

**ALTERNATIVE FEEDING STRATEGIES TO IMPROVE MILKFISH
PRODUCTION EFFICIENCY IN THE PHILIPPINES**

Sustainable Feed Technology/ Experiment/ 07SFT03NC

Evelyn Grace T. de Jesus-Ayson
Aquaculture Department
Southeast Asian Fisheries Development Center (SEAFDEC AQD),
Iloilo, Philippines

Russell J. Borski
Department of Biology
North Carolina State University
Raleigh, NC, USA

ABSTRACT

In the Philippines, cage culture of milkfish in marine environments is increasing. The practice uses high stocking densities, with significantly greater inputs of artificial feeds which more often than not, has led to excessive feeding and consequently excessive nutrient loading in receiving waters, exacerbating problems with pollution. These could have contributed to occurrence of periodic fish kills in areas of marine milkfish culture clusters. Sixty percent of milkfish farming expenses are attributable to feed costs. A series of experiments were conducted in an attempt to develop alternative feeding strategies that will reduce feed inputs without compromising growth and resulting production. In the first experiment, growth was compared in milkfish fed daily, on alternate days and on alternate 2-week or 4-week starvation and refeeding cycles in a tank environment provided with flow-through water system. Results show, that milkfish fed on alternate days do not grow as well as milkfish that are fed daily. Feed restriction for 2 weeks followed by 2 weeks of refeeding elicited a compensatory growth response such that average body weight (ABW) of fish was not significantly different from ABW of fish fed daily. Another experiment compared growth of fish given a ration equivalent to 10% of BW (usual practice) or 7.5% of BW. Results show no significant effect on growth or final ABW or biomass in fish fed daily or on 2-week cycles of feed restriction and refeeding. Thus, a lower feeding ration can be given to milkfish without compromising yield. Results of the tank experiments were verified in actual marine cage and brackishwater pond production systems using an initial feeding rate of 7.5% rather than 10% ABW. In the experiment in cages, survival rates between the control fish and the groups subjected to cycles of 2-week starvation followed by 2 weeks of normal feeding were comparable, except for one replicate of the starved-refed group where survival rate was very low (38.78%). After 3 cycles of starvation and refeeding, weight gain in the starved-refed groups were generally lower than in the control groups, which may suggest that small-sized fish cannot adapt very well to periodic starvation. In brackishwater ponds, growth, survival and total biomass at harvest was comparable between milkfish fed daily and those fed on alternate days. Hence, FCR was lower in the milkfish fed on alternate days compared to fish fed daily. On the other hand, survival was very low in fish subjected to 2 cycles of 2 weeks starvation followed by 4 weeks of normal feeding. These results suggest that as in tilapia, alternate day feeding can be adopted to milkfish culture in brackishwater ponds without

compromising production while at the same time lowering production cost and environmental impact. Overall, these studies provide two practical strategies, reduced ration size and alternate day feeding, to improve production efficiency of milkfish, the largest finfish aquaculture industry in the Philippines

INTRODUCTION

Aquaculture in the Philippines is a high food security priority particularly in the light of the country's rapidly growing populations and their continued dependence on fish protein. Milkfish has been cultured in the Philippines for almost a century (Bagarinao 1999). It is the largest finfish aquaculture industry in the Philippines with a harvest area of 280,000 ha and total production of 300,000 metric tons annually (BAS 2006). There is also a growing export market for milkfish at one million kilograms annually and a value of almost \$3 million, with the U.S. topping imports among all countries. As part of the Philippine government's food security and poverty alleviation programs, expansion of milkfish culture is a high priority (Rosario 2006) both to wean fishers off capture fisheries by providing them with fish farming as an alternative or supplemental form of livelihood, and to increase income of farmers whose poverty levels are disproportionately high (Rivera et al. 2006). Milkfish production is increasing at 5% annually, with much of the production moving away from traditional culture in brackishwater (BW) ponds to fish cages in marine waters, where a 14% increase was seen in 2005 alone (BAS 2006). Cage culture of milkfish in marine environments is done at high densities and with significantly greater inputs of artificial feeds. The use of this practice, however, has led to wastage of artificial feeds and excessive nutrient loading in receiving waters (Sumagaysay-Chavoso et al. 2004), exacerbating problems with pollution and possibly periodic fish kills that have been observed in areas of marine milkfish culture clusters.

Sixty percent of milkfish farming expenses are attributable to feed costs (Rosario 2006, Rivera et al. 2006). Research on tilapia has demonstrated that feeding only on alternate days saves almost 50% on feed costs with little effect on growth, survival or market yield (Bolivar et al. 2006). Like the tilapia, milkfish is a low trophic species and plankton eater. On the other hand, previous research have also demonstrated that longer- term feed restrictions followed by a refeeding period can elicit a compensatory growth response in fish characterized by a 2-3 fold increase in specific growth and feed conversion (Skalski *et al.*, 2005; Picha et al. 2008a, 2009; Turano et al. 2007; see Ali et al. 2003 for review). Cyclic feeding was also shown to reduce total phosphorous load in ponds by as much as 40% (Turano et al. 2008). Although general feed methods and nutritional requirements to raise marketable sized milkfish have been established, largely through research at SEAFDEC AQD (Juario *et al.*, 1984; Alava and Lim, 1988; Sumagaysay 1995, 1998), studies have not assessed whether periodic episodes of feed restriction/refeeding can induce compensatory growth and improve production efficiency in this species.

The overall goal of this investigation is to develop feeding strategies as potential cost containment options for milkfish (*Chanos chanos*) production in both brackishwater (BW) and marine environments. We examined whether feeding schedules that incorporate feed restriction/refeeding increments might limit overall feed input without significantly impacting fish yield. We first conducted preliminary studies in tanks and used the data generated to test different feeding regimens in an intensive culture system in cages in marine waters, as well as in a semi-intensive culture system in brackishwater ponds. The

rationale for testing different feeding regimens in marine cage and in BW pond systems is because each may require different feed inputs due to natural productivity (BW ponds) or lack thereof (marine fish cages). Also, BW ponds represent 70% of total production and marine cage culture is on the rise. Thus, the sustainability of these two culture systems and farmer's profitability could be enhanced through methods that both reduce feed input and limit nutrient loading in receiving waters through excessive feed wastage.

Insulin-like growth factor-I (IGF-I) is the primary hormonal mediator of growth in fish. We and others have found that it may serve as a robust biomarker of growth rates in various fish species that include tilapia, hybrid striped bass, flounder and salmonids (Beckman et al. 2004; Vera Cruz et al. 2006; Luckenbach et al. 2007; Picha et al. 2008b). Its levels change rapidly prior to and in parallel with specific growth responses (Picha et al. 2006). Considering traditional methods of conducting lengthy and costly growth trials, a biomarker of growth such as IGF-I could prove valuable for researchers for the rapid assessment of the numerous, and often confounding number of environmental and nutritional parameters that regulate growth. We undertook studies under controlled growout environments to evaluate the utility of IGF-I mRNA expression as an instantaneous indicator of growth in milkfish.

OBJECTIVES

- ± Evaluate the efficacy of feed schedules that incorporate lower feed ration and different increments of feed restriction and refeeding on milkfish production characteristics and the compensatory ("catch-up") growth response in tanks.
- ± Determine effects of feed restriction on milkfish production characteristics in marine cages.
- ± Determine effects of different feeding regimens on full grow-out trials in brackishwater ponds
- ± Evaluate the potential for insulin-like growth factor-I (IGF-I) as a biomarker of growth status in milkfish.

MATERIALS AND METHODS

Study 1 - Evaluate the efficacy of feed schedules that incorporate lower feed ration and different increments of feed restriction and refeeding on milkfish production characteristics and the compensatory ("catch-up") growth response in tanks.

Experiments were initially conducted in tanks to test the effect of different feed schedules on milkfish growth and survival. Results from these experiments helped in defining the feeding regimens that might best work for milkfish and served as bases in the conduct of field production trials in BW ponds at the Dumangas Brackishwater Station and in fish cages in marine waters at the Igang Marine Station of SEAFDEC AQD, respectively.

The effect of different feeding regimes on growth and survival of milkfish in tanks was examined. The feeding regimes tested are as follows:

Treatment 1: control, daily feeding at 10% ABW

Treatment 2: feeding on alternate dates at 10%

Treatment 3: cycles of 2-week starvation followed by 2 weeks normal feeding
 Treatment 4: cycles of 4-week starvation followed by 4 weeks of normal feeding

Milkfish fingerlings produced at the SEAFDEC AQD fish hatchery and grown in brackishwater nursery ponds with an average body weight of 10-20 g were stocked in 1- ton fiberglass tanks at a density of 100 fish/ton. Fish were fed SEAFDEC AQD formulated feeds under the 4 different feeding regimens. The tanks were provided with flow-through seawater. There were 3 replicate tanks per treatment. All fish were sampled for body weight and standard length measurements every 2 weeks to monitor growth and adjust for feed ration. Samples of liver were also taken from 3 fish in each tank during each sampling schedule for IGF-I mRNA quantification.

Differences among treatment means at the end of the 8-week growth trial were analyzed by one-way analyses of variance (GraphPad Prism, LaJolla, CA. USA).

In another experiment, the effect of reducing feeding level from 10% to 7.5% of ABW on growth and survival of fish fed daily and those subjected to cycles of 2-week starvation followed by 2 weeks normal feeding was examined. The feeding regimes tested were as follows:

Treatment 1: control, daily feeding at 10% ABW

Treatment 2: cycles of 2-week starvation followed by 2 weeks normal feeding (10% ABW)
 Treatment 3: reduced feeding, daily feeding at 7.5% ABW

Treatment 4: cycles of 2-week starvation followed by 2 weeks of reduced feeding (7.5% ABW)

Milkfish fingerlings produced at the SEAFDEC AQD fish hatchery and grown in brackishwater nursery pond with an average body weight of 10- 20 g were stocked in 1- ton fiberglass tanks at a density of 100 fish/ton. Fish were fed SEAFDEC AQD formulated feeds under the 4 different feeding regimens. The tanks were provided with flow-through seawater. There were 3 replicate tanks per treatment. All fish were sampled for body weight and standard length measurements every 2 weeks to monitor growth and adjust for feed ration. Liver samples were taken from a subgroup of fish for measurement of hepatic IGF-I mRNA levels. Livers were processed and IGF-I mRNA measured by real time quantitative PCR according to our previously established protocols (Picha et al. 2007; Vera Cruz et al. 2006).

Differences among treatment means at the end of the 12-week growth trial were analyzed by one-way analyses of variance (GraphPad Prism, LaJolla, CA. USA).

Study 2 - Determine effects of feed restriction on milkfish production characteristics in marine cages.

Based on the results of the tank experiments (Figure 1 and 2) and preliminary experiments in a simulated cage culture system set up in a 50- ton tank (data not shown), an experiment

was conducted to compare milkfish production characteristics in an intensive culture system in fish cages in marine waters. Fish were subjected to two feeding regimes:

Treatment I: control, fed daily at 7.5% body weight

Treatment II: cycles of 2-week starvation followed by 2 weeks of daily feeding at 7.5% body weight.

Six units of fish cages measuring 5 x 5 x 3m were set up in Igang Marine Station of SEAFDEC AQD. Milkfish fingerlings (12-35 g ABW) produced at the SEAFDEC AQD fish hatchery and grown in a private milkfish nursery facility in Nueva Valencia, Guimaras were stocked at a density of 35 fish/m³. Fingerlings were fed SEAFDEC AQD formulated feeds initially at 7.5% of ABW given in 4 rations daily. The amount of feed was reduced as the fish gained weight. This was shown to be as effective as the standard industry practice of feeding initially at 10% of body weight. Water quality parameters including dissolved oxygen level, chlorophyll a and phosphorous was monitored in relation to establish potential relationships with feed input and fish biomass. To monitor growth and adjust the feed ration, 25 fish in each cage were subsampled and measured for body weight and standard length every 2 weeks. At the termination of the experiment, actual head count and measurement of actual biomass harvested was done. Percent survival and feed conversion ratio (FCR) were determined.

Differences among treatment means in production parameters at the end of the 14-week growth trial were analyzed by paired t-Test (GraphPad Prism, LaJolla, CA. USA).

Study 3 – Determine effects of different feeding regimens on full grow-out trials in brackishwater ponds

Based on results of the tank experiments, an experiment on milkfish production in semi - intensive brackishwater ponds was conducted to compare the effects of alternate day feeding and 2-week restricted and 4-week refeeding cycles to that of fish fed daily. The pond production study was conducted at SEAFDEC AQD's Dumangas Brackishwater Station.

For this experiment, 3 treatment groups were used and each treatment had 2 replicates. The treatments are as follows:

T1: control, normal daily feeding at 7.5% of average body weight and gradually decreasing to 4% with increased fish biomass

T2: same feeding rate as control but given on alternate days only

T3: cycles of 2 weeks restricted feeding followed by 4 weeks normal feeding at a rate similar to controls

Six units of ponds (700 m²) were used. Ponds preparation followed established procedures for eradication of unwanted species and enhancement of the growth of lablab, the natural food of milkfish in ponds. However, because of continuous heavy rains, good growth of lablab was not achieved. Milkfish fingerlings produced at the SEAFDEC AQD fish

hatchery and grown in brackishwater nursery ponds to an average body weight of 75 g were used for stocking. Fingerlings were stocked at a density of 350 fish/700m³ and fed SEAFDEC AQD formulated feeds initially at 7.5% of ABW given in 4 rations daily. The amount of feed was reduced as the fish gained weight. Body weight measurements of 40 fish were taken every 2 weeks to monitor growth and adjust for feed ration. After the last sampling, total harvest was done where the total number of fish in each pond compartment was counted and total biomass was measured. Percent survival and feed conversion ratio (FCR) were determined.

Differences among treatment means in production parameters at the end of the 12-week growth trial were analyzed by one-way analyses of variance (GraphPad Prism, LaJolla, CA, USA).

RESULTS

An experiment was conducted to assess the effects of different feeding regimes on growth of milkfish in tanks provided with flow-through water. Figure 1 shows the changes in average body weight and daily growth rates of milkfish under the different feeding regimes. Expectedly, negative growth is observed during periods of starvation. On the other hand, milkfish exhibited increased growth upon refeeding after periods of prolonged starvation. These results show that milkfish fed a ration equivalent to 10% of ABW on alternate days did not grow as well as milkfish fed the same ration daily ($P < 0.05$). On the other hand, ABW of milkfish subjected to 2-week alternate starvation and refeeding cycle was comparable to the control group that was fed daily, suggesting that compensatory growth mechanisms were at work ($P > 0.05$). Milkfish subjected to a 4-week starvation and refeeding cycle attained final ABW that was significantly lower than the control.

Attempts were made to quantify IGF-I expression in livers of milkfish subjected to different feeding regimes. IGF-I expression was normalized against the expression of the housekeeping gene, GAPDH. Ideally, the expression of housekeeping genes does not vary between tissues, developmental stage or physiological state and hence can be used to control for possible differences in sample loading or as normalization to the gene of interest. We found that changes in IGF-I expression observed in the current experiment did not show clear trends, possibly because the expression of GAPDH, which was used to normalize IGF-I expression was variable (data not shown). Other studies also show that housekeeping genes may vary in a tissue-specific manner and with the physiological state of the animal. We are currently exploring the use of other housekeeping genes and methods for normalization of IGF-I mRNA expression.

Based on anecdotal observations we conducted a second, supplemental experiment not initially proposed for this investigation to assess the effects of lower feed ration on milkfish growth. We compared growth of milkfish fed the typical ration of 10% average body weight daily with a lower ration level of 7.5% of body weight. Results show that growth of milkfish measured as body weight and growth rate was not affected by reduction of ration to 7.5% of the body weight, regardless of whether fish were fed daily or on 2-week feed restriction/refeeding cycles ($P > 0.05$: Figure 2).

Another preliminary experiment was conducted to assess the effects of different feeding

regimes on growth of milkfish in a simulated marine cage environment. Results generally reflect the result of the tank experiment. Milkfish fed on alternate days did not grow as well as milkfish fed daily (data not shown). Milkfish subjected to a 2-week alternate starvation and refeeding cycle did not exhibit compensatory growth of comparable magnitude as was observed in tanks. This lack of a robust compensatory growth response may have been due to the presence of algae growing on the nets and of plankton in the water that the fish can feed on. These other natural sources of food may have reduced the level of catabolism during the starvation period, such that animals did not undergo as significant a compensatory growth response when realimentated to daily feeding as was seen in tanks (see Picha et al. 2006). Prolonging the starvation period to 3 weeks also did not enhance the compensatory growth response.

Nevertheless, we proceeded to test the alternative feeding strategies that were effective in the tank trials on milkfish production in intensive marine cage culture. The effect of 2-week starvation and refeeding cycles on milkfish production in an intensive culture system in marine cages was compared to the standard continuous daily feeding strategy at 7.5% body weight. Six units of 5x5x3m cages were stocked with milkfish fingerling at a stocking density of 35 fish/m³. Fish in 3 cages were fed daily while fish in the other 3 cages were subjected to 2-week starvation and refeeding cycles. The stocks (50 fish from each cage) were sampled every two weeks to monitor growth and to adjust for feed ration. Figure 3 shows changes in body weight (BW) and total length (TL) of control fish fed daily and size-matched groups that were subjected to starvation and refeeding cycles. Production parameters after 3 starvation and refeeding cycles are summarized in Table 1. Except for replicate 3 of the starved-refed group, survival rates between the 2 groups are comparable. After 3 cycles of starvation and refeeding, weight gain in replicate 2 of the starved-refed group (initial ABW: 12.2g) was only 72.8% compared to the control group with similar initial body weight (ABW: 12.4g) which exhibited 155% weight gain, which may suggest that small sized fish cannot adapt very well to periodic starvation. Overall, we found that the growth, survival, and feed efficiency of fish in the starved/fed group was lower than that of fish fed daily. The total biomass harvested was significantly lower in the starved/fed group relative to fish continuously fed on a daily basis.

We also evaluated the effect of different feeding regimes on milkfish production in a semi-intensive culture system in brackishwater ponds. Six pond compartments with an area of 700 m² were stocked with milkfish fingerlings at a stocking density of 0.5 fish/m². The following feeding regimens were tested: daily feeding (control), feeding on alternate days and 2 cycles of 2-week starvation followed by 4 weeks of normal feeding. There were two pond replicates per feeding regime tested. Stocks (40 fish from each pond compartment) were sampled every two weeks to monitor growth as well as for adjusting feed rations. Data after 2 starvation and refeeding cycles are summarized in Figure 4 and Table 2. Results of the pond experiment show that growth of milkfish fed daily was better (DGR: 3.12% and 3.64%) than milkfish fed on alternate days (DGR: 2.97% and 2.68%) or fish subjected to 2 cycles of 2-week starvation followed by 4 weeks of normal feeding (DGR: 2.79% and 2.75%). However, the differences were not statistically significant. Survival rate of milkfish fed on alternate days (81.43% and 94.57%) was comparable to milkfish fed daily (63.43% and 90.29%), but were significantly lower in fish subjected to 2 cycles of 2-week starvation followed by 4 weeks of normal feeding (24.29% and 46.57%; $P < 0.05$). Total biomass at harvest was similar for milkfish in

ponds that were fed daily (68.6 kg and 100.8 kg) versus those fed on alternate days (88.57 kg and 96.5 kg). Because the number of surviving fish was very low, total biomass at harvest and FCR in fish subjected to 2 cycles of 2-week starvation followed by 4 weeks of normal feeding ranged from only 23.05 kg to 47.75 kg and 4.73 to 9.62 for the 2 replicates, respectively. FCR of milkfish fed daily ranged from 2.89 to 4.5 while that of milkfish fed on alternate days was between 1.68 and 1.90, respectively. Although the FCR was over 50% lower in fish on the alternate day versus those on daily feeding, there was no overall statistical difference. In addition to having similar biomass at harvest and lower FCR, fish on alternate day feeding also consumed almost 50% less than fish on daily feeding ($P < 0.05$).

DISCUSSION

The results of the series of experiments on feeding strategies and milkfish production show fish respond differently depending on the feeding regime and the culture system in which they are raised. In initial studies in tanks, growth of milkfish subjected to cycles of 2-week starvation followed by 2 weeks of normal feeding was comparable to fish fed daily. Moreover, reductions of feeding rate from 10% to 7.5% of total biomass also resulted in comparable growth regardless of whether animals were fed daily or on 2-week restricted-refeeding cycles that elicit compensatory growth responses. These results have important implications in terms of reduction of costs for the culture of milkfish as well as the negative environmental impact of milkfish farming. Feed costs make up about 50-60% of the total cost for milkfish production. Excessive feeding, especially in intensive culture systems has likewise led to feed wastage and high nutrient loading in the culture environment and pollution resulting in periodic episodes of fish kills. Our results suggest a 25% reduction in feed ration, at least during the initial period of fingerling growout, in addition to reducing the feed amount by half through the use of prolonged periods of feed restriction, can significantly reduce feed costs in tank cultured milkfish.

In the experiment in marine cages, survival rates between the control fish and the groups subjected to cycles of 2-week starvation followed by 2 weeks of normal feeding were comparable, except for replicate 3 of the starved-refed group where survival rate was very low (38.78%). After 3 cycles of starvation and refeeding, weight gain in the starved-refed groups were generally lower than in the control groups. Notably, weight gain in replicate 2 of the starved-refed group (initial ABW: 12.2 g) was only 72.8% compared to the control group with similar initial body weight (ABW: 12.4 g) which exhibited 155% weight gain, which may suggest that small sized fish may not adapt as well to periodic starvation. In addition to lower final weight and weight gain, the total biomass harvested was significantly lower with fish on the restricted-refeeding cycles. This was likely exacerbated by the poorer survival rate of one of the replicates on the cyclic feeding regimen. Although fish on the cyclic feeding consumed approximately 50% less feed, the lower growth rate and biomass harvested suggests that two week-cycles of feed restriction followed by refeeding may not be a suitable cost containment strategy for producing milkfish in intensive cage culture in marine environments. Considering fish responded to the cyclic feeding regimen differently in tanks versus cage culture (see Figures 1 and 2 versus Figure 3), it is possible that alternate day feeding may prove useful in the cage environment, despite it not having been as effective in tank culture. This should be tested as it may significantly improve FCR relative to daily feeding, with a more limited impact on growth and harvest biomass relative to fish restricted and refeed for prolonged periods.

Industry FCR values in fish raised in marine cages normally range from 2.9 or higher. We found that fish fed daily at a ration level of 7.5% ABW had substantially lower FCR values of 2.29 on average (Table 1). This lower FCR may have resulted from the use of the lower ration level relative to the standard of 10% ABW/day used by industry. Additionally, in related work at SEAFDEC, feeds have been reformulated to better target growout of milkfish in marine environments. Hence, the reformulation of feeds along with lower ration level may have contributed to the generally lower FCR we observed in fish fed daily.

Results of the pond experiment show that growth of milkfish fed daily was a slightly better than milkfish fed on alternate days and lowest in those subjected to 2 cycles of 2-week starvation followed by 4 weeks of normal feeding. The differences were not statistically significant however. Similarly, survival rate of milkfish fed on alternate days was comparable to milkfish fed daily, but very low in fish subjected to 2 cycles of 2-week starvation followed by 4 weeks of normal feeding ($P < 0.05$). This was surprising since no mass mortalities were observed during the duration of the experiment. Average total biomass harvested was similar in fish on the alternate day (mean \pm SD; 92.5 ± 5.6) versus those on the standard daily (89.7 ± 29.8) feeding regimen. Fish on the alternate day feeding consumed almost 50% less feed and showed improved feed efficiency (mean FCR of 1.74) relative to fish on the daily feeding schedule (mean FCR = 3.70). By contrast fish on the 2-week restricted and 4-week refeeding protocol had an average FCR value of 7.18. Collectively, these results suggest alternate day feeding may prove useful in reducing feed costs by almost 50% in milkfish culture in brackishwater ponds without compromising production, while simultaneously lowering nutrient loading in the environment. These results are similar to that which has been established with feed reduction strategies that employ alternate day feeding of tilapia in semi-intensive culture in ponds (Bolivar et al. 2006).

It should be noted that in a semi-intensive culture system for milkfish, feeding is supposed to be supplemental and is normally given once the natural food in the pond is exhausted. However, good growth of natural food was not achieved in the course of the experiment because of long spells of heavy rains, thus feeding was done from the start of the experiment until it was terminated. Because of this and limitations in the number of ponds available (2 per treatment) for this study an additional trial should be conducted to confirm the utility of alternate day feeding with production of milkfish in ponds, particularly under conditions where fish are fed only when natural foods (lablab) are exhausted. Nevertheless, the studies point to the strong possibility that reduced feeding may prove highly useful to enhancing production efficiency of milkfish. This is particularly noteworthy since some farmers in Region 6 in the Philippines (a major milkfish producing region comprising the provinces of Iloilo, Capiz, Aklan, Antique and Negros Occidental) who traditionally relied solely on natural food production for milkfish culture are seeing smaller harvests because natural food production has become increasingly difficult to maintain. With the increased reliance on supplemental feeding in the brackishwater culture of milkfish in the Philippines, the alternate day feeding protocol tested here may prove an ideal practical method to reduce costs for small-scale farmers while limiting environmental impacts of their activities.

Collectively, the studies conducted here indicate that a 25% reduction in feed ration levels during a portion of the production cycle can reduce costs of milkfish culture. Moreover, 2-

week cycles feed restriction followed by refeeding and alternate day feeding are effective in providing additional cost savings for production of milkfish in tanks and in the semi-intensive culture of milkfish in brackishwater ponds, respectively.

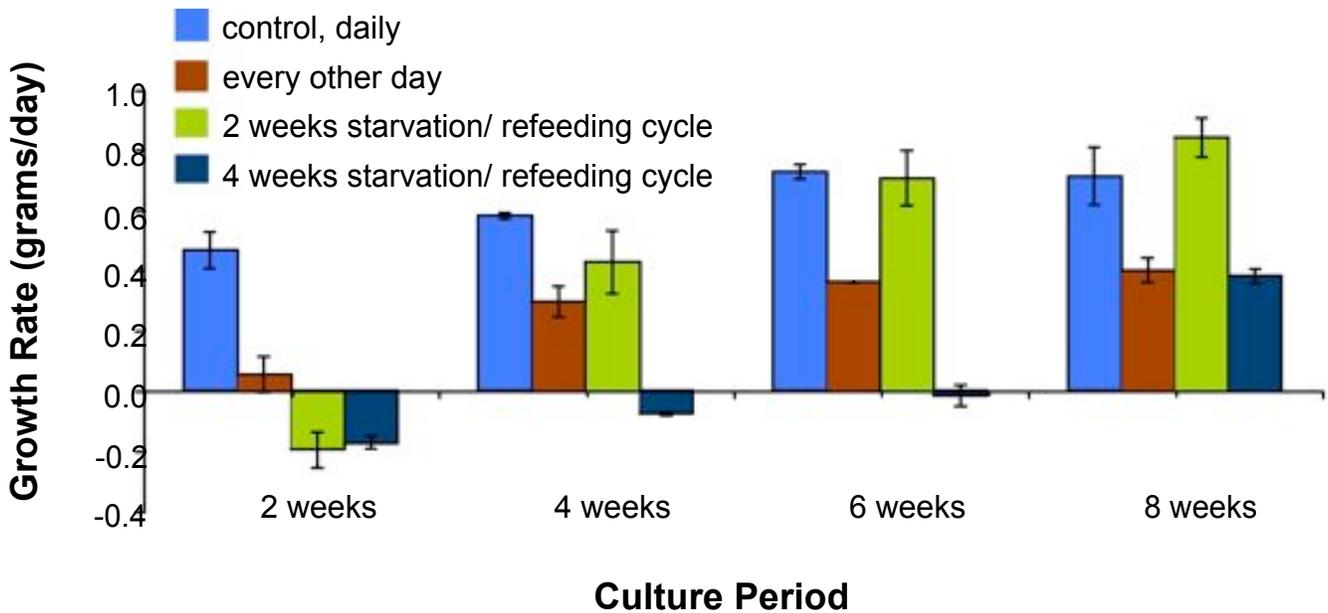
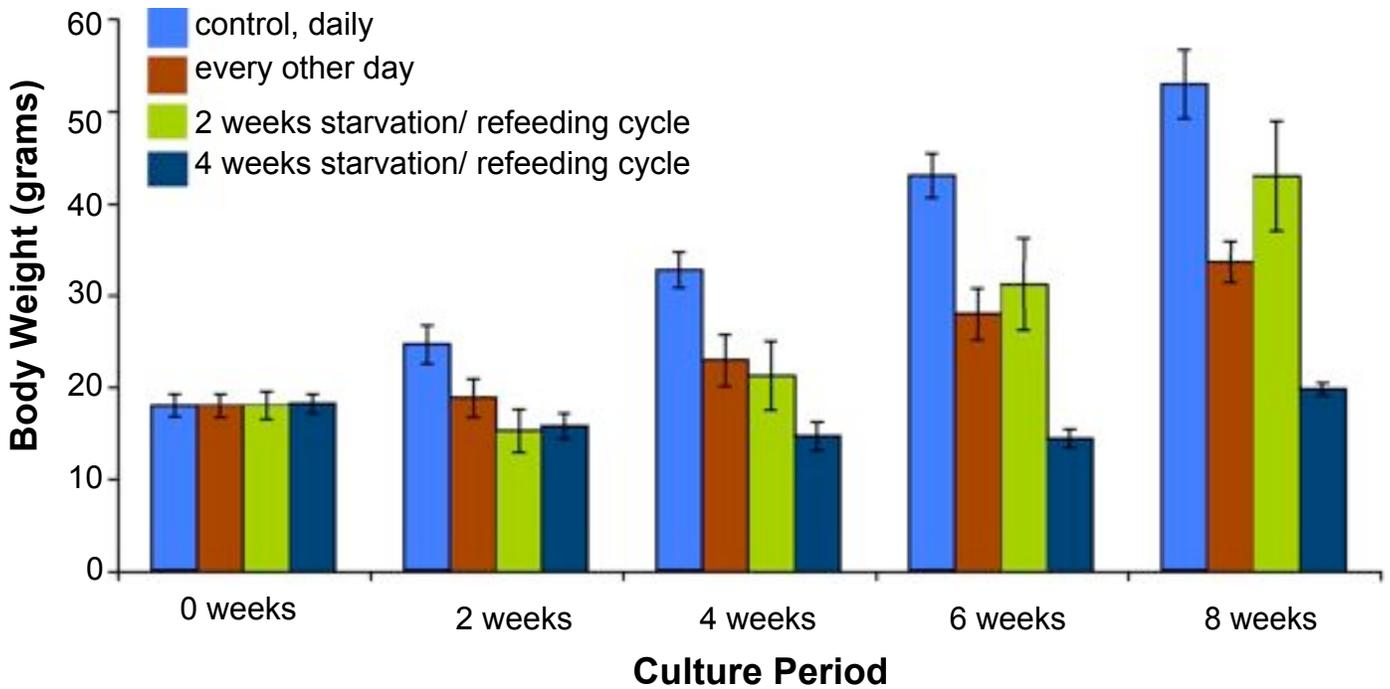


Figure 1. Changes in body weight (grams; top graph) and daily growth rate (grams/day; bottom graph) of milkfish in tanks under different feeding regimes: daily feeding at 10% of total biomass, feeding at 10% of total biomass but on alternate days, alternate 2-week starvation and refeeding cycles, and alternate 4-week starvation and refeeding cycles. During the refeeding period ration level was 10% of biomass daily. Data are mean \pm SEM of three replicate tanks per group. There was no significant difference in body weight and growth rate for fish fed daily and those fed on 2-week restricted/refeeding cycles.

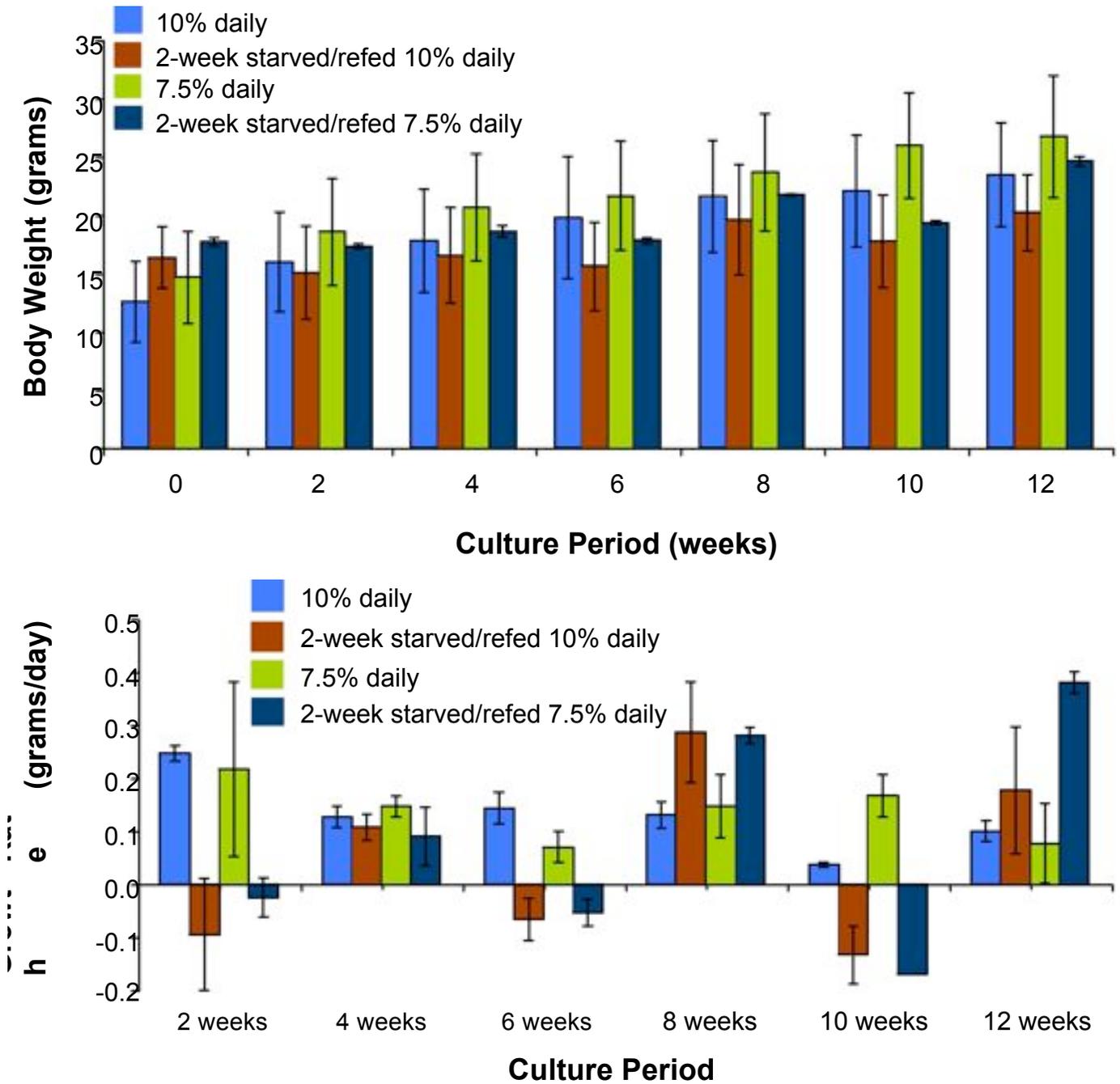


Figure 2. Changes in body weight (grams; top graph) and daily growth rate (grams/day; bottom graph) of milkfish in tanks under different feeding regimes: daily feeding at 10% of total biomass, alternate 2-week starvation and refeeding daily at 10% of total biomass, daily feeding at 7.5% of total biomass, and alternate 2-week starvation and refeeding daily at 7.5% of total biomass. During the refeeding period ration level was 10% of biomass daily. Data are mean \pm SEM of three replicate tanks per group. There were no differences in body weight among groups following 12-weeks of growout.

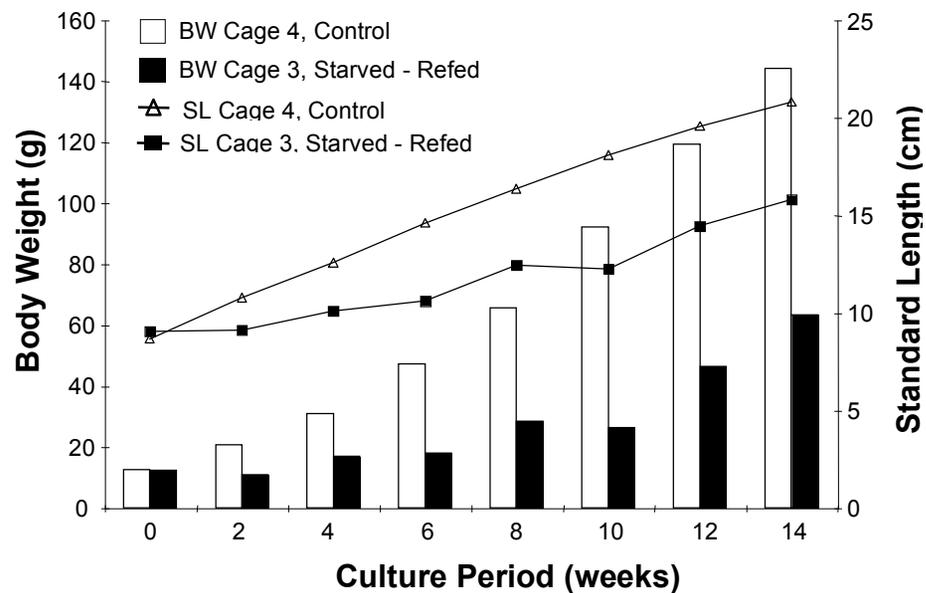
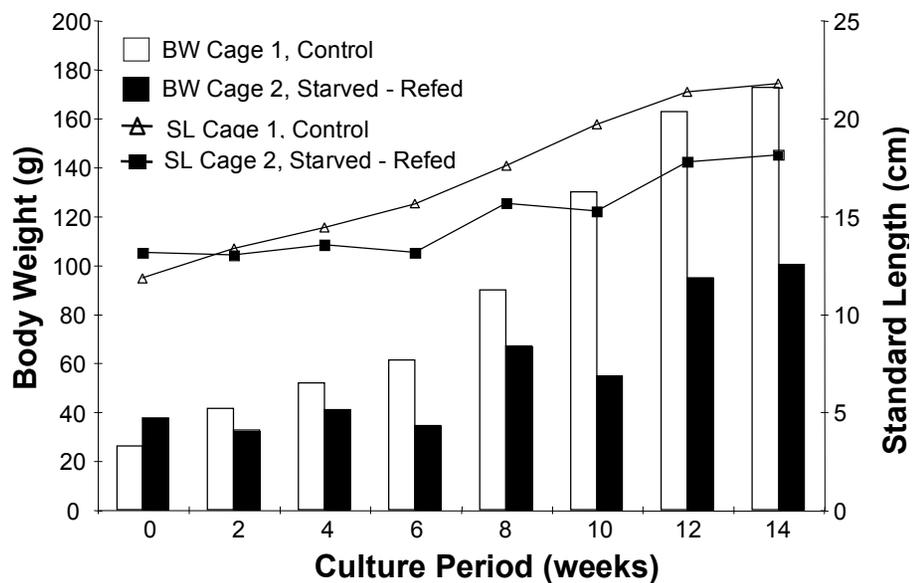


Figure 3. Changes in body weight (grams) and standard length (SL) of milkfish in an intensive culture system in marine cages fed either daily at 7.5% of the total biomass (control) or subjected to alternate 2-week starvation and refeeding cycles (7.5% biomass). The different figures represent size-matched replicates. Data are shown as means of 50 fish sampled from each cage during each sampling schedule. Error bars represent standard errors of the means. Fish on the cyclic feeding schedule grew significantly less than those on the daily feeding schedule ($P < 0.05$).

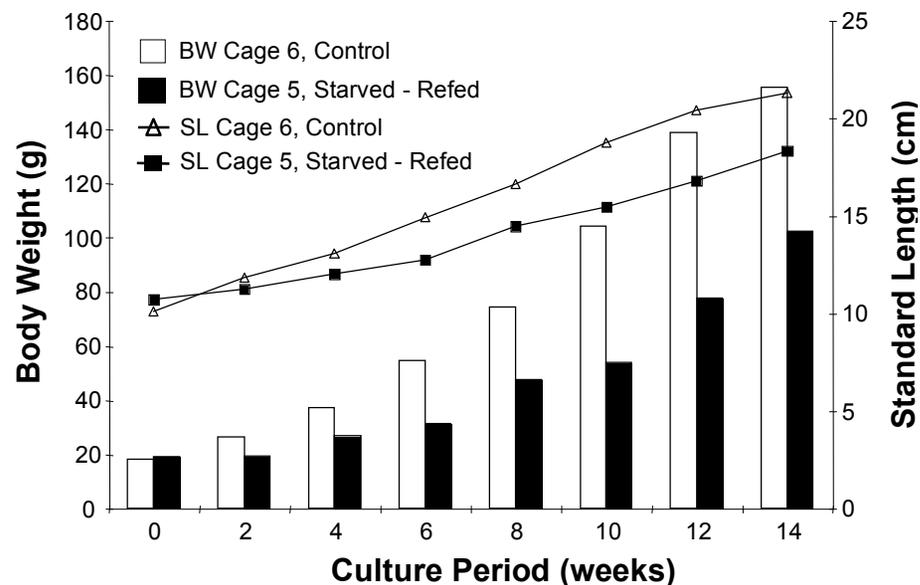


Table 1. Production indicators for the intensive culture of milkfish in marine cages under different feeding regimes. Each cage was stocked with milkfish at a density of 35 fish /m³. There were three replicate cages for each treatment.

Parameter	Treatment A (Fed daily, control)	Treatment B (2-week starvation and refeeding cycles)
Initial ABW (g)	25.95 ± 0.93 12.4 ± 0.93 18.3 ± 1.14	37.35 ± 1.25 12.2 ± 1.25 19.05 ± 0.90
<i>Group Mean ± SD</i>	<i>18.9 ± 6.8 (a)</i>	<i>22.9 ± 13.0 (a)</i>
Final ABW (g)	220.0 ± 8.38 167.4 ± 2.27 168.0 ± 0.25	144.0 ± 5.27 85.0 ± 4.76 192.5 ± 0.24
<i>Group Mean ± SD</i>	<i>166.3 ± 24.2 (a)</i>	<i>117.6 ± 51.2 (a)</i>
% Weight Gain	194.05 155.0 149.7	106.65 72.8 173.42
<i>Group Mean ± SD</i>	<i>185.1 ± 30.2 (a)</i>	<i>140.5 ± 53.84 (a)</i>
Survival Rate (%)	98.28 72.38 103.0	91.43 69.33 38.78
<i>Group Mean ± SD</i>	<i>91.2 ± 16.5 (a)</i>	<i>66.5 ± 26.4 (a)</i>
Actual Biomass Harvested (kg)	567.6 318.0 567.6	345.1 154.7 196.0
<i>Group Mean ± SD</i>	<i>484.4 ± 144.1 (a)</i>	<i>231.9 ± 100.2 (b)</i>
Total Feed Consumed (kg)	1268.68 898.5 1035.30	727.48 368.68 652.30
<i>Group Mean ± SD</i>	<i>1067.5 ± 187.2 (a)</i>	<i>582.8 ± 189.2 (b)</i>
FCR	2.24 2.82 1.82	2.10 2.38 3.33
<i>Group Mean ± SD</i>	<i>2.29 ± 0.5 (a)</i>	<i>2.60 ± 0.64 (a)</i>

Different letters shown in parentheses among rows reflect significant differences between groups ($P < 0.05$).

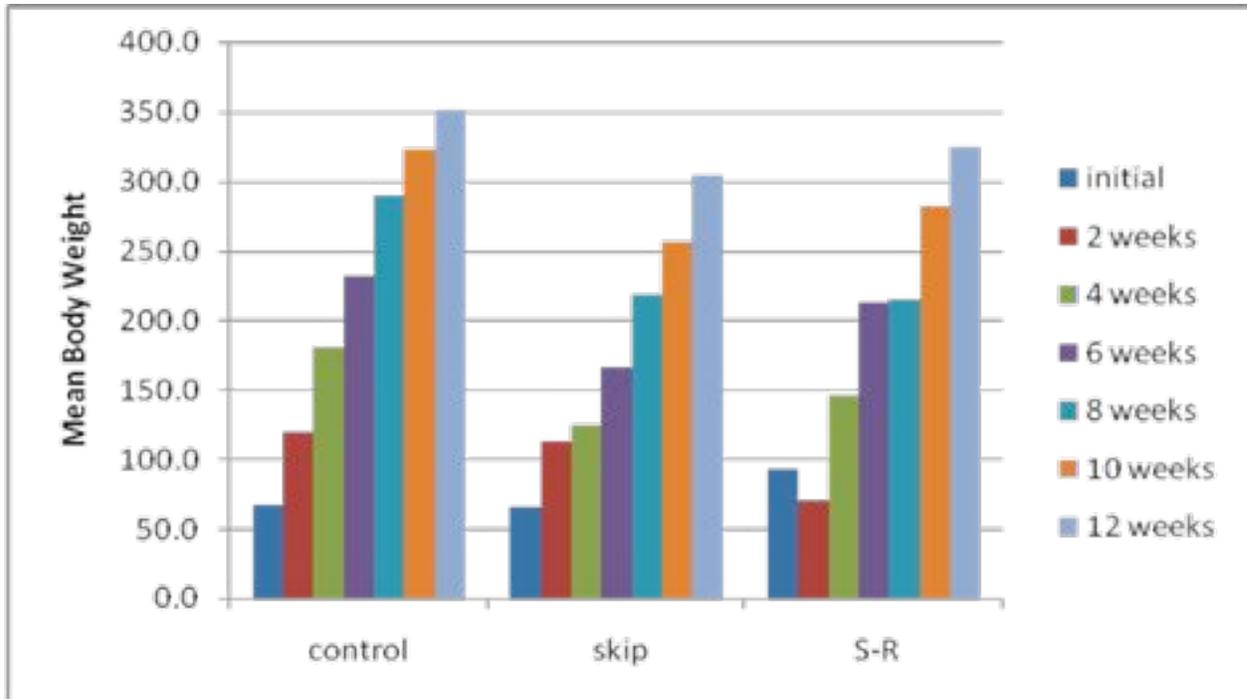


Figure 4. Changes in body weight (grams) of milkfish in a semi-intensive culture system in brackishwater ponds fed either daily at 7.5% of the total biomass (control) or on alternate days (7.5% of biomass) or subjected to alternate 2-week starvation and refeeding cycles (7.5% of biomass daily). Data are shown as means from two replicate ponds.

Table 2. Production indicators for the semi-intensive culture of milkfish in brackishwater ponds under different feeding regimes. Animals were fed either daily at 7.5% of the total biomass (control) or on alternate days (7.5% of biomass) or subjected to alternate 2-week starvation and refeeding cycles (7.5% of biomass daily). Each 700 m² pond was stocked with 350 pcs of milkfish. There were 2 replicate ponds for each treatment. Initial and final body weights were determined from 40 fish sampled from each pond.

Parameter	Treatment A (Fed daily)	Treatment B (Fed alternate days)	Treatment C (2 weeks starvation, 4 weeks refeeding)
Initial ABW (g)	71.0 ± 4.46	71.91 ± 4.5	75.6 ± 3.64
<i>Group Mean ± SD</i>	63.07 ± 3.75 67.0 ± 5.6 (a)	61.27 ± 5.78 66.6 ± 7.5 (a)	108.61 ± 6.31 92.1 ± 23.3 (a)
Final ABW (g)	332.74 ± 12.51	321.51 ± 7.92	309.94 ± 9.47
<i>Group Mean ± SD</i>	369.30 ± 13.01 351.0 ± 25.9 (a)	286.42 ± 8.54 304.0 ± 24.8 (a)	339.51 ± 11.18 324.7 ± 20.9 (a)
% Weight Gain	368.65	347.10	309.97
<i>Group Mean ± SD</i>	485.54 427.1 ± 82.7 (a)	367.47 357.3 ± 14.4 (a)	212.60 261.3 ± 68.9 (a)
DGR (g/day)	3.12	2.97	2.79
<i>Group Mean ± SD</i>	3.64 3.38 ± 0.37 (a)	2.68 2.83 ± 0.21 (a)	2.75 2.77 ± 0.03 (a)
Survival Rate (%)	63.43	81.43	24.29
<i>Group Mean ± SD</i>	90.29 76.9 ± 19.0 (a)	94.57 88.0 ± 9.3 (a)	46.57 35.4 ± 15.8 (b)
Actual Biomass Harvested (kg)	68.60	88.57	23.05
<i>Group Mean ± SD</i>	110.80 89.7 ± 29.8 (a)	96.50 92.5 ± 5.6 (a)	47.75 35.4 ± 17.5 (a)
Total Food Consumed (kg)	308.98	159.32	221.76
<i>Group Mean ± SD</i>	320.46 314.7 ± 29.8 (a)	162.31 160.8 ± 2.1 (b)	226.10 223.9 ± 3.1 (c)
FCR	4.50	1.80	9.62
<i>Group Mean ± SD</i>	2.89 3.70 ± 1.14 (a)	1.68 1.74 ± 0.08 (a)	4.73 7.18 ± 3.46 (a)

Different letters shown in parentheses among rows reflect significant differences between groups ($P < 0.05$).

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