am. Fish. Soc., 104, 342~348.

Guerrero, R.D. 1982. Control of tilapia reproduction. In *Biology and Culture of Tilapias,* R.S.V. Pullin and R.H. Lowe-McConnel, eds. International center for living Aquatic resources management. Conference proceeding 7, Manila, pp. 309~316.

Jo, J.-Y. 1988a. Effects of 17-methyltestosterone concentration in the diet on sex reversal and growth of *Tilapia aurea.* In Doctoral Dissertation, Auburn University, Alabama, pp. 4~27.

Jo, J.-Y. 1988b. Residual effects of 17-methyltestosterone on second year growth, body composition and gonad weight of *Tilapia aurea.* In Doctoral Dissertation, Auburn University, Alabama, pp. 28~54.

Jo, J.-Y. 1988c. Effects of six levels of 17-methyltestosterone on sex reversal and growth in *Tilapia aurea* and *T. nilotica.* In Doctoral Dissertation, Auburn University, Alabama, pp. 55~63.

Jo, J.-Y., R.O. Smitherman and L.L. Behrends. 1988. Effects of dietary 17-methyltestosterone on sex reversal and growth of *Oreochromis aureus.* In *The Second International Symposium on Tilapia in Aquaculture,* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean, eds. ICLARM, Conference Proceeding 15, Department of Fisheries, Bangkok, Thailand and International Center for living Aquatic Resources Management, Manila, pp. 203~207.

Kim, I.-B. 1992. Fish culture. Sin-heung Publishing Company, Pusan, Korea, pp. 251~271.

Macintosh, D.J., T.J. Varghese and G.P.S. Rao. 1985. Hormonal sex reversal of wild-spawned tilapia in India. J. Fish Biol., 26, 87~94.

McGeachin, R.B., E.H. Robinson and W.H. Neill. 1987. Effect of feeding high levels of androgens on the sex ratio of *Oreochromis aureus.* Aquaculture, 61, 317~321.

Nakamura, M. 1981. Effect of 11-ketotestosterone on gonadal sex differentiation in *Tilapia mossambica.* Bull. Jap. Soc. Sci. Fish., 47, 1323~1327.

Phelps, R.P., W. Cole and T. Kats. 1992. Effect of fluoxymesterone on sex ratio and growth of Nile tilapia, *Oreochromis niloticus* (L.). Aquac. Fish. Manag., 23, 405~410.

Pullin, R.S.V. and J.B. Capili. 1988. Genetic improvement of tilapias: Problems and prospects. In *The second International Symposium on Tilapia In Aquaculture,* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, J.L. Maclean, eds. Department of Fisheries, Bangkok, Thailand and Inter-

national center for living Aquatic Resources Management, Manila, pp. 259~266.

Tayamen, M.M. and W.L. Shelton. 1978. Inducement of sex reversal in *Sarotherodon niloticus* (L.). Aquaculture, 14, 349~354.

Torrans, L., F. Meriwether, F. Lowell, G. Wyatt and P.D. Gwinup. 1988. Sex-reversal of *Oreochromis aureus* by immersion in mibolelone, a synthetic steroid. J. World Aquac. Soc., 19, 97~102.

Varadaraj, K. 1990. Production of monosex male *Oreochromis mossambicus* (Peters) by administering 19-norethi sterone acetate. Aquac. Fish. Manag., 21, 133~135.

Varadaraj, K., K.S. Sindhu and T.J. Pandian. 1994. Comparison of conditions for hormonal sex reversal of Mozambique tilapias. Prog. Fish-Cult., 56, 81~90.