FEEDING REDUCTION STRATEGIES AND ALTERNATIVE FEEDS TO REDUCE PRODUCTION COSTS OF TILAPIA CULTURE

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ABSTRACT

Feed constitutes 60-80% of total production costs of tilapia (*Oreochromis spp.*). Reductions in quantity of feed used for fish growout and in the cost of formulated feeds are two approaches to containing feed costs. We evaluated feed reduction strategies and replacement of fishmeal as potential options for improving production efficiency of Nile tilapia (O. niloticus). In a 120 day trial on commercial farms, fish subjected to 60-days delayed, followed by 30-days alternate day and then 30 days 67% subsatiation feeding showed lower growth rates and survivorship and overall harvest size then fish fed daily at full prescribed levels. Approximately 55% less feed was applied to animals on the combined reduced feeding regimen relative to those fed on a traditional full daily feeding schedule. In a separate study on commercial ponds, tilapia raised on 50% subsatiation ration levels had growth rates, survivorship, and final harvest size that did not differ significantly from fish fed a full daily ration over 120 days. Fish on the reduced ration also consumed 56% less feed and had 100% improved feed conversion relative to fish fed full ration. We then tested the utility of substituting less costly alternative protein sources (yeast extract, poultry meal, fermented deboned meat poultry byproduct) to fishmeal in tilapia diets over a 105 day tank trial. Fish fed the different diets exhibited similar specific growth rates, although animals fed diets containing yeast extract and fermented poultry byproduct had slightly lower body size. Using circulating insulin-like growth factor-I (IGF-I) as a potential proxy of growth, we found as with specific growth rates that IGF-I did not vary among fish on the different diets. In a fourth study fish were grown out in ponds for 120 days on an alternate day reduced feeding regimen using diets with and without 6% fishmeal that incorporated plant ingredients widely available in the

Philippines (cassava meal, copra meal, coconut oil, rice bran) and porkmeal to replace fishmeal. Fish showed similar performance on diets containing 0% and 6% fishmeal. A marginal budget analysis showed an 8% improved return on fish fed the cheaper diet lacking fishmeal. This along with the alternative day feeding strategy previously shown to be as effective as daily feeding protocols has the potential of reduce overall feed costs for growing marketable size tilapia by > 60%. Collectively, these series of studies show that reduced feeding strategies and substitution of diets containing fishmeal with cheaper and more sustainable sources of protein are effective options for reducing the costs without negatively impacting the production of tilapia.

INTRODUCTION

Feed is widely recognized as the most costly component of fish farming. A cost-farm budget analysis shows that feed constitutes 60- 80% of total production costs of tilapia (*Oreochromis niloticus*) for small-scale, rural farmers in the Philippines (ADB 2005). Because of this, any reductions of feed costs can effectively increase income for Philippine farmers. Reductions in both the amount of feed used for growout of marketable fish and in the cost of formulated feeds are two approaches to containing feed costs. Our previous studies show that 1) delaying the onset of supplemental feeding to either 45-days or 75-days in fertilized ponds reduces the amount of feed consumed without any negative impact on the production of marketable tilapia, 2) feeding at a sub-satiation level of 67% did not reduce measurable production of marketable fish relative to fish fed at 100% satiation level, and 3) feeding only on alternate days saved approximately half of feed cost without a significant reduction in growth, survival, or market yield of Nile tilapia in growout ponds (Brown et al. 2000, Bolivar et al. 2003, Bolivar et al. 2006). In this study we examined the utility of combined delayed feeding strategies of 60 days delayed and 30 day alternate day feeding with 67% satiation reduced feeding to evaluate if production costs of tilapia for farmers in the Philippines could be further reduced. An additional on-farm study evaluated whether further reductions in daily feeding to half the amount typically applied might produce additional cost savings for farmers.

The cost of commercial fish feeds are rising sharply as the market demand increases to supply growing aquaculture and the availability of fishmeal declines. About 40% of feed costs are attributable to fishmeal, which constitutes 15-20% of the feed formulation. Much of the fishmeal used for tilapia in the Philippines is imported, and costs are expected to rise in the future as global supplies become constrained by increasing demands from other aquaculture and declines in commercial bait fisheries. Because tilapia are omnivorous fish, which naturally feed on plankton, diatoms, small crustaceans, algae, higher plants and decomposing vegetable matter, they do not require fish in their diet and they are an ideal group of species to recycle food by-products into high quality food protein for humans (Brown 1983). Unlike carnivorous fishes, tilapia can digest high levels of carbohydrate in their diet (Anderson et al. 1984; National Research Council 1993), and they can effectively utilize human food by-products as feed ingredients, such as rice bran, cocoa, various flowers, soya, nut oil, milling waste, brewer's wastage, poultry by-product meal and feather meal, cassava, and ipal-ipal leaf (Jackson et al. 1982). All of these lower-cost ingredients are readily available in the Philippines to completely replace or significantly reduce the inclusion of fishmeal in tilapia diets. Indeed, various animal protein meals (meat and bone meal, poultry by-product meal, feather meal, and blood meal) and plant proteins (soya, copra, cottonseed and others) have been shown to be either partially or completely replace fishmeal in tilapia diets (El-Sayed 1998; for reviews see Lim and Webster 2006 and El-Sayed 2006). We have determined that tilapia can be fed diets containing up to 33% sweet potato and lactic acid-stabilized poultry carcasses (60:40 co-extruded blend) without adverse effects on growth performance or consumer panel sensory indices (aroma, flavor and texture) (Middleton et al., 2000). However, the use of food by-products to produce least-cost fish feed is primarily constrained by their poor nutrient content, poor digestibility, or poor functional properties in manufacturing feed that can withstand the rigors of pond feeding (Li et al. 2006). Few studies have addressed the combinations of animal and plant protein types that might suffice in replacing or significantly reducing fishmeal in tilapia feed. Also, most investigations focus on the performance and nutritional characteristics of different protein sources rather than their ability to improve profit margins in tilapia production (see El-Sayed 2006). This study compares the utilization of protein sources that can replace fishmeal in tilapia diets, namely fermented mechanically deboned meat poultry byproduct, yeast extract protein, and poultry by-product meal. We also examined the use of pork by-product meal as a replacement for fishmeal in diets formulated with ingredients widely available in the Philippines on the grow out performance of Nile tilapia fed on alternate days in earthen ponds at Central Luzon University.

Based on our previous laboratory work (Vera Cruz et al. 2006), the abundance insulin-like growth factor-I (IGF-I), specifically hepatic mRNA levels, has the potential to be a rapid growth indicator in the Nile Tilapia (*Oreochromis niloticus* L.), We attempted to evaluate whether hepatic-derived IGF-I mRNA might correlate to growth under conditions in the field (ponds) and also to assess whether circulating hormone levels, thought to be derived primarily from liver, might also prove useful as a growth indicator (Picha et al. 2008). Evaluation of IGF-I as a growth biomarker was done in the context of the studies on feed reduction strategies and nutrition outlined above.

MATERIALS AND METHODS

Study 1 - Evaluation of combined 60 day delayed feeding, 30-day alternate day feeding, and 67% satiation feeding versus continuous satiation daily feeding on on-farm growout of Nile tilapia in earthen ponds

This study evaluated two (2) feeding program treatments on the growth performance of Nile tilapia. Treatment group 1 was subjected to 60 days of delayed feeding, 30 days alternate-day feeding and 30 days full feeding on a daily basis but at a sub-satiation level of 67%. Treatment group 2, the control group, were fed daily at 100% of recommended feed level based on fish biomass.

Sex-reversed Nile tilapia fingerlings (0.20 – 0.25 g body weight) of the Genetically Improved Farmed Tilapia (GIFT) strain were used in the study. The study utilized six separate tilapia farms in the Nueva Ecija region with areas ranging from 586 to 1,280 sq m. Each farmer-cooperator provided two ponds, one for each treatment group, for the growout study. Fingerlings were stocked at 4 fish m^{-2}. A day after stocking, fingerlings on the control regime (treatment group 2) were fed with commercial feeds following the recommended feeding guide of two feed suppliers. Fish were initially fed at a rate of 20% of the fish biomass that was lowered down to 2% of the fish biomass towards the end of the culture period. Ponds were fertilized with ammonium phosphate (16-20-0) and urea (46-0-0.) at the rate of 28 kg N and 5.6 kg P ha^{-1} $week^{-1}$, respectively to enhance the growth of natural foods in pond water. Fish were subsampled every two weeks wherein one hundred (100) individual fish were captured by the cast net method and measured for average weight and length to assess the growth of stocks and for feed adjustment. Water quality parameters, such as dissolved oxygen, water temperature, total ammonia-nitrogen and water pH were monitored weekly starting at 0900 hours. After 120 days of culture, stocks were harvested for bulk weight of all the stocks, survival rate, and the extrapolated gross fish yield (total weight of fish at harvest (kg) / area of the pond (m^2)). Other variables, including total feed consumption, feed conversion ratio (FCR; feed consumed/body weight), specific growth rate (SGR; % daily body weight and length gain; $[(\ln W_f - \ln W_i)/(T_f - T_i) \times 100]$) were calculated. Differences among means between groups were analyzed using the paired Student's t-test.

Liver was collected from fish subsampled at monthly intervals and at the end of the experiment for analyses of IGF-I mRNA and its corollary to growth. Tissue was placed in RNA Later (Qiagen Inc., Valencia, California, USA) and stored at -20C until processing. Total liver RNA isolation and processing and hepatic IGF-I mRNA determinations were conducted according to previously described methods for Nile tilapia (Vera Cruz et al. 2006). Total RNA was isolated using Trizol® according to the manufacturer's protocol (Invitrogen™). High salt precipitation solution was used for glycogen removal in the samples. RNA was treated with DNA-free™ (Ambion®) to remove any possible genomic DNA contamination. RNA was quantified and purity was assessed by spectrophotometry (JASCO V-530 UV/VIS Spectrophotometer). On reverse transcription, first strand cDNA was synthesized in 20ul RT reactions with 1 ug total RNA template Omniscript® reverse transciptase, 10x RT buffer, 5uM dNTP, 10 uM oligo-dT primer (Promega®) and RNase inhibitor (RNasin®, Promega®). Normalization of samples was carried out against total RNA content and was done using absorbance measures at OD_{260} in JASCO V-530 UV/VIS Spectrophotometer. Samples were reverse transcribed by incubation at 37 °C for 60 min. IGF-I quantification using TaqMan® qRT-PCR was performed at the Southeast Asian Fisheries Development Center (SEAFDEC) at Tigbauan, Iloilo, Philippines on a Rotor Gene 6000 (Corbette Research), using the standard conditions at 50°C for 2 min, 95°C for 10 min, followed by 40 cycles of 95°C for 15 s, 60°C for 1 min. Gene-specific primers (Invitrogen) and FRET probes (Applied

Biosystems) for qRT-PCR were designed with the Primer Express® Program (Applied Biosystems). The forward primer was 5'-GTCTGTGGAGAGCGAGGCTTT-3', corresponding to bases 324 to 344 and the reverse primer was 5'-CACGTGACCGCCTTGCA-3', corresponding to bases 377 to 393. The sequence of the probe was 5'-TTTCAATAAACCAACAGGC-TATGGCCCC-3'. The selected reporter and quencher dyes for the probe were FAM and TAMRA, respectively. Reactions for each sample were done with each well containing 25 ul PCR mixture (10 ng cDNA template, 1X TaqMan® universal PCR master mix, 900 nM forward and reverse primers and 250 nM probe).

Study 2 – Evaluation of 50% daily feed ration levels versus full daily feed ration on on-farm growout of Nile tilapia in earthen ponds.

This study was composed of two (2) treatment groups and replicated six (6) times. Groups were as follows: I – 50% of recommended daily ration based on biomass, and II – a control group fed daily at 100% of recommended daily feed ration based on fish biomass (20% down to 3%). Sex-reversed Nile tilapia fingerlings (0.20 – 0.25 g body weight) of GIFT strain were used in the study. The study utilized six separate tilapia farms in the Nueva Ecija region with areas ranging from 400 – 1380 m^2. Each farmer-cooperator provided two ponds, one for each treatment group, for the growout study. Fingerlings were stocked at 4 fish m^{-2}. Fish were fed daily at either a 50% (Treatment I) or 100% (Treatment II) level based on fish biomass. Ponds were fertilized with ammonium phosphate (16-20-0) and urea (46-0-0.) at the rate of 28 kg N and 5.6 kg P ha^{-1} $week^{-1}$, respectively to enhance the growth of natural foods in pond water.

Fish were subsampled and production parameters were measured and analyzed as described under Study 1. Liver was collected from fish subsampled monthly and at the end of the experiment for analyses of IGF-I mRNA and its corollary to growth as described above.

Study 3 – *Effects of Fermented Mechanically Deboned Meat Poultry by-Products, Poultry Meal and Nupro Yeast Extract as a potential protein source substitution for Fish Meal in tilapia feed formulations*

We evaluated other protein sources as a substitute for fishmeal in tilapia diets in tank trials using sex reversed male Nile tilapia (Aquasafra, Sarasota, FL). Fish were either fed a balanced tilapia diet (32% crude protein, 7% crude fat) containing 6% fishmeal (FM), or diets in which fishmeal was substituted with other protein sources; fermented mechanically deboned meat poultry byproduct (MDM), Nupro yeast extract (NUP) or poultry meal (PM). All four test protein meals had similar crude protein content (62-65% Crude Protein), but the MDM had a higher fat content, thus requiring less supplemental poultry fat to formulate experimental diets of similar nutrient composition (Table 3). All the feed was manufactured into pellets using a pellet press and crumbled into 2 mm crumbles.

Fish of similar size were raised in recirculating freshwater tanks (1000 L) at the Tidewater Research Station (Plymouth NC) for 105 days beginning at an average body weight of approximately 90 g (N = 2 tanks/group with 35 fish/tank). A separate group of smaller fish of identical age (56 g, N = 1 tank/group, 35 fish/tank) was also tested to ascertain whether growth responses might vary with body size. Unless otherwise indicated data presented represent that from the replicated groups containing larger fish, although the smaller fish responded virtually identically to the different diets as that of the larger fish. Fish were grown at 25ºC and water quality parameters were maintained well within the tolerance levels for tilapia. Fish were fed twice daily at 3% body weight per day throughout the experiment. Total feed applied to the tanks was adjusted based on body weight approximately every 3 weeks. All fish were weighed and measured for total length at 0, 34, 72 and 105 days of the experiment. Fish were sampled for plasma IGF-I analyses at the beginning (day 0) and end (day 105). Blood was taken via heparinized syringe from the caudal vein of anesthetized fish and plasma separated by centrifugation and frozen at -20C (Picha et al. 2008). At the end of the experiment a subsample of animals (3-4 fish/tank) were also frozen for proximate analyses.

For proximate analyses, fish were weighted, grinded, and dried under ventilation a 65ºC for 48 hours to determine dry matter content of each fish. Samples were subsequently further grinded to attain smaller particle sizes and analyzed for crude protein, crude fat, and energy content.
Protein efficiency ratio was calculated as the total amount of protein consumed divided by the total amount of body protein gained during the 105 day period.

Differences in mean body weight and total body length were analyzed by repeated measures ANOVA followed by the Fisher's LSD test for predetermined comparisons among groups. Specific growth rate (% body weight gain/day), feed conversion ratio, and body composition data were analyzed by a Student's t-test.

Study 4: Effect of pork meal replacement of fishmeal in diets formulated with locally-available ingredients in the Philippines on the growth of Nile tilapia cultured in earthen ponds using alternate-day feeding strategy

In this study we evaluated the utility of using pork meal, a source of animal protein substantially lower in cost than fishmeal and widely available in the Phillipines, as a replacement of fishmeal in diets of tilapia grown in ponds. Alternate day feeding was previously shown to reduce production costs of tilapia without significantly altering final yield as almost 50% less feed could be used to grow fish than that incorporating standard daily feeding practices. Hence, this study evaluated if replacement of fishmeal with pork meal is as effective in producing tilapia under an alternate-day feed reduction strategy, as those diets containing standard levels of fishmeal. We established a collaboration with Santeh Feed Corp. (Bulacan, Philippines), a major producer of fish feeds in the Philippines. Mr. Ning Pascaul of Santeh helped formulate the feeds using various locally available ingredients in the Philippines.

This study was composed of two (2) treatment groups with four replicates per treatment. Groups were as follows: treatment I – formulated feeds with 6% fishmeal and treatment II – formulated feeds lacking fishmeal and containing pork meal. The constitution of the formulated
tilapia grower floating feeds is shown in Table 6. The grow-out phase of this study were done in eight 500 m^2 earthen ponds at the Freshwater Aquaculture Center, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines. Size 20 (weight range = 0.35-0.37 g) fingerlings of the GIFT strain were stocked in each pond at 4 fish m^{-2}. Fish were initially fed on alternate days with prestarter (36% crude protein) for 30 days and then starter feeds for 30 days. Following this 60-day period, animals were fed formulated grower feeds with and without fishmeal on alternate days until the end of the experiment. The feed ration was based on the average fish biomass amd ranging from 10% down to 3% body weight per day (Table 7). Fish sampling was done every two weeks using cast net method to monitor fish growth and for feed adjustment. Estimated survival were as follow: first month – 100%, second month – 95%, third month – 90% and fourth month – 85%. Ponds were fertilized weekly with ammonium phosphate (16-20-0) and urea (46-0-0.) at the rate of 28 kg N and 5.6 kg P ha^{-1} $week^{-1}$, respectively to enhance the growth of natural foods in pond water. Water quality parameters (dissolved oxygen concentration, water temperature and Secchi disc visibility) were monitored weekly between 9 to 10 o'clock in the morning. Water depth was maintained at 1 m in each pond. The total numbers of fish were counted and bulk weighed at the end of the 120 days culture period. Final mean weight, daily weight gain, gross yield and survival rates were calculated. A simple cost and return analysis were computed to compare the cost benefits between the two treatments. Data were analyzed using paired t-Test.

RESULTS AND DISCUSSION

Study 1 - Evaluation of combined 60 day delayed feeding, 30-day alternate day feeding, and 67% satiation feeding versus continuous satiation daily feeding on on-farm growout of Nile Tilapia in earthen ponds

Figure 1 shows the body weight and total length of fish on the delayed/reduced feeding regime (treatment I) versus fish fed daily at full ration levels (treatment II). We found fish had lower body weights and lengths after 60-days of delayed feeding than control fish fed daily. During the third month of culture, fish on the delayed feeding were then fed on alternate days. These fish had an average body weight of 52.09 g compared with 84.77 g for fish fed daily. Body length did not change significantly among the two groups during this period. On the final month of culture, fish on the delayed/reduced feeding protocol were then fed daily at 67% satiation. During this period, fish showed a greater growth rate than fish fed daily, although full catch-up growth was not achieved. By the end of the experiment average body weight of treatment I fish on the delayed/reduced feeding protocol was 118.05 g, relative to 149.82 g for treatment II fish fed daily on a full ration throughout the study. Stocks were harvested wherein number of fish and total weight were recorded for survival and gross fish production. Each farm was monitored during harvest ensuring the security of the data. Extrapolated gross yield, feed conversion and other production variables is presented in Table 1.

Following the 120-day culture period, the performance of the fish stock with regards to the mean final weight and length, daily gain in weight and length, specific growth rate, and feed conversion ratio were lower in fish on the delayed and reduced feeding protocol, albeit the effect was statistically insignificant relative to fish fed daily at full ration ($P > 0.05$; Table 1). Survival rate and extrapolated gross yield was significantly lower in fish on the delayed/reduced feeding protocol ($P < 0.05$; Table 1). It is likely the reduced gross yield of fish on the delayed/reduced feeding protocol, may have resulted in part to their lower survival rates (32%), although the fish on normal feeding also showed relatively low survivorship (< 50%). Although the reason for poorer survival rates is unclear, it may have been due in part to the presence of predators, as several adult catfishes and mudfishes were present in ponds or perhaps to extreme weather conditions where hot mornings and sudden afternoon rains prevailed during the culture period. These conditions may have led to lower survival rates of fish on the delayed/reduced feeding protocol, particularly early on when fish showed significant loss in condition factor (body weight/length^3) during the initial 60 days of delayed feeding. Results show that using combination of feed reduction strategies significantly reduced the quantity of feeds consumed by about 55%.

Study 2 – Evaluation of 50% daily feeding versus the typical 100% of daily feeding ration on on-farm growout of Nile tilapia in earthen ponds.

Figure 2 shows the body weight and total length of fish on the 50% reduced feeding ration (treatment I) versus fish fed daily at full ration levels (treatment II). Initial stocking size between the two groups was virtually identical (0.21 ± 0.03 g and 0.21 ± 0.02 g body weight). Following the 120-day culture period fish on the reduced feed ration showed had a lower final mean weight of 123.57 ± 15.71 g and mean daily weight gain of 1.03 ± 0.13 g ($P < 0.05$; Figure 2, Table 2) relative to fish on full daily ration that had a final weight of 148.95± 13.06 g and daily weight gain 1.24 ± 0.11 g ($P < 0.05$;). A 7% lower total length was also observed with fish on reduced ration. Despite the difference in final weight and length the specific growth rate did not differ between groups (reduced ration, 5.03 ± 0.18 %; full ration, 5.46 ± 0.13 %; $P > 0.05$; Table 2).

Survival rates were similar between fish on the reduced and full feeding rations (reduced ration, 62.5 ± 6.08 %; 63.1 ± 10.59 %; Table 2). The extrapolated gross yield of fish on the reduced ration (2754.9 ± 234.16 kg/ha) was moderately lower and did not differ from fish on the full ration (3440.9 ± 613.27 kg/ha; $P > 0.05$; Table 2). The total quantity of feeds consumed was 56% lower in fish on the reduced ration protocol relative to those provided a full ration. This dramatic reduction in feeds consumed was accompanied by a > 100% improvement in feed efficiency. Mean feed conversion ratio (FCR) was 1.0 ± 0.06 for fish grown on reduced ration while that for fish on the full ration was 2.1 ± 0.38

(P < 0.05; Table 2).

Water quality parameters, including water temperature and dissolved oxygen concentration was monitored throughout the culture period (Figure 3). Temperature and DO concentration were within the normal range. However, frequent fluctuations especially on water temperature due to unstable weather condition was observed throughout the culture period.

We attempted to evaluate the utility of IGF-I mRNA as a biomarker of growth in pond reared fish from both *Study 1* and this study. However, after performing RNA isolation, DNA-free treatment, cDNA synthesis and IGF-I quantification, sample readings were negligible (data not shown). It is likely that the RNA was degraded as frequent power interruptions had exposed samples to temperatures higher than the recommened (-20 – -80ºC). It will be critical in future studies to rapidly process samples through the cDNA synthesis step, as DNA is considerably more stable than RNA.

Study 3 – *Effects of Fermented Mechanically Deboned Meat Poultry by-Products, Poultry Meal and Nupro Yeast Extract as a potential protein source substitution for Fish Meal in Nile tilapia feed formulations*

We evaluated protein sources as a substitute for fishmeal in tilapia diets in tank trials using sex reversed male Nile tilapia. Fish were either fed a balanced tilapia diet (32% crude protein, 7% crude fat) containing 6% fishmeal (FM), or diets in which fishmeal was substituted with other protein sources; fermented mechanically deboned meat poultry byproduct (MDM), Nupro yeast extract (NUP) or poultry meal (PM) (See Table 3)

The data presented are from the replicated groups containing larger fish, although the smaller fish responded virtually identically to the different diets as that of the larger fish. Fish fed the PM based diets achieved a similar final mean body weight as fish fed the FM-based diets (mean SEM; PM, 437 ± 1.26 g versus FM, 448 ± 1.31 g; Figure 4). Final mean weight was significantly greater in fish fed FM and PM than those fed MDM (411 ± 11.29 g) and NUP (422 1.43 g) diets. We observed that the feed pellets of the MDM feed had larger mean particle size than the FM diets (2000 microns versus 1200 microns), which may have compromised feed intake when the fish were small and thus significantly reduced specific growth rate during the 0-34 day time period. Body lengths did not differ among the groups. Although fish on the PM and FM diets had showed elevated growth rates, there was not a significant overall effect of the different diets on specific growth rates over the 105 day growout period (Figure 5) (mean ± SD; PM, 3.29 ± 0.007 % BW/day; FM, 3.39 ± 0.005 % BW/day; MDM, 3.03 ± 0.082 % BW/day; and NUP, 3.15 ± 0.037 % BW/day).

We evaluated whether changes in circulating IGF -I might parallel changes in growth rate under controlled tank trials. Relative to the start of the study, we observed that plasma IGF-I increased significantly in fish sampled by the end of the experiment in all groups ($P > 0.05$; Figure 6). However, as with specific growth rate, there was no significant difference in systemic IGF-I among fish fed the different diets. Future studies should evaluate if measures of the IGF-I protein in blood might change under conditions where growth rates clearly differ.

Feed conversion ratios did not differ among the groups, except for fish on the MDM diet, where the feed conversion ratio was higher relative to animals on the FM diet ($P < 0.05$; Table 4). The effect of MDM inclusion on feed form may have resulted in more feed wastage, rather than compromising nutrient utilization or digestibility. Indeed, there was not a significant difference in protein efficiency ratio (a measure of dietary protein digestibility and utilization) among diets containing FM, MDM, or NUP. However, the protein efficiency ratio (weight gain over the period observed / total protein intake) was significantly lower in fish fed the PM diets than those fed the FM diet ($P < 0.05$; Table 4). There were no significant treatment effects on crude protein, crude fat (ether extract), and energy content of fish after 105 days of feeding the different diets (Table 5).

Collectively, these results suggest that alternate protein sources may serve as suitable substitutes of fishmeal in tilapia diets and could ultimately provide cost savings while reducing dependence on fishmeal derived from capture fisheries.

Study 4: Effect of pork meal replacement of fishmeal in diets formulated with locally-available ingredients in the Philippines on the growth of Nile tilapia cultured in earthen ponds using alternate-day feeding strategy

We conducted a study in collaboration with Santeh Feed Corporation (Philippines) to evaluate porkmeal, which is widely available in the Philippines, as a substitute for fishmeal on growout of tilapia in earthen ponds in the Philippines. Collaborations with industry insured that diet formulations incorporated locally-available ingredients including copra cake, cassava meal, local fish oils and coconut oil (Table 6). We also utilized an alternate day feeding scheme that was previously shown to work as effectively as daily feeding in producing marketable fish (Bolivar et al. 2006).

Figure 7 shows growth in body weight and length of fish raised in quadruplicate in ponds for 120 days using grower diets with and without 6% fishmeal. Changes in body weight and length were virtually identical among the groups fed isocaloric diets (Figure 7). Table 6 summarizes the production parameters of Nile tilapia grown on the different diets including weight and length gain, feed conversion, extrapolated yield per hectare and survival rate. Overall, results show that the different production parameters did not differ among fish fed the two diets.

Survival rate was high in fish fed the 0% (84.2%) and those provided the 6% fishmeal (89.3%) diet. Extrapolated yield and feed consumed per hectare was 3,080 kg/ha and

3,231.4 kg/ha, respectively, for fish on the 6% fishmeal formulated diet, and 3,062 kgs and 3,129.9 kgs per hectare, respectively, for fish on the 0% fishmeal diet. Feed conversion was slightly lower in fish fed 0% versus 6% fishmeal diets.

Water quality parameters including dissolved oxygen, water temperature and secchi disc visibility were similar among the two groups and fell within the range tolerable for tilapia growout. However, dissolved oxygen levels declined in ponds during the last month of growout for both groups of fish. This may have resulted in reduced feeding activity and overall growth of both groups of fish.

We conducted a simple cost and return analysis using current prices for all inputs and the value of marketable tilapia (Table 9). We found an approximate 8% higher net return for production of fish on the 0% fishmeal formulated diets (PhP 55,944.42) had than those grown on the 6% fishmeal diet (PhP 51,742.76).

CONCLUSION

It is estimated that 60-80% of total variable costs for growing tilapia is attributable to feeds. Through a series of four studies we found that alternative feeding strategies that reduce total feed consumption and replacement of fishmeal in tilapia diets have the potential to provide cost savings to tilapia farmers. The combined delayed and reduced feeding strategies that incorporate a sequential series of 60-day delayed, 30 days of alternate day, followed by 30 days of 67% subsatiation feeding produced fish with lower growth rates and approximately 40% lower extrapolated gross yield as compared with fish fed daily at full prescribed levels. Approximately 55% less feed was fed to the fish on the delayed/reduced feeding regimen relative to those fed on a traditional full daily feeding schedule. Based on these results, the combined feed reduction strategy showed reduced feed costs, but also resulted in significantly lower yields at harvest, suggesting this feeding strategy may not provide a signficant cost benefit relative to animals fed the typical continuous full daily feeding. Shortening the delayed feeding period, where most growth potential in weight and length was lost, to 30-45 days might prove useful in improving survival and the gross yield of fish subjected to combined reduced and delayed feeding strategies. It appears that combining both delayed and reduced feeding, at least based on the experimental paradigm tested here, is less effective than applying delaying feeding, 67% satiation, or alternate day feeding strategies alone.

In trials on six separate farms, we found that feeding at 50% subsatiation was effective in producing tilapia of similar gross yield as that of fish grown on full daily feeding. Fish on this reduced feeding protocol consumed almost 60% less feed, showed a 100% improvement in feed efficiency, and had no appreciable loss in specific growth rate or gross yield relative to animals fed a full ration level. Collectively, reducing feed rations by as much as 50% has the potential to produce substantial cost savings to farmers. A simple cost-return analysis shows a greater net return of approximately US$1300 for fish grown on half the ration relative to those grown on a typical full ration level.

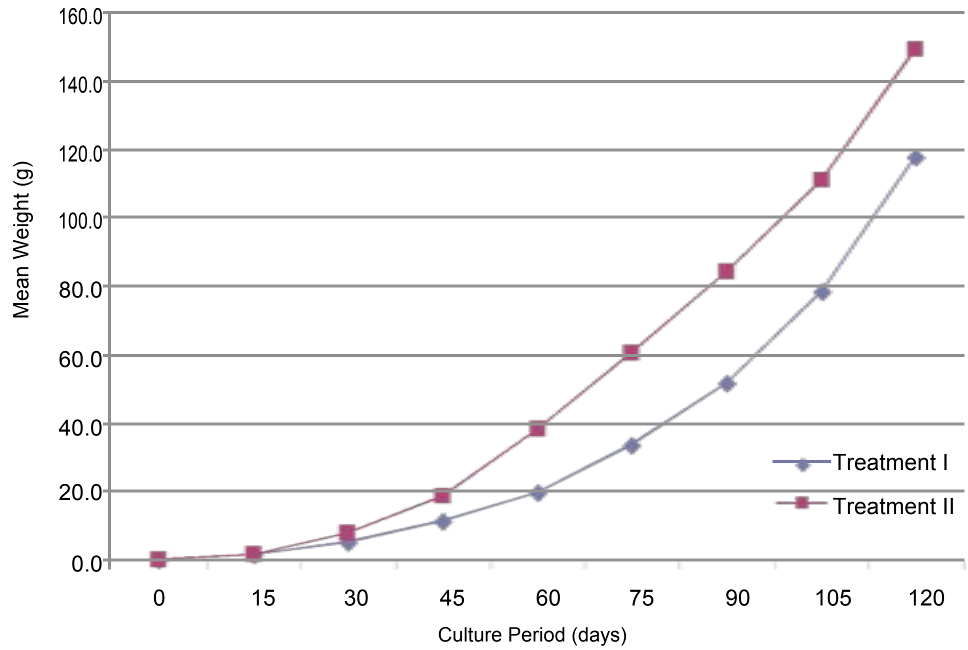
In study 3, we found that fermented deboned meat poultry byproduct (MDM), Nupro yeast extract (NUP) and poultry meal (PM) show strong promise as subtitutes for fishmeal in isocaloric balanced tilapia diets that incorporate 6% inclusion rate of fishmeal, a level typically used for commercial feeds in the Philippines. Performance of fish on the poultry meal diets was virtually identical to that of fish fed fismeal diets, while fish on the fermented poultry byproduct and yeast extract had similar specific growth rates. Even though the MDM and NUP resulted in slightly lower body weight and feed conversion (FCR) than the fishmeal (FM) diets, there were no significant differences in protein efficiency ratio (PER) among these three diets. Thus the quality of protein for tilapia in MDM and NUP is similar to FM. Evidently, the larger crumble size of the feeds containing the MDM and NUP may have comprimised feed intake and resulted in more feed wastage when the fish were small during the first 34 days of the trial. Because both the MDM and NUP had undergone minimal heat processing prior to pellet processing the feed, their functional properties as a pellet binder were much greater than the fishmeal and poultry meal products. This enhanced pellet binding characteristics of MDM and NUP is an advantage in manufacturing stable feed pellets provided pellet size is suitable for the size of fish consuming the feed. In contrast to the MDM and NUP, the PER of PM was determined to be significantly lower than fishmeal (1.95 vs 2.13, $p < 0.05$), even though dietary inclusion of these two protein meals resulted in statistically similar body weights and FCR.

Collectively, these results clearly indicate that the alternate protein sources evaluated in study 3 may serve as suitable substitutes of fishmeal in tilapia diets and could ultimately provide significant cost savings while reducing dependence on fishmeal derived from capture fisheries. Our results agree with the results of other researchers that evaluted the feeding value of fermented poultry byproducts, poultry meal and yeast protein in comparison to fishmeal for tilapia. Middleton et al. (2001) observed that fermented poultry byproduct can be included up to 13% in the diet of tilapia without adverse effects on growth performance and consumer sensory panel indicies (aroma, flavor, and texture) of tilapia filets. Likewise, Medri et al. (2000) observed that dietary inclusion up to 30% of distillery yeast (*Saccharomyces cerevisae*) can be fed to tilapia without adverse effects on growth performance. In contrast to the total replacement of dietary fishmeal with fermented poultry byproduct or yeast extract as done in our studies, Middleton et al (2001) and Medri et al. (2000) included at least 8% fishmeal in all of their experimental diets. Finally, Yildirim et al. (2009) found that poultry meal can replace 50% of the fishmeal in tilapia diets without adverse effects on growth, but 100% fishmeal replacement with poultry meal resulted in reduced growth rate and feed conversion.

We previously show that alternate day feeding resulted in significant cost-savings relative to daily feeding at full ration (Bolivar et al. 2006). Using this more cost-effective alternate day feeding strategy, we assessed whether elimination of fishmeal from diets and its replacement with a cheaper animal protein (porkmeal) might provide additional cost savings to tilapia production. The diets were produced by a local feeds company and incorporated locally available Philippine ingredients where possible. We show that fish fed formulated feeds lacking fishmeal had similar daily weight gain, specific growth rate, and survivorship as fish fed fishmeal diets. Feed consumption, gross harvest yield and feed conversion were also similar among fish on the experimental diets. A cost-return analysis shows that incorporation of a diet lacking fishmeal produced an 8% or almost $100 in cost savings in feed for each hectare of tilapia farmed. This along with the alternative day feeding strategy has the potential of reduce overall feed costs for growing marketable size tilapia by 60% relative to the typical practice of applying fishmeal formulated diets on a daily basis. A future study directly comparing daily and alternative day feeding strategies with diets formulated with and without fishmeal througout the entire production cycle of tilapia is warranted to establish the actual cost savings farmers are likely to have.

Based on success in the laboratory, we attempted to field test the utility of using IGF-I mRNA as an indicator of tilapia growth. However, tissue samples from the pond studies evaluating feed reduction strategeis showed RNA degradation negating the capacity to reliably measure IGF-I mRNA. For future studies, tissues will be rapidly processed to produce cDNA, which is substantially more stable than RNA and less susceptbile to degradation that may arise from temperature fluctuations due to power outages. Samples will then be measured shortly thereafter for IGF-I gene expression. We did find that measurement of the protein in blood, that is circulating IGF-I, which we show is a strong indicator of growth in fish (Picha et al. 2008) may also be suitable as an indicator of growth in tilapia. Circulating IGF -I nor specific growth rate varied in animals subjected to alternative diets in which fishmeal was substituted for yeast and poultry based animal protein. Additional work should evaluate if circulating IGF-I correlates to growth status of fish that exhibit differential growth responses to nutritional or environmental parameters.

Collectively, these series of studies show that reduced feeding strategies and substitution of diets containing fishmeal with cheaper and more sustainable sources of protein are effective options for reducing the costs without negatively impacting the production of tilapia.



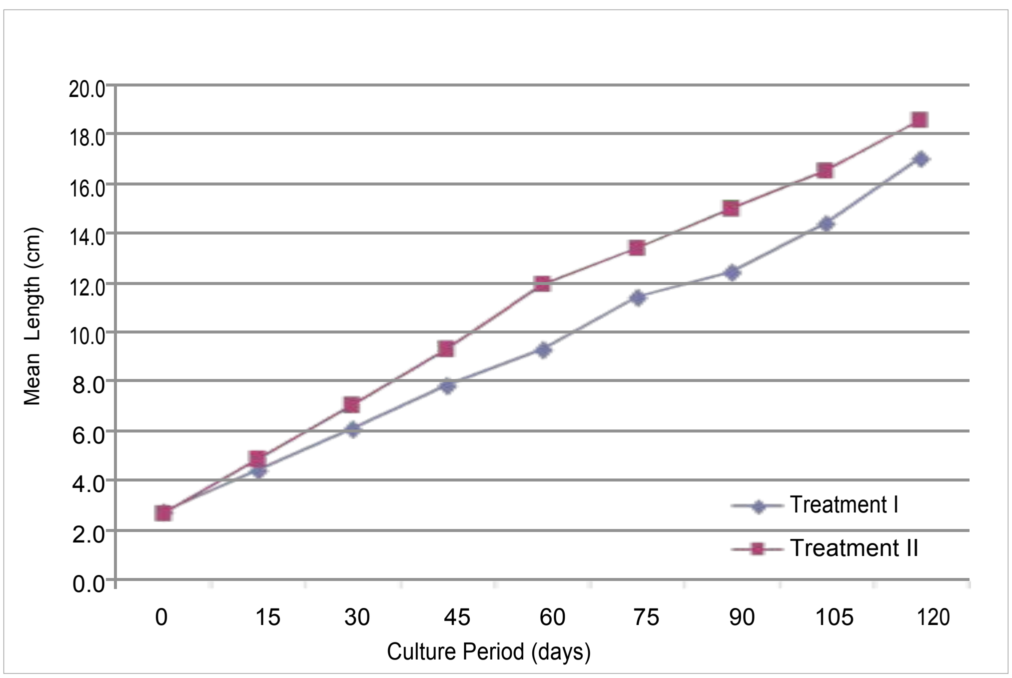


Figure 1. Mean body weight (top) and total length (bottom) of fish after a120 day culture period. Fish were grown under a combined delayed and reduced feeding protocol consisting of 60 days delayed feeding, 30 days alternate-day feeding, followed by 30 days full feeding on a daily basis but at a sub-satiation level of 67% (treatment I) versus those grown at 100% of recommended feed level based on fish biomass (treatment II).

Table 1. Production parameters (mean ± SEM) of fish grown under a combined delayed and reduced feeding protocol consisting of 60 days delayed feeding, 30 days alternate-day feeding, followed by 30 days full feeding on a daily basis but at a sub-satiation level of 67% (treatment I) versus those grown at 100% of recommended feed level based on fish biomass. Fish were grown on local farms in ponds for 120 days.

Parameter	Delayed/Reduced Feeding	Typical Daily Feeding
Mean Initial Weight (g)	0.35 ± 0.01[a]	0.35 ± 0.01[a]
Mean Final Weight (g)	118.05 ± 5.68[a]	149.82 ± 13.53[a]
Mean Daily Weight Gain (g)	0.98 ± 0.05[a]	1.25 ± 0.11[a]
Mean Specific Growth Rate (%/day)	4.86 ± 0.05[a]	5.04 ± 0.07[a]
Mean Initial Length (cm)	2.8 ± 0.05[a]	2.7 ± 0.04[a]
Mean Final Length (cm)	17.1 ± 0.44[a]	18.6 ± 0.61[a]
Mean Final Gain in Length (cm)	14.4 ± 0.42[a]	15.9 ± 0.58[a]
Mean Feed Conversion Ratio	2.4 ± 0.34[a]	2.7 ± 0.45[a]
Mean Survival Rate (%)	32.1 ± 9.59[a]	47.9 ± 9.11[b]
Mean Extrapolated Gross Yield (kg ha^{-1})	1,283.1 ± 264.95[a]	2,674.6 ± 670.39[b]
Mean Quantity of feeds (kg ha^{-1})	2,590.0 ± 269.11[a]	5,711.3 ± 399.07[b]

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

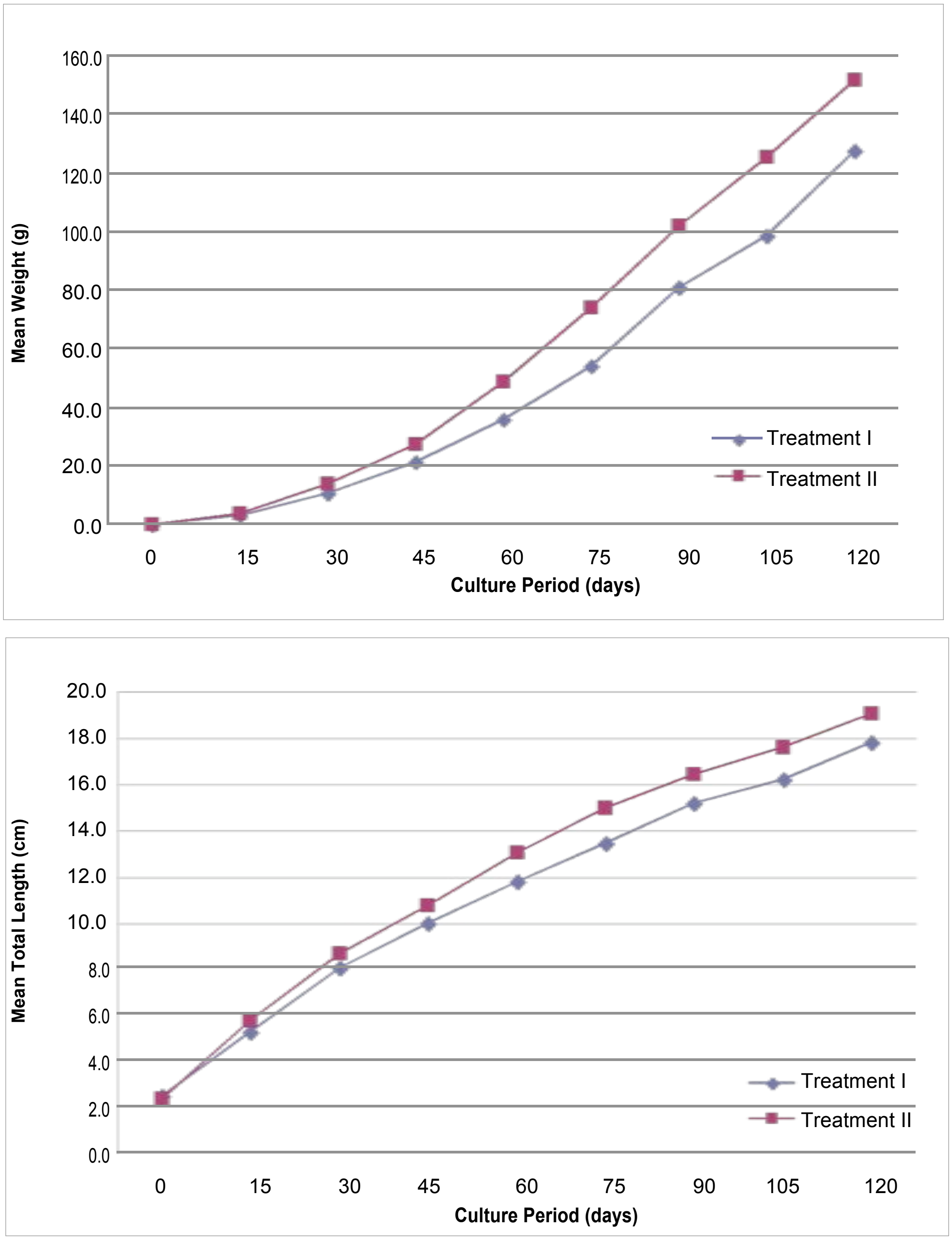
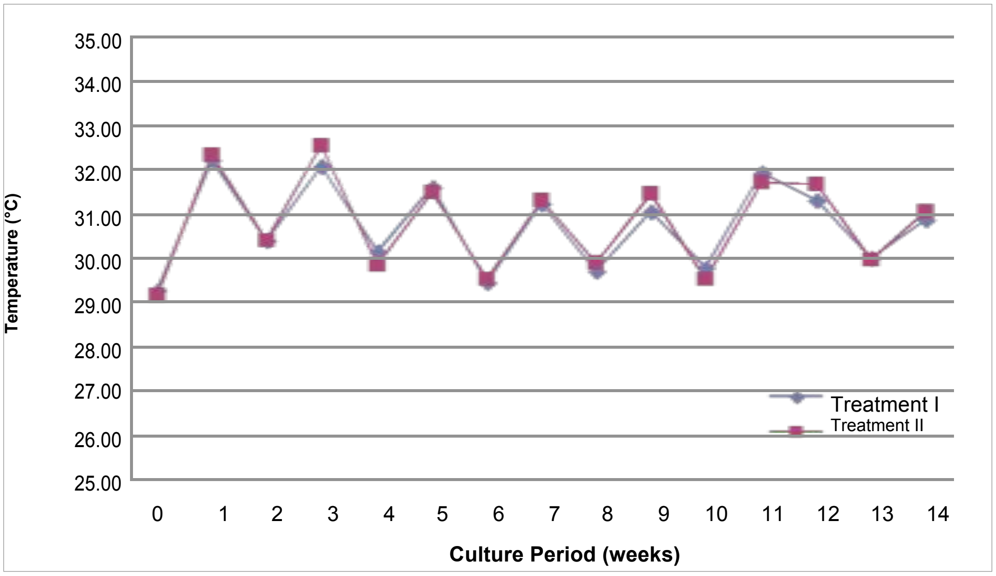


Figure 2. Mean body weight (top) and total length (bottom) of fish after a120 day culture period. Fish were grown at 50% reduced daily ration level (Treatment I) or at a full daily ration level (Treatment II).

Table 2. Production parameters (mean ± SEM) of fish grown on 50% reduced daily ration versus those grown on full daily ration. Fish were grown on local farms in ponds for 120 days.

Performance	50% Reduced Daily Feed Ration	Full Daily Feeding
Mean Initial Weight (g)	0.21 ± 0.03^{a}	0.21 ± 0.02a
Mean Final Weight (g)	123.57 ± 15.71^{a}	148.95 ± 13.06^{b}
Mean Daily Weight Gain (g)	1.03 ± 0.13^{a}	1.24 ± 0.11^{b}
Mean Initial Length (cm)	2.5 ± 0.11^{a}	2.4 ± 0.09^{a}
Mean Final Length (cm)	17.6 ± 0.61^{a}	18.9 ± 0.56^{b}
Mean Final Gain in Length (cm)	15.2 ± 0.61^{a}	16.5 ± 0.61^{b}
Mean Specific Growth Rate (%/day)	5.03 ± 0.18^{a}	5.46 ± 0.13^{a}
Mean Survival Rate (%)	62.5 ± 6.08^{a}	63.1 ± 10.59^{a}
Mean Feed Conversion Ratio	1.0 ± 0.06^{a}	2.1 ± 0.38^{b}
Mean Extrapolated Gross Yield (kg ha^{-1})	2754.9 ± 234.16^{a}	3440.9 ± 613.27^{a}
Mean Quantity of feeds (kg ha^{-1})	2588.0 ± 121.75^{a}	5928.7 ± 178.06^{b}

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



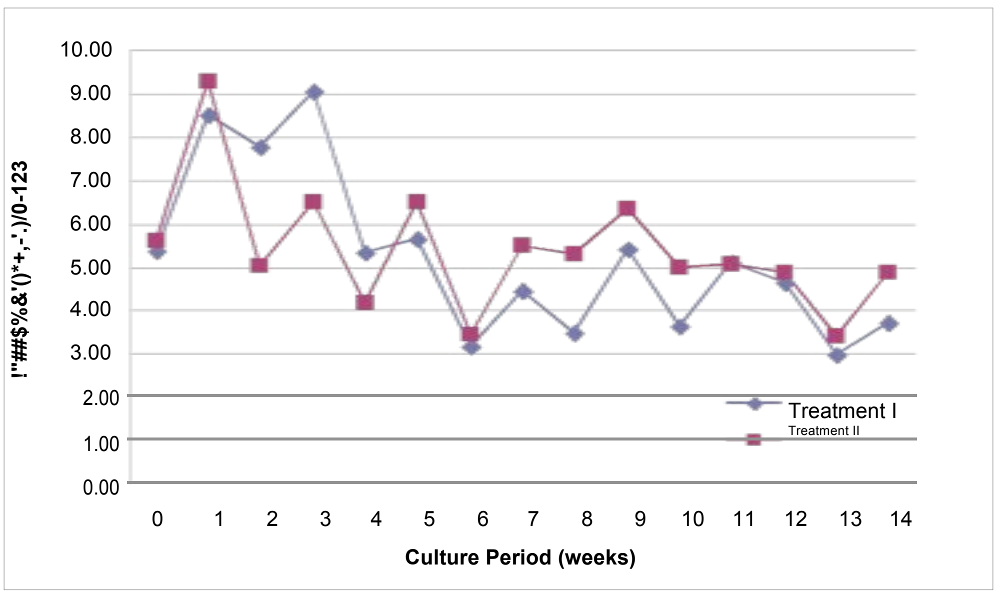


Figure 3. Mean water temperature (top) and dissolved oxygen concentration (bottom) in ponds during the 120 day culture period. Mean body weight (top) and total length (bottom) of fish after a120 day culture period. Fish were grown at 50% reduced daily ration level (Treatment I) or at a full daily ration level (Treatment II).

Table 3. Composition of caloric balanced test diets contained 6% fishmeal, and fishmeal replaced with 6% Nupro yeast extract, poultry meal, and fermented mechanically deboned meat poultry byproduct (MDM). Test diets were used in a 105-day growout of tilapia in tanks.

Ingredients	Fishmeal Diet	Nupro Diet	Poultry Meal Diet	Mechanically Deboned Meat
Soy Bean Meal	50.8	50.8	50.8	50.6
Corn	27.2	27.2	27.2	26.5
Wheat Midds	10	10	10	10
Fishmeal	6	--	--	--
Nupro	--	6	--	--
Poultry Meal	--	--	6	--
MDM	--	--	--	6
Poultry fat	4.43	4.43	4.43	3.94
Limestone	0.44	0.44	0.44	0.68
Dical P	0.33	0.33	0.33	1.29
Salt	0.22	0.22	0.22	0.27
Se Premix	0.15	0.15	0.15	0.15
Ascorbic Acid	0.13	0.13	0.13	0.13
TM Premix	0.10	0.10	0.10	0.10
Vit Premix	0.10	0.10	0.10	0.10
Choline CL 60	0.10	0.10	0.10	0.10
Lysine	0	0	0	0.14
TOTAL	**100**	**100**	**100**	**100**
Dry matter (%)	86.92	87.73	87.37	86.72
Crude Protein (%)	28.9	28.29	30.67	27.03
Acid Det. Fiber (%)	6.57	5.04	6.77	5.32
Crude Fat (%)	6.18	6.31	6.05	7.28
Calcium (%)	0.68	0.66	0.66	0.57
Phosphorus (%)	0.73	0.69	0.73	0.65
Sulfur (%)	0.27	0.31	0.28	0.26
Magnesium (%)	0.21	0.24	0.21	0.21
Sodium (%)	0.13	0.14	0.10	0.10
Potassium (%)	1.11	1.28	1.12	1.08
Cooper, ppm	14	18	14	14
Iron, ppm	276	271	236	250
Manganese, ppm	98	120	105	103
Zinc, ppm	116	142	121	116
Ash (%)	5.72	5.15	5.55	5.54
Neutral Det. Fiber (%)	8.72	9.33	9.89	9.52
Non-fiber CHO (%)	37.41	38.65	35.22	38.84
ME (kcal/kg)	3000	3000	3000	3000

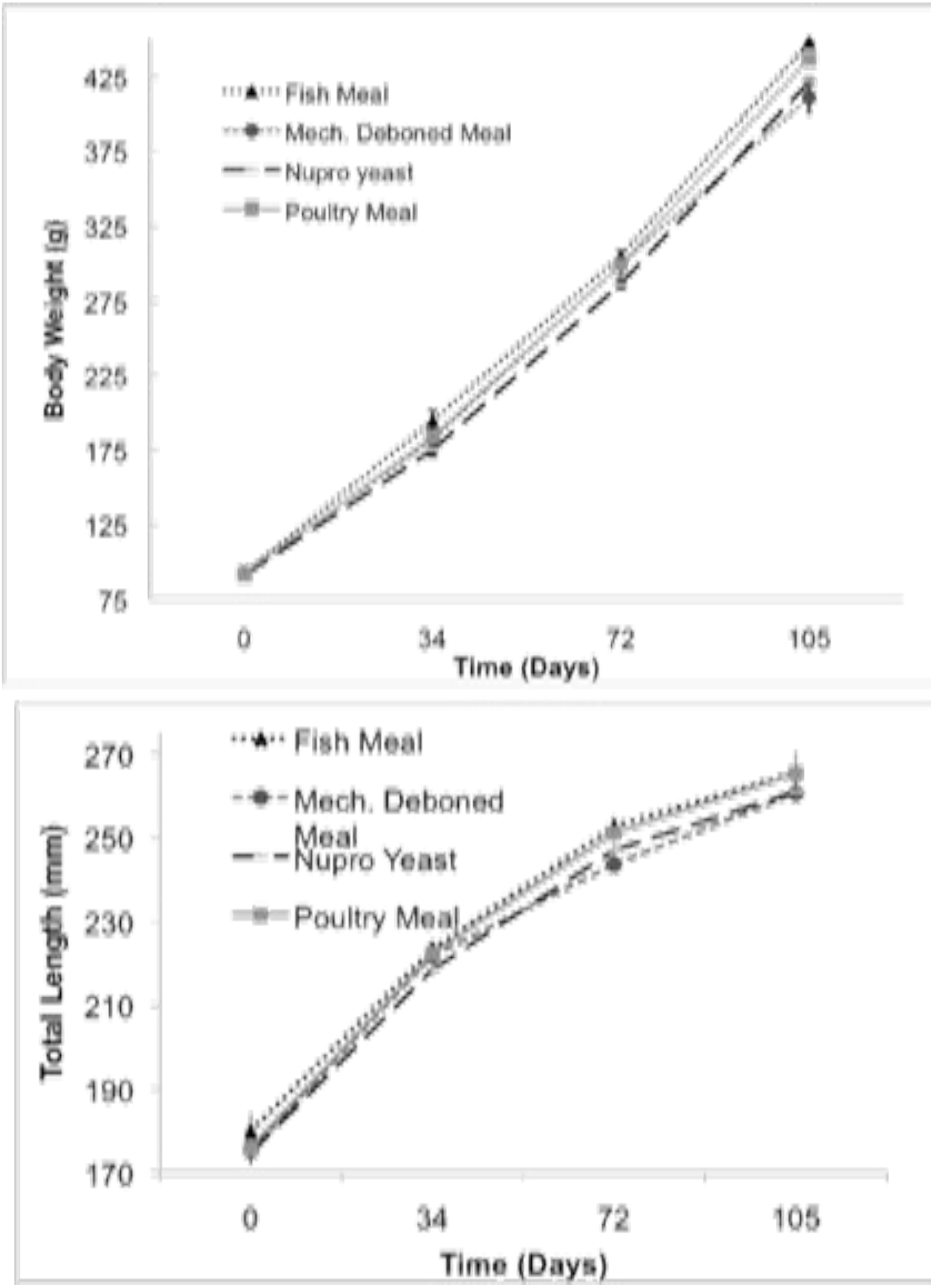


Figure 4. Body weight and total length (mean ± SD) of Nile tilapia following a 105-day growth study in tanks. Animals were fed diets containing 6% fishmeal or diets in which fishmeal was replaced with 6% Nupro yeast extract, poultry meal, and fermented mechanically deboned meat poultry byproduct. N = 2 tanks, 37 fish /tank. Fish on diets containing Nupro and deboned meat poultry byproduct had lower body weights than fish fed diets containing fishmeal or poultry meal ($P < 0.05$).

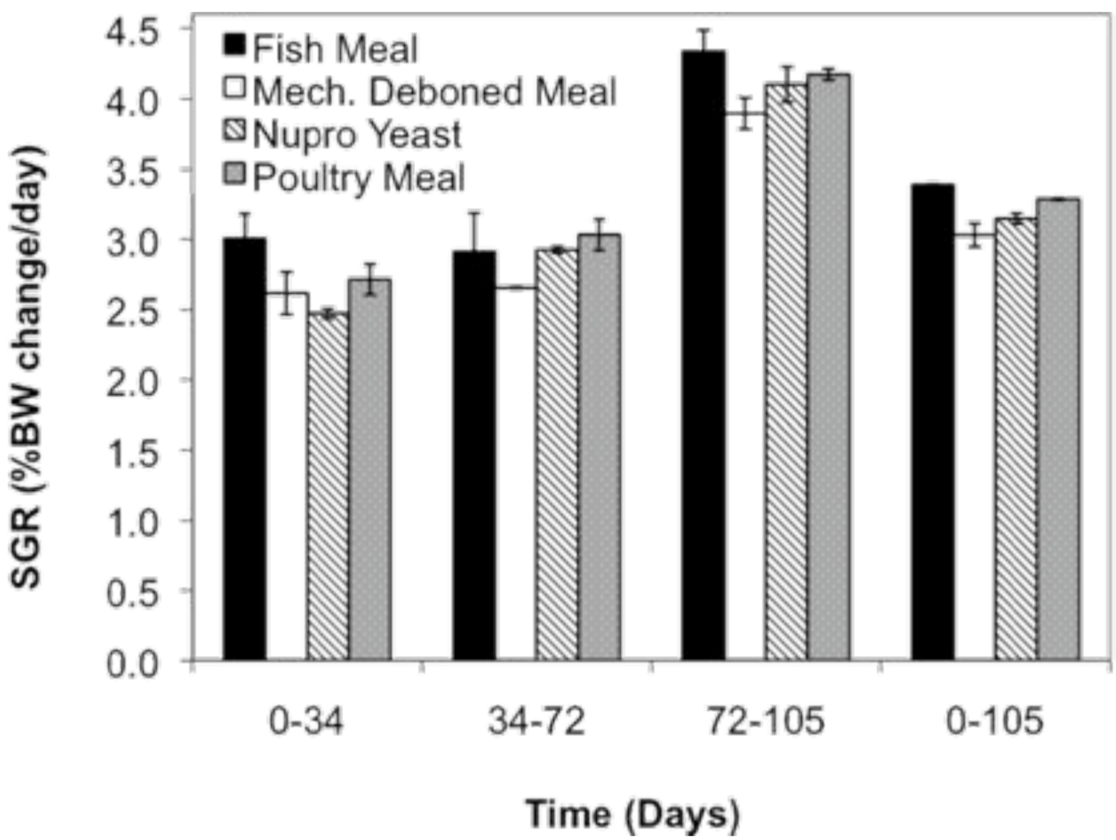


Figure 5. Specific growth rate (mean ± SD) of Nile tilapia over a 105-day growth study in tanks. Animals were fed diets containing 6% fishmeal or diets in which fishmeal was replaced with 6% Nupro yeast extract, poultry meal, and fermented mechanically deboned meat poultry byproduct. N = 2 tanks, 37 fish /tank.

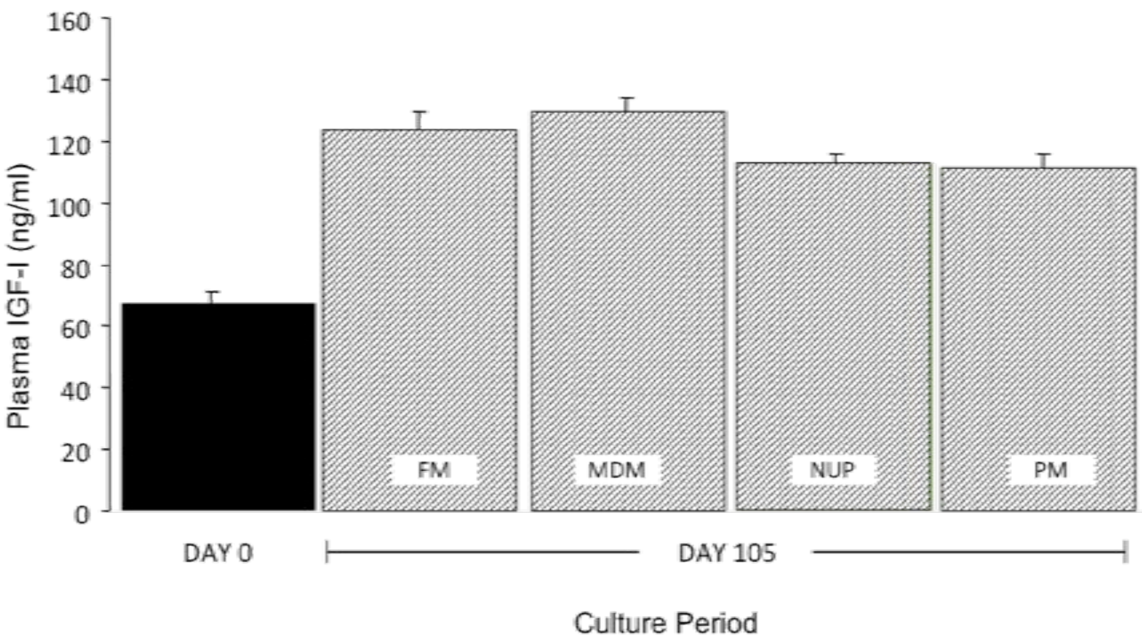


Figure 6. Plasma IGF-I levels (mean ± SEM, N = 8/group) in Nile tilapia over a 105-day growth study in tanks. Animals were fed diets containing 6% fishmeal (FM) or diets in which fishmeal was replaced with 6% Nupro yeast extract (NUP), poultry meal (PM), or fermented mechanically deboned meat poultry byproduct (MDM). Relative to levels at the start of the experiment, plasma IGF-I increased in all groups at day 105 ($P < 0.05$). There were no differences in plasma IGF-I in fish fed different diets.

Table 4. Feed Conversion Rate (FCR) and protein efficiency ratio (PER) of tilapia following 105 days growout on diets with 6% fishmeal or without fishmeal where fishmeal was replaced with 6% Nupro yeast extract (NUPRO), poultry meal (PM), and fermented mechanically deboned meat poultry byproduct (MDM). (mean ± standard deviation; N = 2 tanks/group, 37 fish/tank)

Treatments	FCR	PER
Fish Meal	1.62±0.008 B	2.13±0.004 A
NUPRO	1.75±0.07 AB	2.02±0.033 AB
MDM	1.82±0.03 A	2.04±0.078 AB
Poultry Meal	1.68±0.005 AB	1.95±0.006 B
Probability	*0.02**	*0.048**

FCR= total feed consumed by fish/weight gain by fish
PER= weight gain over the period observed / total protein intake
Values with different letters are significantly different ($P < 0.05$)

Table 5. Proximate analyses of tilapia carcasses following growout on diets containing 6% fishmeal or where fishmeal was replaced with 6% Nupro yeast extract, poultry meal, and fermented mechanically deboned meat poultry byproduct (MDM). Body weight, BW; and crude protein, CP; ether extract or crude fat (EE), and energy content (mean ± SEM; N = 6 animals/group).

Treatments	BW (g)	CP (%)	EE (%)	Energy (cal/g)
Fish Meal	412.91±91.40	23.14±1.49	9.95±1.40	5710±167
NUPRO	353.05±73.44	22.97±2.06	10.41±1.69	5803±160
MDM	393.61±63.73	23.09±0.99	10.07±1.58	5617±432
Poultry Meal	446.39±68.23	22.82±1.06	9.92±1.19	5697±196
Probability	*0.30*	*0.98*	*0.94*	*0.72*

Table 6. Composition of caloric balanced grower test diets with 6% fishmeal and 0% fishmeal (fishmeal substituted with porkmeal) that was used in the growout of tilapia for 120 days in earthen ponds at Central Luzon State University in the Philippines. Ingredients (inclusion rate in kg ton^{-1} of feed) represent those locally available in the Philippines.

RAW MATERIALS	Grower – 6% Fishmeal	Grower – 0% Fishmeal
Soybean Meal (HP) 45%	422.00	400.00
Corn Gluten	50.00	53.00
Hydrolyzed Animal Protein	30.00	30.00
Fishmeal Tuna 55%	60.00	0.00
Pork Meat Meal 55%	0.00	74.00
Copra Cake	73.00	76.00
Rice Bran	178.20	182.90
Cassava Meal	150.00	150.00
Fish Oil (Local)	5.50	5.00
Coconut Oil	5.00	5.00
Mono dicalcium phosphate	12.00	10.00
Salt	5.00	5.00
Mineral Premix	3.00	3.00
Vitamin Premix	6.30	6.10
TOTAL WEIGHT	**1000.00**	**1000.00**
DE Fish (kcal/kg)	2477.92	2484.50
Crude Protein (%)	30.99	31.07
Crude Fat (%)	6.21	6.23
Crude Fiber (%)	4.41	4.29
Starch (%)	17.36	17.40
Ash (%)	8.20	9.05
Ca (%)	0.96	0.91
Avail. Phosphorus (%)	0.67	0.66
Lysine (%)	1.51	1.50
Methionine (%)	0.54	0.50
Methionine + Cysteine (%)	0.97	0.96
Threonine (%)	1.06	1.07
Tryptophan (%)	0.33	0.42

Table 7. Feeding guide used for growing tilapia in ponds for 120 days using grower feed formulated with 31% crude protein (CP) with or without 6% fishmeal.

Culture Days	Estimated Survival (%)	Feeding Rate (%)	Type of Feed + Crude Protein (%)
0	100	10	Pre-starter (36% CP)
15	100	10	Pre-starter (36% CP)
30	95	7	Starter (34% CP)
45	95	7	Starter (34% CP)
60	90	6	Formulated Grower Feed (31% CP)
75	90	5	Formulated Grower Feed (31% CP)
90	85	4	Formulated Grower Feed (31% CP)
105	85	3	Formulated Grower Feed (31% CP)
120	-	-	-

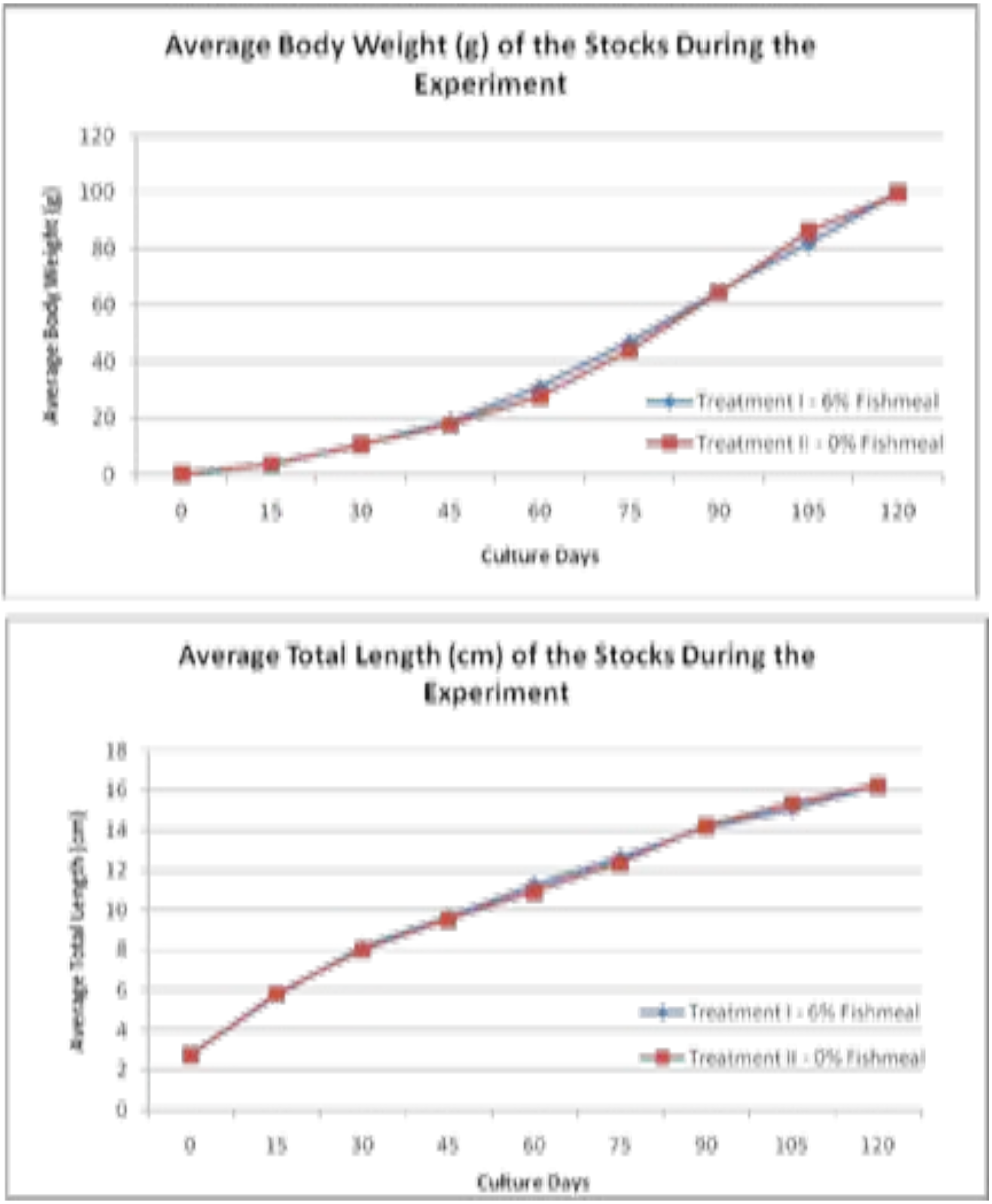


Figure 7. Mean body weight (top) and total length (bottom) of fish after a120 day culture period in earthen ponds. Fish were fed on alternate days with grower diets containing 6% fishmeal or 0% fishmeal (porkmeal substituted for fishmeal).

Table 8. Production parameters (mean ± standard deviation) of fish fed on alternate days with grower diets with 6% fishmeal or 0% fishmeal (porkmeal substituted for fishmeal). Fish were grown in ponds for 120 days.

Parameters	**Treatment I (6% Fish Meal)**	**Treatment II (0% Fish Meal)**
Initial Average Weight (g)	0.372 ± 0.049[a]	0.356 ± 0.028[a]
Final Average Weight (g)	99.531 ± 19.190[a]	99.746 ± 14.331[a]
Average Gain in Weight (g)	99.159 ± 19.175[a]	99.390 ± 14.355[a]
Average Daily Gain in Weight (g/day)	0.826 ± 0.160[a]	0.828 ± 0.120[a]
Specific Growth Rate (%)	4.652 ± 0.172[a]	4.693 ± 0.176[a]
Initial Average Total Length (cm)	2.8 ± 0.12[a]	2.8 ± 0.06[a]
Final Average Total length (cm)	16.261 ± 1.116[a]	16.241 ± 0.823[a]
Average Gain in Length (cm)	13.467 ± 1.107[a]	13.491 ± 0.880[a]
Average Daily Gain in Length (cm/day)	0.112 ± 0.009[a]	0.112 ± 0.007[a]
Survival Rate (%)	89.3 ± 5.3[a]	84.2 ± 3.1[a]
Extrapolated Feed Consumed per Hectare (kg/hectare)	3231.4 ± 711.5[a]	3129.9 ± 425.7[a]
Extrapolated Yield per Hectare (kg/hectare)	3080.0 ± 598.9[a]	3062.0 ± 520.8[a]
Feed Conversion Ratio	1.05 ± 0.05[a]	1.03 ± 0.05[b]

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

Table 9. Simple cost and return analysis per hectare of production of fish grown on diets with 6% fishmeal and 0% fishmeal (porkmeal substitution of fishmeal) over a 120-day culture period. Values are shown in Philippine pesos (~50 PhP = $1 USD)

Descriptions	Treatment I – 6% Fishmeal	Treatment II – 0% Fishmeal
Gross Return	PhP 169,400.00	PhP 168,410.00
Costs (PhP, Philippines peso):		
Fingerlings	17,200.00	17,200.00
Commercial Feeds	99,043.44	93,497.46
Fertilizers		
16-20-0	526.40	658.00
46-0-0	887.40	1,110.12
Total Cost:	117,657.24	112,465.58
NET RETURN	PhP 51,742.76	PhP 55,944.42

Assumptions:

Price of Fingerling: P 0.43 piece^{-1}
Price of Commercial Feeds:
Pre-starter: P35.00 kg^{-1}
Starter: P28.25 kg^{-1}
Formulated Feeds with 6% Fishmeal: P31.00 kg^{-1}

Formulated Feeds with 0% Fishmeal:
P30.00 kg^{-1} Price of marketable Tilapia: P55.00 kg^{-1}
Price of Fertilizers:
16-20-0: P18.80 kg^{-1}
46-0-0: P17.40 kg^{-1}

LITERATURE CITED

ADB (Asian Development Bank). 2005. An evaluation of small-scale freshwater rural aquaculture development for poverty reduction. 163 pp

Anderson, J. A.J. Jackson, A.J. Matty, and B.S. Capper. 1984. Effects of dietary carbohydrate and fibre on the tilapia *Oreochromis niloticus* (Linn.). Aquaculture 37:303-314.

Bolivar, R.B., Jimenez, E.B.J. and Brown, C.L. 2006. Alternate day feeding strategy for Nile tilapia grow out in the Philippines: Marginal cost-revenue analysis. North American Journal of Aquaculture, 68: 192-197.

Bolivar, R.B., C.L. Brown and E.T. Jimenez. 2003. Feeding Strategies to Optimize Tilapia Production in Ponds. Book of Abstract. Aquaculture 2003. Louisville, Kentucky, USA. p. 26.

Brown, C.L., Bolivar, R.B., Jimenez, E. T., and Szyper, J.P. 2000. Timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds. p. 237-240. *In:* Fitzsimmons, K. and Filho, J.C. (eds.). Tilapia Aquaculture in the 21st Century. Proceedings from the Fifth International Symposium on Tilapia Aquaculture. September 3-7. Rio de Janeiro, Brazil. 682 p.

Brown, E.E. 1983. World Fish Farming: Cultivation and Economics. 2nd edn. AVI

Publishing, Westport, CT. 397 pp.

El-Sayed, A.F.M. 1998. Total replacement of fishmeal with animal protein sources in Nile tilapia, Oreochromis niloticus. Aquaculture Research. 29-275-280.

El-Sayed, A.F.M. 2006. Nutrition and Feeding. In: Tilapia Culture. CABI Publishing, Oxford, U.K. 277 pp.

International Fishmeal and Fish Oil Organization (IFFO). 2005. Advantages of Using Fish Meal in Animal Feeds. http://www.iffo.org.uk/tech/F M-Anim.pdf

Jackson, A.J., B.S. Caper, A.J. Matty. 1982. Evaluation of some plant proteins in complete diets for the tilapia *Sarotherodon mossambicus*. Aquaculture 27:97-109.

Li, M.H., Lim, C.E., and Webster, C.D. 2006. Feed Formulation and Manufacture. In: Tilapia: Biology, culture and nutrition. C.E. Lim and C.D. Webster (Eds). The Haworth Press, Inc., New York. 517-559.

Lim, C.E. and Webster,C.D. 2006. Nutrient Requirement. In: Tilapia: Biology, culture and nutrition. C.E. Lim and C.D. Webster (Eds). The Haworth Press, Inc., New York. 469-501.

Middleton, T.F, P.R. Ferket, L.C. Boyd, H.V. Daniels, and M.L Gallagher. 2001. An evaluation of co-extruded poultry silage and culled jewel sweet potatoes as a feed ingredient for hybrid Tilapia (*Oreochromis niloticus X O. mossambicus*). Aquaculture 198:269-280.

Medri, V., G.V. Pereira, and J.H. Leonhardt. 2000. Growth of nile tilapia *Oreochromis niloticus* fed with different levels of alcohol yeast. Rev. Brasil. Bio. 60(1):113-121.

National Research Council. 1993. Nutrient Requirements of Fish. National Academic Press, Washington, DC.

Picha, M.E., Turano, M.J. Beckman, B.R., Borski, R.J. (2008) Hormonal biomarkers of growth and applications to aquaculture: A mini-review of growth hormone, insulin-like growth factor-I and IGF binding proteins as growth indicators in fish. North American Journal of Aquaculture 70:196–211.

Yildirum, O., A. Turker, S. Erug, M. Yigit, and A. Gulsahin. 2009. Growth performance and feed utilization of tilapia zillii (Gervais, 1848) fed partial or total replacement of fish meal with poultry by-product meal. African J. of Biotechnology 8(13):3092-3096.