SUPPLEMENTAL FEEDING FOR RED TILAPIA CULTURE IN BRACKISHWATER

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Abstract

An experiment was conducted at the Asian Institute of Technology, Thailand, to investigate effects of feeding regimes on growth of sex-reversed Thai red tilapia (*Oreochromis* sp.). There were five different supplemental feeding regimes: 0%, 25%, 50%, 75% and 100% of satiation. Red tilapia fingerlings (33.2-33.4 g size) were stocked at 62.5 fish m^{-3} in fifteen 0.8-m^3 net cages suspended in a 200-m^2 earthen pond and cultured for 90 days. The pond was maintained at 10% salinity and fertilized weekly at rates of 4 kg N and 1 kg P ha^{-1} d^{-1}.

Growth performance of red tilapia was significantly better in feeding treatments than in the non-feeding treatment. Red tilapia growth and average feeding rate increased but FCR and net economic return decreased with increasing percentages of satiation feeding levels from 25% to 100%. Considering low FCR, good growth and yield performance, high economic return and potential for growing to greater size, 50% satiation feeding was the most efficient feeding rate.

Introduction

Many tilapia species are euryhaline and can grow in saline water after proper acclimation (Suresh and Lin, 1992). Varieties of red tilapia have been successfully cultured in saline waters (Watanabe, 1991). However, most of those tilapia culture trials were conducted in intensive systems with pelleted feeds, requiring frequent water exchanges or use of cages. Compared to the voluminous literature available for semi-intensive culture of tilapia in freshwater ponds, information on semi-intensive culture in saline ponds is almost non-existent. On the other hand, there has been a strong desire to culture tilapia in brackishwater ponds in Southeast Asia as well as Central/South America during the last few years (Green, 1997). There are a large number of shrimp ponds available in these regions, either resulting from failure in shrimp farming or desires to diversify shrimp culture. These ponds provide a good opportunity for aquaculture, and tilapia appears to be the most appropriate choice for such a culture system, because there are few other domesticated finfish species that feed on low-cost natural foods, such as detritus and plankton. This interest in brackishwater culture is particularly strong in Thailand and Vietnam where shrimp culture is now commonly reduced to one crop per year, leaving the ponds empty for half a year. Tilapia culture is also attractive to shrimp farmers to utilize abundant phytoplankton in shrimp ponds or in pond effluents. The results from a recent PD/A CRSP experiment conducted in Thailand showed that Thai red tilapia (*Oreochromis* sp.) grew better at 10 ppt than at other salinities in ponds fertilized using common CRSP fertilization guidelines (4 kg N and 1 kg $P \cdot ha^{-1} \cdot d^{-1}$; Yi *et al*., 2002). However, under such semi-intensive culture systems with fertilizer as the sole nutrient input, growth of red tilapia slowed down after they reached 100 g, resulting in small size at harvest (about 150 g) after 5 months of culture. Market price in many countries is much higher for larger tilapia. To rear tilapia to the size greater than 500 g to fetch the higher market price, supplemental feeds are usually required. In freshwater ponds, the most efficient culture system is to grow tilapia to 100-150 g with fertilizer alone, then supplemental feed at 50% satiation feeding level (Diana *et al*., 1994, 1996). However, such information is not available for red tilapia culture in brackishwater.

The purpose of this experiment was to determine the appropriate levels of supplemental feed in fertilized ponds with 10 ppt salinity for maximum growth of Thai red tilapia.

Materials and methods

This experiment was carried out at the Asian Institute of Technology (AIT), Thailand, during March-June 2001. The experiment was conducted using Thai red tilapia in a randomized complete block design in 15 cages (1x1x1.2m) suspended in a 200-m^2 fertilized earthen pond at 10 ppt salinity. Five treatments were used to test effects of different supplemental feeding regimes: 1) 0% (no feeding); 2) 25% satiation feeding; 3) 50% satiation feeding; 4) 75% satiation feeding; 5) 100% satiation feeding. Satiation rations in treatments 2 through 5 were determined by estimating the total amount of floating pelleted feed (crude protein 30%, Charoen Pokphand Co., Ltd., Bangkok, Thailand) consumed by red tilapia between 0800-0900 h and 1400-1500 h every Saturday. The tested percentages of satiation feeding were used to calculate the amount of feed to apply for respective treatments during Sunday through Friday.

Sex-reversed fingerlings of Thai red tilapia (33.2-33.4 g size) were purchased from a local farm and acclimated to 10 ppt in acclimation tanks by raising salinity level 5 ppt every two days. The fingerlings were then stocked at 62.5 fish m^{-3} in all cages on 30 March 2001. During the experiment, average weights of red tilapia were determined biweekly by bulk weighing 50% of the initial stock in each cage. Fish were randomly sampled by dip net. Red tilapia in every cage were harvested, counted and bulk weighed on 28 June 2001 after 90 days of culture. Daily weight gain (g $fish^{-1} d^{-1}$), yield (kg m^{-3}) and extrapolated yield (kg m^{-3} $year^{-1}$) were calculated.

The pond was fertilized weekly with urea and triple super phosphate (TSP) at 4 kg N and 1 kg P ha^{-1} d^{-1}. Initial pond fertilization took place two weeks prior to stocking fish.

Salinity was initially regulated by trucking hypersaline water (150 ppt) to AIT and diluting it to 10 ppt. Salinity was maintained at 10 ppt and monitored weekly. Water depths in the pond and cages were maintained at 1 and 0.8 m, respectively, throughout the experiment by adding water at about 10 ppt salinity weekly to replace evaporation and seepage losses. All cages were aerated for 6 hours daily from 0200-0800 h using one airstone in each cage.

Integrated water samples were collected from the entire water column near the two ends and center of the pond and also from each cage biweekly at approximately 0900 h. Analyses were done for pH, alkalinity, total ammonium nitrogen (TAN), nitrite nitrogen (nitrite-N), nitrate nitrogen (nitrate-N), total Kjeldahl nitrogen (TKN), soluble reactive phosphorus (SRP), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS) and total volatile solids (TVS) using standard methods (Parsons *et al*., 1984; APHA *et al*., 1985; Egna *et al*., 1987). Secchi disk visibility, temperature and dissolved oxygen (DO) were also measured at the time of collecting water samples with a Secchi disk and YSI model 54 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio, USA). Diel measurements for temperature, DO and pH were conducted in each pond at 0600, 0900, 1600, 1800, 2200, and 0600 h once a month.

Data were analyzed statistically using analysis of variance, paired-sample t-test and linear regression (Steele and Torrie, 1980) with SPSS (version 7.0) statistical software package (SPSS Inc., Chicago, USA). Differences were considered significant at an alpha of 0.05. Statistical analyses for survival rates (%) were performed on data after arcsine transformation. Mean values of survival rates in this text are listed in normal scale followed by their confidence limits. All other means are given with ±1 standard error (S.E.).

Economic analysis was conducted to determine economic returns of red tilapia in the different treatments (Shang, 1990). The analysis was based on farm-gate prices in Thailand for harvested red tilapia and current local market prices for all other items expressed in US dollar (US$1 = 40 baht). Farm-gate prices of red tilapia was \$0.50 and \$0.75 kg^{-1} for the size 100-200 g and 200-300 g, respectively. Market prices of sex-reversed red tilapia fingerlings (\$0.0125 $piece^{-1}$), electricity (\$0.05 kWh^{-1}), pelleted floating feed (\$0.4875 kg^{-1}), urea (\$0.1875 kg^{-1}) and TSP (\$0.3125 kg^{-1}) were applied to the analysis. The calculation for cost of working capital was based on an annual interest rate of 8%.

Results

Survival of red tilapia in cages ranged from 96.7% to 99.8%, and did not differ significantly among treatments ($P > 0.05$). Significant difference in caged red tilapia growth between the non-feeding treatment (0 % satiation feeding) and the feeding treatments (25% through 100% satiation feeding) was shown at the first fish sampling (15 days after stocking, $P < 0.05$), while significant difference among feeding treatments was detected starting from the second fish sampling (30 days after stocking, $P < 0.05$, Fig. 1). Growth and yield of caged red tilapia increased significantly with increased feeding rates from 0 to 75% satiation ($P < 0.05$), while there were no significant differences between the 75% and 100% satiation feeding treatment ($P > 0.05$). Mean daily weight gains were significantly different one after another among treatments, with the highest value in the 100% satiation feeding treatment ($P < 0.05$, Table 1).

Feed conversion ratio (FCR) was significantly better in treatments with lower percentages of satiation feeding ($P < 0.05$, Table 1). Total weight gain of caged red tilapia was linearly and positively correlated ($r = 0.98$, $n = 15$, $P < 0.01$) with total feed input to cages (Fig. 2). Compared to weight gain in the non-feeding treatment, addition of feed at 25%, 50%, 75% and 100% satiation feeding resulted in 57%, 75%, 95% and 105% greater weight gain, respectively(Fig. 3). By subtracting weight gain in the non-feeding treatment from that in the feeding treatments, natural food appears to contribute to 64%, 57%, 51% and 49% of the energy for weight gain in treatments with 25%, 50%, 75% and 100% satiation feeding levels, respectively. Feeding rates varied from 0.64 to 3.06% body weight per day (%BW/d) in the feeding treatments, and increased with increasing percentage of satiation feeding levels (Fig. 4). The average feeding rates were 0.76%, 1.37%, 2.07%, and 2.42% BW/d in the feeding treatments with 25%, 50%, 75% and 100% satiation feeding. Feeding rates also appeared to decline over time in the highest feeding treatments.

All water quality parameters except Secchi disk visibility were measured in cages and open water, and no significant differences were found among cages or between cages and open water ($P > 0.05$). The mean values of water quality parameters measured in cages and ponds at each sampling were summarized in Table 2. Mean temperature ranged from 29.9 to 32.2 C. Values of pH at the end of the experiment were significantly higher than those at beginning ($P < 0.05$). Concentrations of DO at dawn and alkalinity decreased significantly over time ($P < 0.05$). Concentrations of nutrient parameters fluctuated throughout the experimental period, with TKN, TAN, TP and SRP increasing significantly but nitrite-N and nitrate-N decreasing significantly through the experiment ($P < 0.05$). Concentrations of chlorophyll *a* and TSS were significantly higher at the end than at the beginning of the experiment ($P < 0.05$), while TVS concentrations were not significantly different ($P > 0.05$).

The economic analysis indicated that red tilapia culture with supplemental feeding at 25-75% satiation feeding levels was profitable (Table 3). Net return in the feeding treatments decreased with increased feeding levels, and the 100% satiation feeding resulted in negative net return. The net return in the non-feeding treatment was lower than that in both 25% and 50% satiation feeding, but greater than that in the 75% and 100% satiation feeding.

Discussion

Physical, chemical and biological parameters did not differ among cages or between cages and open water in the present experiment, indicating that all red tilapia had the similar culture environment and equal access to natural foods. Compared to non-feeding cages, the addition of supplement feed resulted in significantly higher yields and growth rates. The growth differential between non-fed and fed red tilapia started during the first two weeks of culture, similar to results for Nile tilapia (*O. niloticus*) cultured in freshwater ponds (Diana *et al*., 1994), while the growth differential among different levels of food input began after the first two weeks of culture and continued to differentiate throughout the experiment. Moav *et al*. (1977) reported insignificantly different production between fish with or without supplemental feeding in fertilized freshwater polyculture ponds, which was likely due to lower densities of stocked fish (Diana *et al*., 1994).

Table 1. Growth performance of all-male Nile tilapia fed at 0%, 25%, 50%, 75% and 100% of satiation in 0.8-m^3 cages. Mean values with different superscript letters in the same row were significantly different among treatments ($P < 0.05$).

Performance measures		Treatments				
		0%	25%	50%	75%	100%
Stocking						
Total weight	(kg $cage^{-1}$)	1.7±0.0	1.7±0.0	1.7±0.0	1.7±0.0	1.7±0.0
Mean weight	(g $fish^{-1}$)	33.3±0.0	33.3±0.1	33.3±0.0	33.3±0.0	33.3±0.0
Harvest						
Total weight	(kg $cage^{-1}$)	6.9±0.1^a	9.8±0.1^b	10.8±0.4^c	11.8±0.1^d	12.4±0.3^d
Mean weight	(g $fish^{-1}$)	138.4±2.2^a	203.2±2.5^b	221.5±5.0^c	241.9±5.1^d	253.9±2.8^d
Mean weight gain	(g $fish^{-1}$)	105.1±2.2^a	169.9±2.5^b	188.2±5.0^c	208.6±5.1^d	220.6±2.8^d
Daily weight gain	(g $fish^{-1}$ day^{-1})	1.17±0.10^a	1.92±0.14^b	2.11±0.18^c	2.33±0.15^d	2.47±0.19^e
Net yield	(kg m^{-3} $crop^{-1}$)	6.5±0.1^a	10.2±0.1^b	11.4±0.5^c	12.7±0.2^d	13.4±0.3^d
	(kg m^{-3} $year^{-1}$)	26.4±0.4^a	41.3±0.3^b	46.3±2.2^c	51.6±0.6^d	54.2±1.4^d
Gross yield	(kg m^{-3} $crop^{-1}$)	8.6±0.1^a	12.3±0.1^b	13.5±0.5^c	14.8±0.2^d	54.2±1.4^d
	(kg m^{-3} $year^{-1}$)	34.8±0.4^a	49.8±0.3^b	54.7±2.2^c	60.0±0.6^d	62.6±1.4^d
FCR		----	0.67±0.01^a	0.93±0.04^b	1.15±0.01^c	1.28±0.03^d
Survival	(%)	99.8 (93.8-100.0)	96.7 (93.0-99.1)	98.3 (82.0-100.0)	99.3 (82.1-100.0)	98.3 (82.0-100.0)

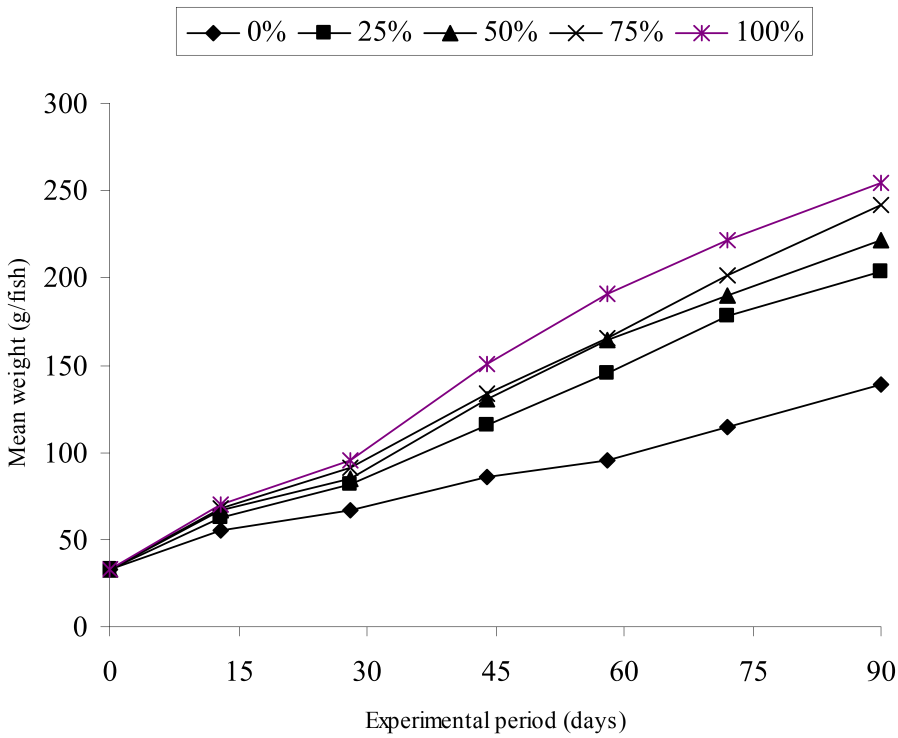

Fig.1. Growth of Thai red tilapia fed at 0%, 25%, 50%, 75%, and 100% satiation feeding levels over the 90-day experimental period.

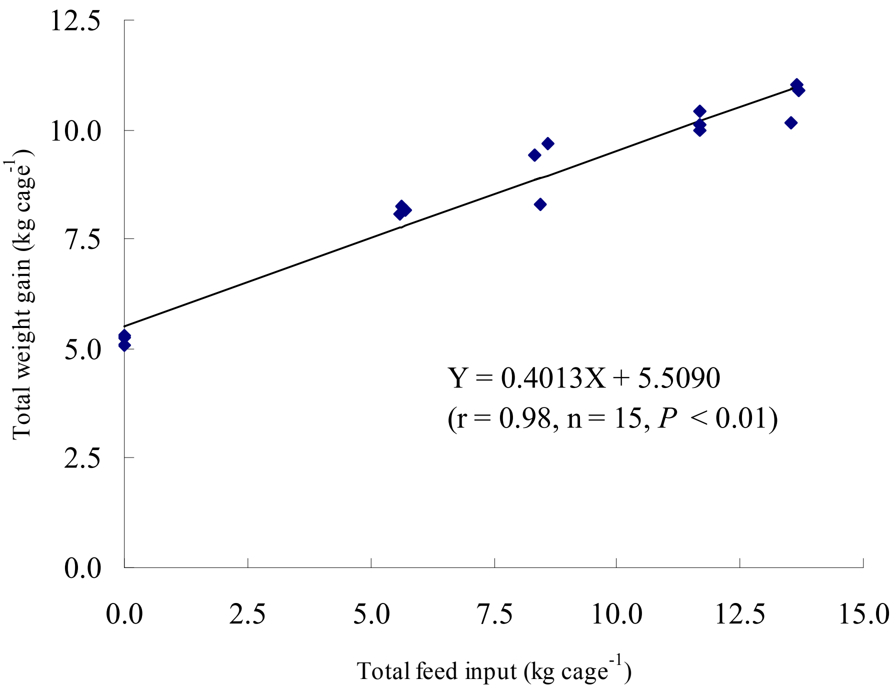

Fig.2. Relationship between total feed input to cages and total weight gain of caged red tilapia.

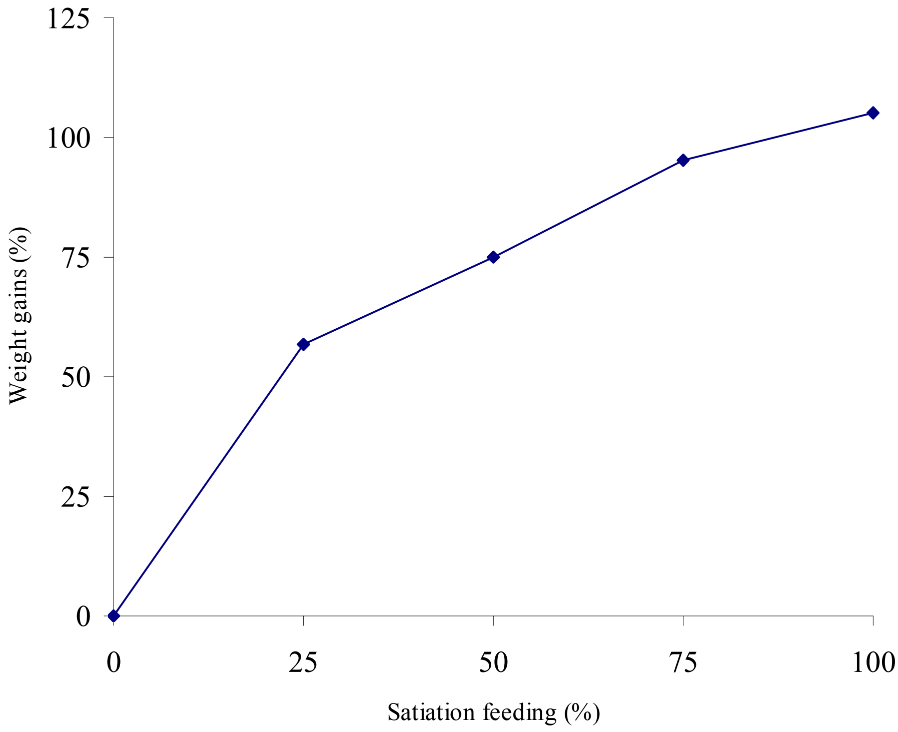

Fig.3. Percentages of total weight gains for each feeding treatment compared to the total weight gain of non-feeding treatment.

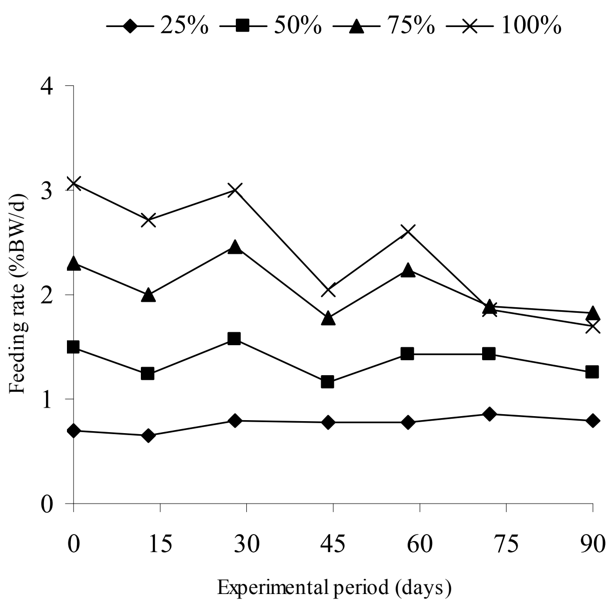

Fig.4. Mean feeding rates (%BW/d) for red tilapia at 25%, 50%, 75% and 100% satiation feeding levels over the 90-day experimental period.

Table 2. Mean (± S.E.) values of water quality parameters measured in cages and open water at 0900 h (except DO that was measured at dawn) at various points during the experimental period. Parameters (excluding Secchi disk visibility) marked with an asterisk had significant differences among the time periods.

Parameters	Day 6	Day 19	Day 34	Day 47	Day 60	Day 74	Day 88
*DO at dawn (mg L^{-1})	4.61±0.00	----	2.33±0.02	----	1.68±0.01	----	0.30±0.00
Temperature (C)	31.8±0.0	32.2±0.0	30.0±0.0	32.9±0.0	31.0±0.0	29.9±0.0	30.3±0.0
*pH	7.9±0.0	6.5±0.0	6.2±0.0	6.7±0.0	6.5±0.0	5.2±0.0	5.9±0.0
*Alkalinity (mg L^{-1} as $CaCO_3$)	78±1	42±1	42±1	37±0	15±1	10±0	13±1
*TKN (mg L^{-1})	2.61±0.08	3.29±0.20	6.11±0.13	5.79±0.17	2.41±0.18	3.13±0.08	5.70±0.24
*TAN (mg L^{-1})	0.56±0.03	2.30±0.02	4.59±0.04	3.62±0.15	0.89±0.09	2.21±0.02	2.84±0.03
*Nitrite-N (mg L^{-1})	0.05±0.00	0.24±0.00	0.24±0.00	0.80±0.00	0.28±0.00	0.02±0.00	0.03±0.00
*Nitrate-N (mg L^{-1})	0.23±0.00	0.19±0.00	0.06±0.00	0.58±0.02	0.09±0.00	0.03±0.00	0.03±0.00
*TP (mg L^{-1})	0.16±0.00	0.10±0.00	0.43±0.00	0.17±0.00	0.22±0.00	0.91±0.01	0.44±0.01
*SRP (mg L^{-1})	0.01±0.00	0.03±0.00	0.14±0.00	0.00±0.00	0.01±0.00	0.43±0.01	0.07±0.00
*Chlorophyll *a* (mg m^{-3})	61±3	14±1	33±1	39±4	49±1	52±4	100±3
*TSS (mg L^{-1})	76±2	79±1	54±1	55±1	96±4	61±1	69±1
TVS (mg L^{-1})	29±2	48±1	19±1	24±1	48±3	27±1	33±1
Secchi disk visibility (cm)	55	100	64	64	62	61	41

Table 3. Economic analysis (in US$) for red tilapia in each experimental treatment.

Parameter	Feeding Treatment				
	0%	25%	50%	75%	100%
GROSS REVENUE					
Red tilapia	3.45	7.35	8.10	8.85	9.30
Total	3.45	7.35	8.10	8.85	9.30
VARIABLE COST					
Red tilapia fingerlings	0.63	0.63	0.63	0.63	0.63
Urea	0.21	0.21	0.21	0.21	0.21
TSP	0.21	0.21	0.21	0.21	0.21
Pelleted feed	0.00	2.75	4.12	5.69	6.64
Electricity	1.35	1.35	1.35	1.35	1.35
Cost of working capital	0.19	0.41	0.52	0.65	0.72
Total	2.59	5.56	7.04	8.74	9.76
NET RETURN	0.86	1.79	1.06	0.11	-0.46

Hepher (1978) developed the concept of critical standing crop (CSC), which is the biomass of fish in any aquaculture system that results in growth reductions for each individual. In the present experiment, treatments differed significantly in growth of red tilapia from the first biweekly fish sampling, and growth continued linearly until harvest, indicating that CSC had to occur at a size less than 50 g. The results support findings in Nile tilapia grown in freshwater ponds (Diana *et al.*, 1994).

The good growth (1.17 g day^{-1}) of red tilapia at high density in non-feeding cages indicates that natural foods were abundant and important to growth in this experiment. This growth rate was comparable or higher than that in other studies (Green 1992; Diana *et al.*, 1994, 1996). The good growth of non-fed red tilapia also indicate the abundant natural foods in the experimental pond in the present experiment, that was also implied by declining alkalinity throughout experiment due to carbon utilization for photosynthesis (Knud-Hansen *et al.*, 1991). Tilapias under culture conditions prefer artificial to natural foods (Schroeder, 1978), and thus the contribution of natural foods to red tilapia may decrease with increasing availability of artificial feed, giving higher FCR in the treatments with higher percentage of satiation feeding. In other words, supplemental feed was more effective for incremental fish growth at lower percentages of satiation feeding.

Combined fertilizer and feed application resulted in efficient use of nutrients (Green, 1992; Diana *et al.*, 1994, 1996). Applying feed at a lower percentage of satiation makes tilapia more efficient at utilizing natural food. In a previous study, Diana *et al.* (1994) determine 50-75% satiation feeding to be the most efficient feeding rates for Nile tilapia culture in freshwater ponds. The partial budget analysis in the present experiment showed that 25% satiation feeding was most profitable, followed by 50% satiation feeding. However, growth started to slow at the end of the culture period in the 25% satiation feeding

(Fig. 1). It appears that a 25% ration was not sufficient to support for further growth to a size (> 500 g) that would fetch higher market prices. Considering low FCR, good growth and yield performance, high economic return and potential for growing to greater size, 50% satiation feeding is the most efficient feeding rate in the present experiment.

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