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Effects of Fiber in Supplemental Feeds on Milkfish (*Chanos chanos* Forsskal) Production in Brackishwater Ponds

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Abstract

The study explores the nutritive value of fiber in supplemental feeds for milkfish. The feeding rates were adjusted so that all treatments involved equal protein-N load (6 g·kg^{-1} fish/day), and varying energy and fiber loads. Rice hull provided the bulk of dietary fiber. Fresh chicken manure, containing 16% protein, served as control. Four 800-m^2 earthen ponds divided into four compartments were used. Milkfish juveniles (29 g) were stocked at 7,000·ha^{-1}. After three months of culture, milkfish growth and production and protein efficiency ratio were significantly higher (α = 0.05) in fed ponds than in manured ponds. Average yield and manure conversion ratio in manured ponds were 436 kg·ha^{-1} and 14.5, respectively. There was no significant difference in yields (600-624 kg·ha^{-1}) between feed treatments. Fish exposed to low protein/33% fiber diet had a worse feed conversion ratio (5.8) than those exposed to high protein/15 or 24% fiber diets (3.6). The results indicate that energy was not limiting in the high fiber (24%) treatment compared to low fiber (15%), but additional fiber (33%) did not further improve growth; and fiber in low protein diets was utilized further as a direct or indirect source of energy. Thus, a low protein/high fiber diet can be an economical way of increasing milkfish production in brackishwater ponds.

Introduction

Milkfish, *Chanos chanos* (Forsskal), contributes significantly to aquaculture production in Asia, particularly in the Philippines. In recent years, the area used for milkfish production has been slowly decreasing as farmers shift to the culture of more lucrative species. The cost of farm inputs has also increased rapidly without a corresponding increase in the market price of milkfish. Most fish farmers stock milkfish at 1,000-3,000 per hectare and attain an average annual production of 870 kg·ha^{-1} (Smith and Chong 1984). With ponds becoming less readily available and with the declining profitability of milkfish culture, technological innovations that would increase production and profitability need to be assessed. One approach is to look for the cheapest nutrient inputs that will increase fish yields, for intensification to be economically feasible. Recent studies showed that higher yields can be attained by increasing stocking density and by supplemental feeding (Sumagaysay et al. 1990; Sumagaysay et al., in press).

The cost of supplemental feed is the largest component of the operating cost in semi-intensive culture. Agricultural by-products and feedstuffs of plant origin are generally cheap and easily available but high in fiber. This study explores the nutritive value of fiber in supplemental feeds for milkfish. It is hypothesized that even though milkfish does not possess cellulase and therefore cannot digest fiber, fiber may have a nutritive value when it eventually finds its way to the food chain through the detrital pathway. If fiber is utilized, then the cost of supplemental feeds for milkfish can be greatly reduced by increasing the quantities of high fiber ingredients of plant origin.

This study was designed to evaluate the nutritional value of dietary fiber in supplemental feed for milkfish reared in ponds; determine the effect of dietary energy and fiber on water quality; and assess the economic advantage of including dietary fiber in supplemental feeds.

Materials and Methods

Experimental Design

The experiment was designed so that all treatments involved equal protein-N load and varying energy and fiber loads. Rice hull provided the bulk of dietary fiber. Fresh chicken manure, which is traditionally used in milkfish culture, served as control treatment. Diet 1 contained almost similar protein to chicken manure (16%) and Diets 2 and 3 contained 26% protein. To attain similar protein-N load (6 g·kg^{-1} fish/day) in ponds, chicken manure and Diet 1 were given at 3.5% body weight (ash-free dry matter) and Diets 2 and 3 were given at 2.4%. If fiber has an energy value similar to the Nitrogen-Free Extract (NFE), Diet 1 had the highest energy, and Diets 2 and 3 were almost isocaloric (Table 1).

Table 1. Proximate composition and ingredients of experimental diets.

Composition	Chicken manure[a]	Diet 1	Diet 2	Diet 3
Crude protein (%)	18.5	14.1	26.3	26.9
Lowry protein (%)	16.0	-	-	-
Crude fat (%)	1.8	5.7	9.0	10.8
Crude fiber (%)	-	33.3	24.0	15.2
NDF (%)	22.5	49.5	38.4	31.7
Ash (%)	20.0	19.9	13.8	15.2
NFE (%)[b]	39.7	10.8	12.5	15.4
Gross energy[c] (kcal·kg^{-1} feed)	2,702	1,778	2,849	3,172
Energy load[c] (kcal·100 g^{-1} fish/day)	945	622	683	761
Assumed gross energy[d] (kcal·kg^{-1} feed)	3,624	3,808	4,423	4,472
Assumed energy load[d] (kcal·100 g^{-1} fish/day)	1,268	1,333	1,062	1,073
Ingredients (g·100 g^{-1} diet)				
Rice hull		55.0	30.0	-
Peruvian fishmeal		10.0	10.0	10.0
Soybean (defatted)		10.0	30.4	22.0
Rice bran		3.5	-	46.1
Copra meal		16.5	19.6	11.9
Coconut oil		1.8	9.7	5.3
Dicalcium phosphate		3.2	0.3	4.7

[a]Thomforde (1987).
[b]% NFE = 100 - (% protein + % fat + % ash + % NDF).
[c]Calculations were based on the following gross energy values: protein, 5.65; fat, 9.45; NFE, 4.10 kcal·100 g^{-1}.
[d]Total energy values of protein, fat, NFE and fiber. Neutral detergent fiber (NDF) is assumed to have energy value equal to NFE.

Feed Preparation and Analysis

The diets were prepared at the Brackishwater Aquaculture Center feed laboratory at Leganes, Iloilo, Philippines. Fresh chicken manure was obtained every morning from a nearby poultry house.

The moisture, ash, crude protein, crude fat and crude fiber of feed and manure were analyzed following Horwitz et al. (1975). Neutral detergent fiber was analyzed following the procedure of Van Soest and Wine (in Van Soest and Robertson 1985).

Pond Design and Management

The study was conducted in four 800-m^2 ponds, subdivided into four equal compartments by plastic sheets and marine plywood.

The ponds were prepared to grow natural food a month before the fish were stocked. Agricultural lime and chicken manure were broadcast evenly on moist pond bottoms at 2 $t{\cdot}ha^{-1}$ and N-P fertilizer (16-20-0) was broadcast twice at 50 $kg{\cdot}ha^{-1}$; one week after, chicken manure was applied. The water level was raised to 20 cm a day before milkfish juveniles were stocked. Pond water was partially changed for three consecutive days, every spring tide. Water depth was maintained at 25 cm for the first month of culture and was gradually increased to 80 cm for the last month of culture.

Stocking, Manure Loading and Feeding Management

Milkfish juveniles (29 g) were stocked at 7,000$\cdot ha^{-1}$ or 140 fish per compartment. Feeding commenced 25 days after stocking when natural food had become drastically reduced. Daily feed ration (3.5% of biomass for Diet 1; 2.4% of biomass for Diets 2 and 3) was given at 0800, 1200 and 1600 hours. Liquid manure at 3.5% of biomass was broadcast daily between 0900 and 1000 hours. Manure and feed loads in the ponds were computed on ash-free dry basis. At least 10 fish (7% of total stock) from each compartment were sampled for weight every two weeks. Amounts of feed and manure were adjusted accordingly. To maintain natural food production and to supply nutrients necessary for organic matter decomposition, N-P fertilizer (16-20-0) was broadcast twice a week at 7.5 $kg{\cdot}ha^{-1}$ per week.

Water Quality Analyses

The effect of manure and experimental diets on water quality and food intake of milkfish was assessed by measuring pond water parameters one week before treatment started, and one day before water exchange during feeding period. Water samples were taken at 0600 hours from two opposite points of the pond and mixed to represent one sample for each compartment. Ammonia and reactive nitrite were determined using the methods described by Strickland and Parsons (1972), and ammonia-N was converted to unionized ammonia (Boyd 1982). Total alkalinity was determined (APHA 1975) and converted to total CO_2 (Strickland and Parsons 1972). Gross primary productivity was estimated using the 7-point diel dissolved oxygen method described by Olah et al. (1978). Dissolved oxygen, temperature and salinity were monitored using a YSI model 57 dissolved oxygen/temperature meter and an Atago S/Mill refractometer.

Biological Analyses

The activity of heterotrophic microorganisms in ponds was studied through the rate of fiber digestion. This was quantified through the loss of weight of a piece of cotton cloth suspended in the water (Schroeder 1978) for three weeks. Bacterial plate count of stomach and esophagus content of five fish per treatment was done in one block, two days before harvest.

The dominance of certain organisms and other materials eaten by milkfish was determined by qualitative analysis of the stomach and esophagus contents. Five fish were caught from each compartment at 1000 and 1300 hours a day before and after the last water exchange, before harvest. Feeding index was calculated as: [(weight of intestine + contents)/(weight of fish)] x 100. Hepatosomatic indices (wet weight of the liver/wet weight of the fish) of five fish per compartment taken during harvest were determined to assess caloric intake. From the same group of fish, pooled samples of tissue were homogenized, air dried and ground for protein, fat and moisture analysis.

Data Analysis

Data were analyzed for treatment difference using the Analysis of Variance for randomized complete block design and Duncan's Multiple Range Test.

Results

Growth and Production

After three months of culture, milkfish growth and production were significantly higher ($\alpha = 0.05$) in fed ponds than in manured ponds

(Table 2). There were no significant differences in yields between the feed treatments. Significantly poorer feed efficiency (5.8) was observed for Diet 1 that contained 14% protein and was fed at higher rate (3.5% of body weight). Feed conversion ratio (FCR) was similar (3.6) for Diets 2 and 3 which contained 26% protein, different energy levels and fed at lower rate (2.4% of body weight) (Table 2). Protein efficiency ratio (PER) was significantly better (α = 0.05) in fed ponds (1.13-1.28) than in manured ponds (0.56).

Table 2. Growth, production, feed efficiency and survival of milkfish.

	Chicken manure	Diet 1	Diet 2	Diet 3
Weight at start of feeding (g)[a]	44[a] ±13	44[a] ±10	45[a] ±11	45[a] ±11
Final mean weight (g)[a]	68[a] ±10	87[b] ±12	93[b] ±5	95[b] ±9
% Weight gain[a,c]	176[a] ±66	258[b] ±87	306[b] ±130	297[b] ±105
Specific growth rate[a,b]	0.77[a] ±0.38	1.01[b] ±0.29	1.14[b] ±0.42	1.15[b] ±0.36
Production ($g \cdot ha^{-1} \cdot day^{-1}$)[a]	32.8[a] ±8.2	75.1[b] ±13.0	79.9[b] ±12.4	79.4[b] ±7.9
Yield ($kg \cdot ha^{-1}$)[a]	436[a] ±62	600[b] ±85	624[b] ±43	619[b] ±62
FCR, MCR (g feed, manure/g gain)[a]	14.5[a] ±4.2	5.8[b] ±1.3	3.6[c] ±0.7	3.6[c] ±0.6
PER (g gain/ g protein)[a]	0.56[a] ±0.20	1.28[b] ±0.23	1.16[b] ±0.24	1.13[b] ±0.21
Recovery (%)[a]	92[a] ±3	98[a] ±1	96[a] ±2	93[a] ±2

[a]Values represent the mean SEM of four replicates. Unlike superscripts indicate significant differences (α = 0.05) between treatments. Growth rate, production, MCR (manure conversion ratio), FCR (feed conversion ratio) and PER were calculated based on 72 feeding days.

[b]Specific growth rate = [(ln(final mean weight) - ln (initial mean weight))/number of culture days] x 100.

[c]% weight gain = [(final weight - initial weight)/initial weight] x 100. Initial mean weight was 29 g.

Physicochemical and Biological Parameters

The data are shown in Table 3. A decrease in primary productivity was evident as fish biomass in the pond increased. Total carbon dioxide (CO_2), nitrite (NO_2) and unionized ammonia (NH_3) concentrations were well below critical levels. A 2 x 2 factorial analysis showed differences in the feeding index of fish at 1000 and 1300 hours but none before and after water exchange. The stomach and esophagus contents of sampled fish in all treatments contain abundant feed and/or debris, plankton and diatoms, and few filamentous algae and zooplankton. Highest average bacterial plate count of the stomach and esophagus contents was observed in fish fed highest fiber level and lowest in fish fed lowest fiber level.

Table 3. Soil/water quality and biological data.

Physicochemical parameters	Chicken manure	Diet 1	Diet 2	Diet 3
Total CO_2 (ppm)	43.5	46.9	48.6	49.1
Reactive NO_2 (ppb)	153	133	109	129
Unionized NH_3 (ppb)	2.1	1.1	1.5	1.7
Salinity (ppt)[a]		27.5 -36.0		
Morning dissolved oxygen (ppm)[a]		3.4 - 5.4		
Water temperature (°C)[a]		26.2 -33.7		
Dry soil pH[a]		4.2 - 7.8		
Biological data				
Primary productivity (mg $O_2 \cdot l^{-1} \cdot day^{-1}$)[b]	13.6 - 9.4	11.9 - 6.7	12.8 - 6.6	12.6 - 6.7
Feeding index (1000 hours)	8.8 - 9.6	8.4 -11.2	8.4 - 8.6	7.8 - 8.9
(1300 hours)	8.2	7.8	6.9 - 7.8	6.4 - 6.8
Hepatosomatic index	0.012	0.013	0.012	0.012
Tissue protein (%)	80.3	81.4	82.6	80.6
Tissue fat (%)	3.3	4.3	4.4	5.5
Bacterial plate count (stomach and esophagus contents; cells·g^{-1})	1.4×10^7	6.0×10^7	6.4×10^6	1.7×10^6
Microbial activity (bottom; % daily loss cloth/day)	4.3	4.1	3.8	3.9

[a]Values for all treatments.
[b]Range from first to last month of culture.

Economic Analysis

The cost of feed increased as dietary protein and energy increased, and as fiber decreased. Costs of manure and feed inputs are shown in Table 4. Diet 1 was the most profitable (despite a higher FCR) because the cost of feed/kg was almost 42% lower.

Table 4. Cost of manure and feed input in ponds exposed to different treatments.

	Chicken manure	Diet 1	Diet 2	Diet 3
Yield ($kg \cdot ha^{-1}$)[a]	436	600	624	619
Gross income ($P \cdot ha^{-1}$)[b]	8,720	12,000	12,480	12,380
Amount of input[c] (kg dry weight$\cdot ha^{-1}$)	1,447.6	1,487.7	1,012.8	1,042.0
Cost of input ($P \cdot kg^{-1}$ dry weight)	2.00	3.71	6.44	6.39
Total cost of input[d] ($P \cdot ha^{-1}$)	2,895.20	5,519.37	6,522.43	6,658.38
Net income ($P \cdot kg^{-1}$)[e]	5,825	6,481	5,958	5,722

[a]Yield per hectare per crop at $7{,}000 \cdot ha^{-1}$; culture conducted during cold season and in pond with acid problem.
[b]Gross income = yield x price of fish/kg = yield x $P20 \cdot kg^{-1}$
[c]Total amount of feed, manure given for 72 days.
[d]Product of cost of feed, manure$\cdot kg^{-1}$ and amount of feed, manure in kg dry matter$\cdot ha^{-1}$.
[e]Gross income - total cost of input (20 P = $US1; 1987).

Discussion

Utilization of Fiber

Generally, fibrous ingredients like rice hull (which contains 2.9% crude protein and 54% neutral detergent fiber) are used as filler to formulate low-protein, low-cost diets. But in addition, undigested fiber can pass through other pathways in the earthen environment and be utilized as an energy source.

The lack of difference in growth, production and food conversion ratio between Diets 2 and 3 with differing fiber and energy levels shows that energy was not limiting in the high fiber treatment (Diet 2), but additional fiber given the same protein load (Diet 1), did not further improve growth. The results indicate that fiber can be utilized as an energy source either directly or indirectly by the fish but the extent of utilization is limited by protein-N input. Due to the inferior quality of manure (e.g., poor amino acid balance), production resulting from its application was lower than for pelleted diets at similar nutrient loads. Manure was either utilized directly as feed (confirmed through qualitative gut analysis) or indirectly as fertilizer. Even then, the quantity of pond organisms produced through fertilization may not be enough to supply the nutrient requirement of the standing crop for maximum growth. These results are consistent with the findings of Thomforde (1987) and Wohlfarth and Schroeder (1979).

The extent of fiber digestion in animals depends on the quality of feed (i.e., protein level), quality of fiber (lignification), pH of the gut and the anatomical structure of the digestive tract (Maynard et al. 1980; Van Soest and Robertson 1985; Moriarty 1973 quoted by Colman and Edwards 1987). Cellulase activity has been detected only in a few species of fish and this was attributed to the presence of alimentary tract microflora (Stickney and Shumway 1974). The trend of increasing microbial population with fiber content in the diet suggests that this may have significant contribution in the digestion of fiber. Further studies are needed to examine the pathway and contribution of microorganisms to fiber utilization and fish production.

The utilization of fiber by milkfish, as indicated by growth, production and feed conversion can also be made possible through the detrital pathway. Undigested fiber can have a nutritive value when it passes through the detrital food web (Schroeder 1978, 1980; Naiman and Sibert 1979). Milkfish, being an opportunistic feeder (Odum 1970 quoted in Schroeder 1980), has the potential to harvest microorganisms such as bacteria and protozoa by ingesting undigested fiber particles. The number of attached bacteria is known to be positively correlated with the concentration of particulate organic matter (Kirchman and Ducklow 1987). This may explain why milkfish fed at higher rates have higher bacterial populations in their stomach and esophagus. The average rate of fiber digestion on the pond bottom was also higher in these treatments.

A similar study conducted in ponds showed that tilapia fed fibrous diets gave production results comparable to fish fed high protein pellets (Fineman-Kalio 1984). In the present study, if fiber were to be completely utilized as an energy source, then the actual gross energy of the diets would be 3,624, 3,808, 4,423, 4,472 kcal·kg^{-1} feed and energy load in ponds would be 1,268, 1,332, 1,062, 1,073 kcal·100 g^{-1} fish/day for chicken manure, Diets 1, 2 and 3, respectively. Higher energy load in terms of fat and carbohydrate usually increases carcass fat. The high energy load (large quantity from fiber) in Diet 1 did not significantly increase the growth and production and also resulted in the lowest carcass lipid. This suggests that fiber in Diet 1 was partially utilized.

Economic Feasibility of Using High Fiber Diets

The high fiber/high protein diet (Diet 2) was not significantly lower in cost than the low fiber/high protein diet (Diet 3). The low protein (14%)/high fiber (33%) diet, fed at higher rate (3.5% of body weight), greatly lowered cost of feed input.

The results suggest an economical way of increasing production. Based on the levels of energy and protein of the diet, feeding rate can be manipulated to reach desired energy and protein loads in ponds.

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