Effects of Replacing Fish Meal in Diets on Growth and Body Composition of Palmetto Bass (*Morone saxatilis* × *M. chrysops*) Raised in Cages

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ABSTRACT. Juvenile palmetto bass (*Morone saxatilis* × *M. chrysops*) with an average weight of 20 g were stocked into 12 floating cages (1.2 × 1.2 × 2.4 m) and fed one of four practical diets formulated to contain various percentages (0, 15, 30, or 45%) of fish meal (FM). Diets were formulated to be isonitrogenous (43% protein) and isocaloric (3.9 kcal available energy/g). Fish were fed twice daily, all they would consume in 40 minutes (0900 and 1730), for 125 days. Final individual weight and specific growth rate (SGR) of fish fed diets containing 15, 30, or 45% fish meal were not significantly different ($P > 0.05$) and averaged 342 g and 2.3%/day, while growth of palmetto bass fed a diet containing soybean meal (SBM), and meat-and-bone meal, without FM, was significantly ($P < 0.05$) lower (282 g and 2.1%/day). There were no significant differences ($P > 0.05$) in percentage moisture, protein, and lipid in fillet from palmetto bass in the four treatments, of which these values averaged 75.1%, 80.7%, and 14.5%, respectively. Amino acid composition of fillets was similar among treatments. These data suggest that a diet containing 15% FM is sufficient for diet palatability and good growth in juvenile palmetto bass. Additional research on diet for-

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mulations without FM should be conducted. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworth.com]*

INTRODUCTION

The striped bass, *Morone saxatilis*, and its hybrids have recently received considerable attention in the United States as a commercial aquaculture species. Tuncer et al. (1990) reported that the original hybrid, *M. saxatilis* × *M. chrysops*, known as the palmetto bass, exhibits superior growth and survival compared to striped bass. There have been reports on the nutritional requirements of larval striped bass and its hybrids, mostly pertaining to fatty acid requirements and the use of live foods (Baragi and Lovell 1986; Webster and Lovell 1990; Clawson and Lovell 1992; Tuncer and Harrell 1992). Recently, more information on the nutritional requirements of juvenile fish has been reported (Keembiyehetty and Gatlin 1992; Nematipour et al. 1992; Brown et al. 1993a; Brown et al. 1993b; Nematipour and Gatlin 1993; Griffin et al. 1994a; Griffin et al. 1994b; Griffin et al. 1994c; Webster et al. 1995a); however, commercial production of hybrid striped bass has largely relied on diets formulated for salmonids.

Because protein is the most expensive component in most aquaculture diets, feed producers attempt to provide the minimum level of protein that will supply essential amino acids to fish. One approach to reduce feed cost is to partially or totally substitute less expensive plant proteins for more expensive animal proteins. Fish meal (FM) is an important ingredient in aquaculture diets because of its high protein quality and palatability. However, of all diet ingredients, FM is one of the most expensive. Complete replacement of FM with plant-source proteins has met with variable success (Cowey et al. 1971; Andrews and Page 1974; Lovell et al. 1974; Shiau et al. 1988; Mohsen and Lovell 1990; Webster et al. 1992; Webster et al. 1995b). Mohsen and Lovell (1990) reported that channel catfish had higher growth rates fed a diet containing 20% FM compared to fish fed diets containing 0, 5, and 10% FM. Grass carp, *Ctenopharyngodon idella*, fed a diet with a high percentage of soybean meal (SBM) and supplemental amino acids had lower growth than fish fed a control diet (Dabrowski and Kozak 1979). Webster et al. (1992) reported that blue catfish, *Ictalurus furcatus*, fed a diet containing 13% FM had higher growth rates than fish fed diets containing 0, 4, and 9% FM. However, Webster et al. (1995b) reported that blue catfish fed a diet without FM had similar growth compared to fish fed a diet with 15% FM. Reigh and Ellis (1992) reported that red drum, *Sciaenops ocellatus*, did not consume diets in which all of the FM was replaced by SBM. However, fish fed diets containing a 50:50 blend (protein basis) of SBM and FM had growth similar to that of fish fed a diet with 100% of protein from FM.

Little information on practical diet formulation for juvenile palmetto bass is available in the literature. The objective of this study was to evaluate growth and body composition of palmetto bass fed isonitrogenous, practical diets containing various percentages of menhaden FM.

MATERIALS AND METHODS

Experimental Conditions and Animals

Palmetto bass juveniles (average individual weight of 20.0 ± 0.5 g) were obtained from a commercial supplier (Mississippi Fisheries, Inc., Greenville, Mississippi[1]), and 200 fish were stocked into each of twelve 3.5-m^3 floating cages moored over the deepest area (4 m) of a 1.0-ha pond (average depth = 2.0 m) at the Agricultural Research Farm, Kentucky State University, Frankfort, Kentucky. Fish were fed one of four extruded diets containing 0, 15, 30, or 45% FM for 125 days, beginning on 23 May 1995. Diets were formulated to contain 40% crude protein and 3.9 kcal/g diet (Table 1). Available energy was calculated using physiological fuel values of 4.0, 4.0, and 9.0 kcal/g for carbohydrate (NFE), protein, and lipid, respectively (Garling and Wilson 1976; Nematipour et al. 1992). Diets were extruded by a commercial feed mill (Integral Fish Foods, Inc., Grand Junction, Colorado) for use in this study. Fish were fed twice daily (0900 and 1730) all they would consume in 40 minutes. There were three replications per treatment.

Diets were analyzed for crude protein, fat, moisture, and amino acid composition. Amino acid composition of the diets was analyzed by a commercial laboratory (Woodson-Tenent Labs, Dayton, Ohio; Table 2). Crude protein was determined by the macro-Kjeldahl method; crude fat was determined by the acid-hydrolysis method; and moisture was determined by drying samples to constant weight (AOAC 1990). Diets were stored in plastic-lined bags at − 10°C until fed.

Each cage had a frame made of polyvinylchloride (PVC) tubing with a removable lid and was constructed of 10-mm polyethylene mesh. A panel of polyethylene mesh (0.2-mm mesh; 20 cm high) was installed around the top of the inside of each cage to prevent loss of floating diet. Cages were anchored to a floating dock, and the distance between cages was 2 m.

Temperature and dissolved oxygen were monitored twice daily (0800

1. Use of trade or manufacturer's name does not imply endorsement.

TABLE 1. Composition of diets containing different levels of FM fed to juvenile palmetto bass raised in cages. Proximate analysis values are means of three replicates except trypsin inhibitor values, which are of duplicate samples.

	Diet (% fish meal)			
Ingredient	0	15	30	45
Anchovy fish meal	0.0	15.0	30.0	45.0
Soybean meal	38.9	56.5	34.0	11.5
Meat-and-bone	36.5	0.0	0.0	0.0
Wheat flour	15.0	15.0	15.0	15.0
Corn meal	0.0	5.4	11.4	20.9
Menhaden fish oil	5.0	4.0	3.0	2.0
Vitamin and mineral mix[1]	2.0	2.0	2.0	2.0
Monocalcium phosphate	2.0	1.5	1.0	0.5
Ascorbic acid	0.1	0.1	0.1	0.1
Choline chloride	0.5	0.5	0.5	0.5
Proximate analysis (dry-matter basis)				
% Moisture	90.25	90.68	88.84	88.15
% Protein	42.85	43.18	44.71	42.13
% Lipid	10.98	7.44	8.27	8.76
% Fiber	2.84	2.84	2.25	1.63
% Ash	15.05	8.97	10.74	10.96
Available energy (kcal/g)[2]	3.84	3.89	3.90	3.93
P:E ratio[3]	112	111	115	107
Trypsin inhibitor[4]	1,900	1,950	1,300	1,150

[1]Vitamin and mineral mix provided the following (mg or IU/g of diet): vitamin A, 6000 IU; vitamin D, 2200 IU; vitamin E, 150 IU; vitamin K, 10 mg; niacin, 200 mg; pantothenic acid, 60 mg; thiamin, 30 mg; riboflavin, 20 mg; pyridoxine, 20 mg; folic acid, 5 mg; B12, 0.01 mg; biotin, 2 mg; manganese, 180 mg; copper, 8 mg; cobalt, 1.5 mg; iron, 66 mg; zinc, 150 mg; iodine, 6 mg; selenium, 0.3 mg.
[2]Available energy in kcal/g of diet.
[3]P:E = protein to energy ratio in mg protein/kcal available energy.
[4]Trypsin inhibitor reported as trypsin inhibitor units (TIU)/g of diet.

TABLE 2. Amino acid composition (% of diet) of diets containing different levels of FM fed to juvenile palmetto bass raised in cages. Values are means of two replications.

Amino acid	Diet (% fish meal) 0	15	30	45
Alanine	2.31	1.97	2.22	2.25
Arginine	2.54	2.46	2.37	2.09
Aspartic acid	2.57	4.04	3.97	3.45
Cystine	0.40	0.44	0.40	0.35
Glutamic acid	5.81	6.51	6.15	5.29
Glycine	3.09	1.93	2.25	2.32
Histidine	1.13	1.22	1.28	1.22
Isoleucine	1.30	1.57	1.52	1.35
Leucine	2.66	2.92	2.92	2.71
Lysine	1.98	2.13	2.19	2.07
Methionine	0.66	0.69	0.77	0.84
Phenylalanine	1.58	1.77	1.67	1.46
Proline	2.57	2.07	2.05	1.86
Serine	1.79	1.94	1.89	1.64
Threonine	1.44	1.60	1.68	1.56
Tyrosine	0.98	1.10	1.05	0.91
Valine	1.59	1.72	1.75	1.60

and 1630) outside the cages, at a depth of 0.75 m, with a YSI model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio). If the oxygen level was graphically predicted to decline below 4.0 mg/l, aeration was provided with an electric paddlewheel (5 hp, S & N Sprayer Co., Inc., Greenwood, Mississippi). Weekly measurements of pH were recorded with an electronic pH meter (pH Pen, Fisher Scientific, Cincinnati, Ohio). Total ammonia-nitrogen, nitrite, and alkalinity were measured weekly with a DREL 2000 spectrophotometer (Hach Co., Loveland, Colorado).

Data Collection

Total number and weight of fish in each cage were determined at harvest. Ten fish were randomly sampled from each cage and individually weighed (g) and were decapitated; dressing variables (dressing percentage, abdominal fat, viscera weight, skinned fillet weight, and frame weight) were then determined. Liver was not included in the viscera weight. All body components were reported as a percentage of total body weight.

Fillets from three fish from each cage were homogenized separately in a blender and analyzed for crude protein, lipid, and moisture. Crude protein was determined by the Kjeldahl method; lipid was determined by ether extraction; and moisture was determined by drying in an oven at 100°C to constant weight (AOAC 1990).

Specific growth rate was calculated as: SGR (%/day) = $[(\ln W_t - \ln W_i)/T] \times 100$, where W_t is the average individual weight of fish at time t, W_i is the average individual weight of fish at time 0, and T is the culture period in days.

Statistical Analysis

Data were analyzed using ANOVA (SAS 1988). Duncan's multiple range test was used to determine differences among means ($P \leq 0.05$). All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984).

RESULTS

Average monthly morning water temperatures ranged from 17.8°C in May to 27.0°C in August; average monthly afternoon water temperatures ranged from 18.8°C in May to 27.9°C in August. Morning dissolved oxygen levels averaged 8.1, 7.0, 6.6, 6.3, and 7.6 mg/L in May, June, July, August, and September, respectively; afternoon values were 9.6, 8.5, 8.9, 8.0, and 8.4 mg/L in those respective months. Total ammonia-nitrogen averaged 0.14 ± 0.08 mg/L; nitrite averaged 0.013 ± 0.016 mg/L; alkalinity averaged 118 ± 19 mg/L; and pH averaged 8.9 ± 0.3 during the study, and these averages were within acceptable values for growth of fish (Boyd 1979).

Amino acid composition of the diets indicated that the diet containing SBM, and meat-and-bone meal, without FM, had numerically lower percentages of aspartic acid, histidine, isoleucine, leucine, lysine, methionine, threonine, and valine than diets containing FM (Table 2). Final individual weight and SGR of palmetto bass fed the diet with 0% FM (282 g and 2.1%/day) were significantly lower ($P < 0.05$) than weight and specific growth rate (SGR) of fish fed diets containing 15, 30, and 45% FM (Table 3). There were no significant differences ($P > 0.05$) in final weight and SGR of fish fed diets containing FM (342 g and 2.3%/day).

Percentages of fillet and frame (head, skeleton, and skin) in palmetto bass were not significantly different ($P > 0.05$) among treatments (Table 3) and averaged 23.1% and 64.0% of the whole body, respectively. Fish fed the diet containing SBM, and meat-and-bone meal, without FM had a higher ($P < 0.05$) percentage of viscera (7.1%) compared to fish fed diets containing 30 and 45% FM (average 5.7%). Fish fed diets containing 0 and 15% FM had higher percentages of abdominal fat (average 3.2% of whole body) than fish fed diets containing 30% and 45% FM (average 2.2% of whole body). Hepatosomatic index (HSI) was significantly higher in fish fed diets containing 0 and 45% FM (average 3.7%) than in fish fed diets containing 15 and 30% FM (average 2.8%).

There were no significant differences in percentage moisture (75.1),

TABLE 3. Individual weight, specific growth rate (SGR), and whole-body analysis of juvenile palmetto bass raised in cages and fed diets containing different levels of FM. Values are means (± SE) of three replications. Means in the same row with different letters are significantly different ($P < 0.05$). Whole-body analyses are expressed as a percentage of whole body. Frame = head, skin, and skeleton. HSI = hepatosomatic index.

	Diet (% fish meal)			
	0	15	30	45
Final indiv. weight (g)	282.4 ± 9.4b	343.8 ± 14.1a	333.0 ± 5.2a	348.6 ± 10.2a
SGR (%/day)	2.12 ± 0.03b	2.27 ± 0.03a	2.25 ± 0.01a	2.28 ± 0.02a
Whole-body analysis				
% Fillet	21.8 ± 0.9a	23.5 ± 0.7a	23.8 ± 0.6a	23.3 ± 0.2a
% Viscera	7.1 ± 0.1a	6.1 ± 0.5ab	5.9 ± 0.4b	5.6 ± 0.2b
% Frame	62.8 ± 0.9a	63.8 ± 0.9a	64.9 ± 1.0a	64.3 ± 0.4a
% Abdominal fat	3.5 ± 0.4a	2.9 ± 0.1a	2.2 ± 0.2b	2.2 ± 0.2b
HSI	3.9 ± 0.1a	2.9 ± 0.0b	2.7 ± 0.2b	3.5 ± 0.1a

protein (80.7), and lipid (14.5%) in fillet of palmetto bass fed any of the diets (Table 4). Muscle from palmetto bass fed the diet containing 15% fish meal had higher ($P < 0.05$) levels of arginine, aspartic acid, glycine, histidine, isoleucine, lysine, threonine, tyrosine, and valine (expressed as percentage of whole muscle) than fish fed the diet without FM (Table 5). Amino acid levels in muscle from fish fed diets containing 0, 30, and 45% FM were not significantly different ($P > 0.05$).

DISCUSSION

Aquaculture of many carnivorous fish species is dependent upon the use of fish meal as the major, if not sole, protein source (Bimbo and Crowther 1992; Rumsey 1994; Tacon 1994). Use of FM in diets for aquaculture species is due to the high quality and digestibility of FM protein. However, there is need to reduce the amount of FM in aquaculture diets to lower feed costs, and decrease reliance on FM.

Soybean meal can partially replace FM in some aquaculture diets. Atlantic salmon, *Salmo salar*, fed diets containing 46% and 56% FM had similar growth rates when SBM partially replaced FM (Olli et al. 1995). However, when FM levels decreased to 35% of the diet, fish had lower growth rates. Cho et al. (1974) reported that half of the herring meal added to a diet for rainbow trout, *Oncorhynchus mykiss*, could be replaced with SBM without adverse effects on growth. Reinitz (1980) reported that a diet with 25% herring meal produced higher growth in rainbow trout than diets containing less FM. Gallagher (1994) reported that growth of small juvenile (5 g) palmetto bass fed diets containing SBM replacing 25% and

TABLE 4. Percentage moisture, protein, and lipid in fillet of palmetto bass raised in cages and fed diets containing different levels of FM. Values are means (± SE) of three replications. There were no significant differences ($P > 0.05$) among treatment.

	Diet (% fish meal)			
	0	15	30	45
% Moisture	74.9 ± 0.4	75.6 ± 0.1	74.6 ± 0.5	75.1 ± 0.4
% Protein	79.0 ± 1.2	82.6 ± 0.8	80.1 ± 1.7	81.1 ± 1.7
% Lipid	18.3 ± 2.0	11.6 ± 2.0	14.0 ± 1.7	14.0 ± 2.5

TABLE 5. Amino acid composition (excluding tryptophan; expressed as g amino acid/100 g muscle) in fillet from juvenile palmetto bass raised in cages and fed diets containing different levels of FM. Values are means (±SE) of three replications containing 2 fish/replicate. Means in the same row with different letters are significantly different ($P < 0.05$).

	Diet (% fish meal)			
Amino acid (%)	0	15	30	45
Alanine	1.15±0.01ab	1.17±0.02ab	1.12±0.01b	1.18±0.02a
Arginine	1.11±0.03b	1.19±0.01a	1.14±0.01ab	1.15±0.01ab
Aspartic acid	2.01±0.04b	2.11±0.03a	1.98±0.01b	2.06±0.02ab
Cystine	0.20±0.01a	0.21±0.01a	0.19±0.01a	0.20±0.01a
Glutamic acid	2.82±0.02a	2.89±0.03a	2.91±0.13a	2.82±0.05a
Glycine	1.02±0.01b	1.10±0.03a	1.04±0.03ab	1.06±0.02ab
Histidine	0.48±0.02b	0.52±0.01a	0.50±0.01ab	0.50±0.01ab
Isoleucine	0.72±0.02b	0.77±0.01a	0.74±0.01ab	0.75±0.01ab
Leucine	1.50±0.03a	1.55±0.02a	1.50±0.02a	1.54±0.01a
Lysine	1.73±0.04b	1.82±0.02a	1.72±0.01b	1.77±0.03ab
Methionine	0.62±0.02a	0.60±0.01a	0.59±0.01a	0.60±0.01a
Phenylalanine	0.76±0.02a	0.81±0.01a	0.77±0.01a	0.78±0.01a
Proline	0.69±0.1a	0.68±0.02a	0.72±0.02a	0.69±0.03a
Serine	0.86±0.02ab	0.89±0.01a	0.85±0.01b	0.87±0.01ab
Threonine	0.91±0.02b	0.95±0.01a	0.90±0.01b	0.93±0.01ab
Tyrosine	0.62±0.01b	0.65±0.01a	0.62±0.01ab	0.64±0.01ab
Valine	0.80±0.02b	0.86±0.01a	0.81±0.01b	0.85±0.02ab

75% of the FM was similar to that of those fed a diet with FM as the sole protein source. A diet without FM was not evaluated. Addition of animal by-products to an SBM-based diet has been reported to improve growth in juvenile channel catfish (Mohsen and Lovell 1990). However, the increase in growth was not entirely explained on the basis of improved essential amino acid composition or digestible energy levels.

Proper amino acid composition of the diet is important for growth of fish. Total sulfur amino acid requirement for juvenile sunshine bass was determined to be 1.0% of the diet, with cystine sparing 40% of methionine (Keembiyehetty and Gatlin 1993). However, Griffin et al. (1994a) reported that the total sulfur amino acid requirement for sunshine bass is 0.73% of diet. Dietary lysine requirement of sunshine bass has been reported to be 1.4% of the diet (Griffin et al. 1992; Keembiyehetty and Gatlin 1992), while dietary arginine requirement is reported to be 1.55% of diet (Griffin et al. 1994b). Based on published requirements, all diets in the present study appeared to meet requirements for lysine, arginine, and methionine. However, the diet with 0% FM did contain lower amounts of these amino acids and this may have been a factor in the reduced growth.

The amino acid composition of muscle of juvenile palmetto bass fed diets containing various percentages of FM was similar. Cowey and Luquet (1983) reported that the essential amino acid composition of fish muscle and the recommended dietary requirements were similar. They suggested that since muscle comprises the largest amount of tissue protein, its amino acid composition will dictate the dietary amino acid requirements. Use of muscle amino acid composition in white sturgeon, *Acipenser transmontanus,* as an indicator of requirement levels was satisfactory (Ng and Hung 1994). However, amino acid concentrations in tissues do not necessarily reflect dietary need, but can be used as an indicator of the amounts of each amino acid relative to each other. In the present study, levels of lysine and sulfur amino acids in muscle of palmetto bass were similar to the apparent dietary requirement.

In the present study, individual weight of palmetto bass fed a diet containing SBM, meat-and-bone meal, and without FM was lower than that of fish fed diets containing 15-45% FM. Specific growth rates of palmetto bass in the present study are in agreement with other reports (Woods et al. 1983; Hung et al. 1993; Zhang et al. 1994). Dietary protein levels of 40-43% appear adequate for growth of palmetto and sunshine bass, *M. chrysops* × *M. saxatilis* (Brown et al. 1992; Nematipour et al. 1992; Webster et al. 1995a).

Although the reason for the reduced growth in fish fed the diet without FM is unclear, the availability of essential amino acids may be reduced in this diet compared to diets containing FM. A second possibility may be reduced digestibility of protein and/or energy of the diet without FM. Sullivan and Reigh (1995) reported that the digestibility for protein and energy for menhaden FM was higher than that for meat-and-bone meal, and slightly higher than that for SBM. This may not be a problem when feeding palmetto bass in ponds, where natural foods may be available. But fish in cages do not have access to such foods, and a highly digestible diet with all essential nutrients may be required.

A third possibility may have been that the diet without FM was not as palatable as diets containing FM. Reigh and Ellis (1992) reported that weight gain and feed intake of red drum decreased as the amount of FM was replaced by soybean meal. It may be that the diet without FM was not as palatable to palmetto bass compared to diets containing FM.

Whole-body analysis indicated that the level of fish meal in the diet may influence the percentage of body weight in viscera and liver. The hepatosomatic index (HSI) was highest for fish fed diets containing 0% and 45% FM. This may indicate that the livers had increased levels of glycogen or lipid. However, HSI values were similar to, or lower than, those reported by others (Nematipour et al. 1992; Webster et al. 1995). In the present study it appears that the level of added lipid may influence the percentage of abdominal fat. This is in contrast to findings of Belal and Assem (1995), who reported that the percentages of viscera and visceral fat in channel catfish, *Ictalurus punctatus*, was not affected by the percentage of FM in the diet. Gallagher (1994) also observed no difference in percentage of body weight composed of abdominal fat in palmetto bass fed diets containing various levels of FM. Fillet yield (as percentage of body weight) was not different among treatments but was lower than reported in other studies (Gallagher 1994; Zhang et al. 1994). This may be due to differences in final fish size or method of removing the fillet from fish.

Proximate composition of fillet in the present study was similar among treatments. These results are in contrast to reports that state that the levels of fat in channel catfish (Mohsen and Lovell 1990) and red drum (Reigh and Ellis 1992) increased linearly with dietary FM levels, even though lipid content, gross dietary energy, and protein to energy ratios of the diets were similar. In those studies, it may be that the fish converted a higher proportion of dietary protein to lipid when fed diets containing higher levels of FM, indicating that amino acid intake was in excess of the requirements. It is unclear why palmetto bass fed in the present study had similar levels of lipid in the fillet. Although diets in the present study were formulated to have similar available energy levels and protein to energy ratios, and to ensure that amino acid intake should have met requirements, it cannot be stated that amino acid intake did not exceed requirement levels.

Results from the present study indicate that a diet with 15% FM and 40% crude protein can be fed to juvenile palmetto bass without adversely affecting weight gain or body composition. This may reduce diet costs for producers and feed mills. Further research on diet formulations with plant or animal protein sources as total replacements of FM should be conducted.

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