

## Effects of Alternate-Week Feeding Strategies on Growth and Feed Efficiency Ratio of Juvenile Nile Tilapia *Oreochromis niloticus* in a Recirculating System

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The effects of alternate-week feeding strategies on growth and feed efficiency ratio of juvenile Nile tilapia were investigated in a recirculating aquaculture system. Twenty fish initially weighing 25.5 g were randomly distributed into each of 18 tanks to conduct three replicates for each of six different feeding strategies. Weight gain of fish in the control that were fed daily for 6-week feeding trial was significantly higher than those of fish subjected to various alternate-week feeding regimes. Weight gain of fish that were starved for 3 weeks and then fed daily for 3 weeks (3WS+3WF) was not significantly different from that of fish, starved and fed daily for alternate 1-week period during the trial (1WS+1WF), but was significantly higher than those of fish starved for 2 weeks, and fed for 2 weeks (2WS+2WF); fish starved for 4 weeks and fed for 2 weeks (4WS+2WF); and fish fed for 5 weeks and fed for 1 week (5WS+1WF.) The amount of feed supplied to fish in the groups of 1WS+1WF and 3WS+3WF was significantly lower than that fed to fish in the control group, but significantly higher than the amount feed supplied to fish in the other three groups. Feed efficiency ratio for fish in the control group did not differ from that for fish in the groups of 1WS+1WF, 2WS+2WF and 3WS+3WF, but was significantly higher than that for fish in the groups of 4WS+2WF and 5WS+1WF. In conclusion, juvenile Nile tilapia that were subject to starvation for 1 to 5 weeks did not exhibit compensatory growth sufficient to attain the same weight as fish fed daily for 6 weeks. In addition, fish subjected to starvation exhibited low feed efficiency ratio compared to fish fed daily, which were probably attributable to poor weight gain.

Key words: Nile tilapia, *Oreochromis niloticus*, Alternate-week feeding strategy, Feed efficiency ratio

### Introduction

The effects on growth performance of refeeding fish after a period of feed deprivation have been reported for several fish species (Dobson and Holmes, 1984; Miglavs and Jobling, 1989; Quinton and Blake, 1990; Jobling and Koskela, 1996; Gaylord and Gatlin, 2000; Qian et al., 2000; Wang et al., 2000; Gaylord and Gatlin, 2001; Xie et al., 2001; Cho and Lee, 2002; Kim et al., 2002). Such feeding strategies may have several potential advantages, including improvement in feed efficiency attributable to vigorous feeding activity after realimentation, reduction of sources of water pollution, and reduction of feed costs during the starvation period. However, in most cases, fish

deprived over 2 weeks do not exhibit sufficient compensatory growth upon refeeding to the match total weight gain of fish fed daily without interruption. Fish subjected to a period of starvation also exhibit poor weight gain and feed efficiency, although compensatory growth has been observed in fish starved for up to 4 weeks in extended feeding trials (Rueda et al., 1998; Gaylord and Gatlin, 2000).

The ability of fish to achieve compensatory growth may vary depending on fish size (Bilton and Robins, 1973), feeding habits (Zhu et al., 2001), food quality (Gaylord and Gatlin, 2001), rearing temperature (Dobson and Holmes, 1984), duration of feeding trial (Rueda et al., 1998; Gaylord and Gatlin, 2000) as well as feed allowance (Jobling and Koskela, 1996; Saether and Jobling, 1999).

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Alternate-day feeding is more efficient feeding strategy than daily feeding for production of olive flounder *Paralichthys olivaceus* because growth and feed efficiency of fish were similar under alternate-day and daily feeding conditions (Kim et al., 2002). Also compensatory growth was obtained in juvenile flounder refed after a 2-week starvation period (Cho and Lee, 2002). However, growth of Arctic charr *Salvelinus alpinus* subjected to starvation was poorer than that of fish fed daily, but no difference in growth was observed among fish that experienced feed restriction (Jobling et al., 1993). Compensatory growth was not obtained in Nile tilapia *Oreochromis niloticus* subjected to alternate-day feeding, although feed efficiency ratio was improved compared to fish fed daily (Cho and Jo, 2005). However, to date, no studies have reported the effects of alternate-week or multiple-week starvation and feeding strategies on performance of Nile tilapia.

In this study, the effects of various alternate-week feeding strategies on growth and feed efficiency ratio of juvenile Nile tilapia were investigated in a recirculating aquaculture system.

### Materials and Methods

The recirculating aquaculture system consisted of 18 rectangular glass tanks (60×47×40 cm, water volume: 100 L) that each had a water exchange rate of 3 L/min. Twenty juvenile Nile tilapia, initially weighing approximately 25.5 g, were randomly distributed into each tank. Fish were acclimated for 3 days prior to the initiation of the feeding trial; the commercial feed was provided daily during the acclimation period.

Three replicates of each of six feeding strategies were conducted. Nile tilapia in the control that were fed daily throughout the 6-week trial. Fish in the 1WS+1WF group were alternately starved for 1 week and fed daily for 1 week for the duration the 6-week trial. Fish in the 2WS+2WF group were starved for 2 weeks, fed for 2 weeks, and starved for the last 2 weeks; those in the 3WS+3WF group were starved for 3 weeks and fed for 3 weeks; those in the 4WS+2WF group were starved for 4 weeks and fed for 2 weeks; and those in the 5WS+1WF group were starved for 5 weeks and fed for 1 week.

After the initiation of the feeding trial, weight of fish in the control and experimental groups was measured at 1-week interval to determine daily feed allowance, which was maintained at 3% of total weight of fish in each tank. Fish were hand-fed with commercial feed (30% crude protein; Woosung feed

Co. Ltd., Korea) twice daily at 0930 and 1730. Water temperature ranged from 23.1 to 29.0°C throughout the 6-week feeding trial.

One-way ANOVA test and Duncan's multiple range test (Duncan, 1955) were used to detect the differences among the treatment groups using the SAS Program version 6.12 (SAS Institute, Cary, NC, USA).

### Results and Discussion

Weight of fish at the first feeding (g/fish), weight gain (g/fish), amount of feed supplied (g/fish) and feed efficiency ratio (FER) of Nile tilapia in each of six groups subjected to various alternate-week feeding strategies are shown in Table 1. Weight of fish at the first feeding tended to decrease with increasing duration of starvation, which is consistent with weight reduction reported for fish subjected to multiple weeks of starvation in other studies (Rueda et al., 1998; Wang et al., 2000).

Weight gain of Nile tilapia in the control group was significantly ( $P<0.05$ ) higher than those of fish subjected to starvation in the other groups. Weight gain of fish in the 3WS+3WF group was not significantly different from that of fish in the 1WS+1WF group, but was significantly ( $P<0.05$ ) higher than those of fish in the 2WS+2WF, 4WS+2WF, and 5WS+1WF groups. According to Jobling et al. (1993), alternate periods of feed deprivation and refeeding resulted in decreased in growth in Arctic charr compared to growth of fish fed daily without interruption; however, at the end of a 24-week feeding trial, no differences in growth were observed among groups of fish subjected to alternate starvation and refeeding on various schedules (i.e. starved for 1 week, fed for 1 week; starved for 1.5 weeks, fed for 1.5 weeks; and starved for 3 weeks, fed for 3 weeks for the duration of the 24-week trial).

Total amount of feed supplied to Nile tilapia in the groups of 1WS+1WF and 3WS+3WF was significantly ( $P<0.05$ ) less than that in the control group, but significantly more than that in the other groups. The lowest amount of feed supplied was observed in fish in the 5WS+1WF group.

The decreased weight gain in Nile tilapia subjected to starvation was probably attributable to the decreased amount of feed supplied compared to fish in the control group in this study. As reported in previous studies, total feed consumption of intermittently starved fish that achieved compensatory growth was almost equal to that of fish fed daily by the end of the feeding trial, owing to hyperphagia shortly after re-

Table 1. Weight (g/fish) at first feeding, weight gain (g/fish), amount of feed supplied (g/fish) and feed efficiency ratio (FER) of juvenile Nile tilapia fed for 6 weeks using different feeding strategies (Mean±SE)

	Control		1WS+1WF		2WS+2WF		3WS+3WF		4WS+2WF		5WS+1WF	
Initial weight of fish (g/fish)	25.6	0.10	25.5	0.14	25.6	0.08	25.5	0.16	25.5	0.16	25.5	0.11
Weight at first feeding (g/fish)	25.6	0.10 <sup>a</sup>	24.9	0.22 <sup>b</sup>	24.4	0.30 <sup>b</sup>	23.7	0.14 <sup>c</sup>	22.5	0.21 <sup>d</sup>	21.9	0.16 <sup>d</sup>
Final weight of fish (g/fish)	62.9	3.05 <sup>a</sup>	37.7	0.77 <sup>bc</sup>	33.8	0.60 <sup>cd</sup>	39.1	1.29 <sup>b</sup>	29.2	0.65 <sup>d</sup>	23.9	0.58 <sup>e</sup>
Weight gain (g/fish)	37.3	3.15 <sup>a</sup>	12.1	0.88 <sup>bc</sup>	8.2	0.54 <sup>cd</sup>	13.7	1.41 <sup>b</sup>	3.6	0.68 <sup>d</sup>	-1.7	0.52 <sup>e</sup>
Feed supplied (g/fish)	48.3	1.25 <sup>a</sup>	17.7	0.24 <sup>b</sup>	13.5	0.46 <sup>c</sup>	18.3	0.43 <sup>b</sup>	9.9	0.10 <sup>d</sup>	4.6	0.00 <sup>e</sup>
FER <sup>1</sup>	0.77	0.047 <sup>a</sup>	0.69	0.049 <sup>a</sup>	0.61	0.054 <sup>a</sup>	0.74	0.062 <sup>a</sup>	0.37	0.065 <sup>b</sup>	-0.36	0.115 <sup>c</sup>

Values with different superscript letters within the same row are significantly different ( $P < 0.05$ ).

1WS+1WF, alternately starved for 1 week and fed for 1 week during the 6-week trial; 2WS+2WF, starved for 2 weeks, fed for 2 weeks, starved for 2 weeks; 3WS+3WF, starved for 3 weeks, fed for 3 weeks; 4WS+2WF, starved for 4 weeks, fed for 2 weeks; 5 WS+1 WF, starved for 5 weeks, fed for 1 week.

FER (feed efficiency ratio)<sup>1</sup> = Weight gain/amount of feed supply.

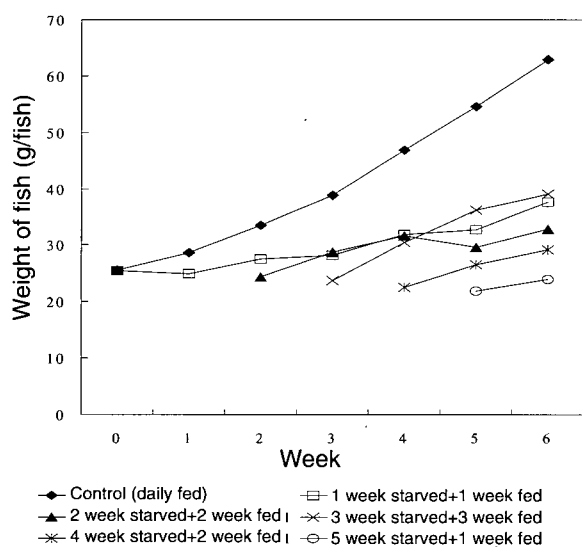


Fig. 1. Weight changes in juvenile Nile tilapia (g/fish) subjected to varied alternate- or multiple-week feeding strategies over a 6-week period.

alimentation (Rueda et al., 1998; Gaylord and Gatlin, 2000; Zhu et al., 2001; Cho and Lee, 2002).

Changes in weight of Nile tilapia subjected to the alternate- and multiple-week feeding strategies throughout the 6-week feeding trial are depicted in Figure 1. Nile tilapia progressively increased in weight throughout the trial; they were significantly ( $P < 0.05$ ) heavier than fish that underwent starvation for any period of during the trial. Weight of fish in the groups of 1WS+1WF and 2WS+2WF increased after re-feeding, but decreased during each starvation period, according to the respective feeding schedules. Zhu et al. (2001) reported that the omnivorous minnow, *Phoxinus phoxinus* fully compensated for 1 and 2 weeks of starvation, whereas the carnivorous stickleback, *Gasterosteus aculeatus* did not achieve full compensation after 2 weeks of starvation when re-fed

in a comparison of varied feeding strategies (fed daily for 6 weeks, fed for 5 weeks after a 1-week fast, or fed for 4 weeks after a 2-week fast).

FER for Nile tilapia in control was not significantly ( $P > 0.05$ ) different from that for fish in the groups of 1WS+1WF, 2WS+2WF and 3WS+3WF, but significantly ( $P < 0.05$ ) higher than that for fish in the groups of 4WS+2WF and 5WS+1WF. The lowest FER was obtained in the group of 5WS+1WF. The lack of improvement in FER for fish subjected to starvation for any period was probably attributable to their poor weight gain compared to fish fed daily without interruption in this study. However, an improvement in FER in fish re-fed after a period of starvation has commonly been observed in many studies (Saether and Jobling, 1999; Gaylord and Gatlin, 2000; Qian et al., 2000; Gaylord and Gatlin, 2001; Gaylord et al., 2001; Cho and Lee, 2002; Kim et al., 2002). Besides, Cho and Jo (2004) reported that after 6 weeks of alternately feeding for 7 days after a 7-day fast, feeding for 2 days after a 2-day fast, or feeding for 1 day after a 1-day fast, FER for Nile tilapia was increased compared to that for fish fed daily for 6 weeks.

In conclusion, Nile tilapia that were subjected to weeklong or multiple weeks of starvation in this study did not exhibit complete compensatory growth compared to fish in control that were fed daily for the entire 6-week trial. Besides, lower poor FER was obtained in Nile tilapia subjected to starvation compared to that in fish fed daily was probably attributable to their decreased weight gain.

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