JOURNAL OF THE
WORLD AQUACULTURE SOCIETY

Vol. 30, No. 4
December, 1999

Effect of Partial and Total Replacement of Fish Meal on Growth and Body Composition of Sunshine Bass *Morone chrysops* × *M. saxatilis* Fed Practical Diets

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Abstract

With the increasing emphasis to replace fish meal (FM) with less expensive protein sources in aquaculture diets without reducing weight gains, an 8-wk feeding trial was conducted with juvenile (15 g) sunshine bass *Morone chrysops* × *M. saxatilis*) to evaluate growth and body composition when fed diets with different levels of FM (0, 7.5, 15, and 30%). Six practical floating diets were formulated to contain 40% protein and similar energy levels, with various percentages of FM, meat-and-bone meal (MBM), soybean meal (SBM), poultry by-product meal (PBM), and/or distillers grains with solubles (DGS). Ten fish were stocked into each of 24 110-L aquaria and were fed twice daily *ad libitum* (0730 and 1600 h). At the conclusion of the feeding trial, final weights of fish fed diet 2 (0% FM, 29% SBM, 29% MBM, and 10% DGS), diet 3 (0% FM, 32% SBM, and 28% PBM), diet 5 (15% FM and 44% SBM), and diet 6 (30% FM and 26% SBM) were not significantly different ($P > 0.05$) and averaged 72 g. However, final weights of sunshine bass fed diet 1 (0% FM, 30% SBM, and 31% MBM) and diet 4 (7.5% FM and 54% SBM) were significantly lower and averaged 55 g. Specific growth rate (SGR) of sunshine bass fed diet 4 was significantly lower (2.14) than fish fed diet 2 (2.70), diet 3 (2.80), diet 5 (2.68), and diet 6 (2.84), while feed conversion ratio (FCR) of fish fed diet 4 was significantly higher than sunshine bass fed diets 2, 3, 5, and 6. Carcass (fish were decapitated) composition of sunshine bass fed diet 4 had a significantly higher percentage of moisture (70%) and protein (54% on a dry-matter basis) than fish fed all other diets. Percentage lipid was similar among fish fed all diets and averaged 41% (dry-matter basis).

Results from the present study indicate that diets in which all of the FM is replaced with a combination of animal- and plant-source proteins can be fed to sunshine bass without adverse effects on weight gain, growth rate, and body composition. Further feeding trials are needed to refine diet formulations used in the present study and should be conducted in aquaria and ponds.

The striped bass *Morone saxatilis* and its hybrids have received considerable attention in the United States as a commercial aquaculture species, due to the cessation of commercial harvesting of striped bass along the East Coast. Culture of hybrid striped bass (HSB) has rapidly increased in the past few years with annual production of 636,000 kg in 1990 to 3.8 million kg in 1997, and projections indicate that U.S. production could be 5.9 million kg by 2000. With this rapid increase in the amount of HSB produced, development of economical nutrient-complete diets is important for the continuing expansion of this industry. Diet costs typically represent between 40% and 70% of the variable costs of an aquaculture operation. However, cost is not the most important consideration for feeding. It is important that a practical diet also contain all the essential amino acids, fatty acids, vitamins, and minerals required by a fish because if these requirements are not met, fish

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growth and health could be compromised, adversely affecting profitability.

Most studies on the nutritional requirements of larval striped bass and its hybrids, have reported fatty acid requirements and the use of live foods (Baraji and Lovell 1986; Webster and Lovell 1990; Clawson and Lovell 1992; Tuncer and Harrell 1992). However, more recently, information on the nutritional requirements of juvenile HSB have been described. Dietary protein requirement has been reported to be between 36% (Brown, P. B. et al. 1993) and 40% (Webster et al. 1995b); dietary energy-to-protein ratio has been stated to be 8 kcal/g of protein (Nematipour et al. 1992) or a protein-to-energy ratio of 99 mg protein/kcal (Webster et al. 1995b). Requirement for dietary lysine has been reported as 1.4% of the dry diet (Griffin et al. 1992; Keembiyehetty and Gatlin 1992); dietary arginine requirement has been estimated as 1.5% of the dry diet (Griffin et al. 1994b); total sulfur amino acid requirement has been reported to range from 0.73% (Griffin et al. 1994a) to 1.0% of the diet (Keembiyehetty and Gatlin 1993). Dietary choline requirement was reported to be 500 mg/kg of diet (Griffin et al. 1994c), while dietary phosphorus was estimated at 0.5% of the diet (Brown, M. L. et al. 1993).

Protein is the most expensive component in most aquaculture diets; thus, producers want a diet 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-protein sources for more expensive animal-protein sources. 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 the most expensive. Aquaculture nutritionists have been able to use less expensive plant protein sources to partially replace FM; however, complete replacement of FM with plant-source proteins has only 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. 1992b; Webster et al. 1995a).

Soybean meal (SBM) is considered to be one of the most nutritious of all plant protein ingredients (Lovell 1988). However, growth data have been inconsistent when SBM replaces all the FM in a diet. Reigh and Ellis (1992) reported that red drum *Sciaenops ocellatus* did not utilize diets in which all of the FM was replaced by SBM. Fish fed diets containing a 50:50 blend (protein basis) of SBM and FM had similar growth to that of fish fed a diet with 100% of protein from FM. McGoogan and Gatlin (1997) reported that red drum fed a diet in which 90% of the protein was derived from SBM had similar weight gains as fish fed a diet in which FM comprised 100% of the dietary protein. Gallagher (1994) determined that juvenile HSB grown in aquaria could be fed a diet with 16% FM and 44% SBM without reduced growth compared to fish fed a diet without SBM. Brown et al. (1997) stated that palmetto bass *Morone saxatilis* × *M. chrysops* fed a diet with 23% FM and 40% SBM had similar growth compared to fish fed a diet with 46% FM and 0% SBM. Webster et al. (1995b) reported that weight gain in sunshine bass *M. chrysops* × *M. saxatilis* fed diets containing 15%, 30%, and 45% FM were not significantly different, but fish fed a diet without FM had significantly lower weight gain.

As the HSB industry expands, there is a need to formulate nutritious diets that are economical and do not require FM as a major protein source. The objective of this study was to evaluate growth and body composition of juvenile sunshine bass fed practical diets containing various percentages of FM and formulated to meet established nutritional requirements.

Materials and Methods

Experimental Diets

Six floating diets (pellet size = 2.0 mm) were formulated with practical, commer-

TABLE 1. *Formulations (% of total) of six practical diets fed to juvenile sunshine bass and the analyzed composition of the diets.*

Ingredient	Diet number					
	1	2	3	4	5	6
Menhaden fish meal	0.0	0.0	0.0	7.5	15.0	30.0
Soybean meal	30.0	29.0	32.0	54.0	44.0	25.5
Meat and bone meal	30.5	29.0	0.0	0.0	0.0	0.0
Poultry by-product meal	0.0	0.0	28.0	0.0	0.0	0.0
DGS[1]	0.0	10.0	0.0	0.0	0.0	0.0
Red wheat flour (mids)	15.0	15.0	15.0	15.0	15.0	15.0
Corn meal	15.9	8.4	16.4	16.15	19.9	24.15
Menhaden fish oil	4.5	4.5	4.5	3.5	2.5	2.0
Vitamin & mineral mix[2]	2.0	2.0	2.0	2.0	2.0	2.0
Monocalcium phosphate	1.5	1.5	1.5	1.25	1.0	0.75
Ascorbic acid (Stay-C)	0.1	0.1	0.1	0.1	0.1	0.1
Choline chloride	0.5	0.5	0.5	0.5	0.5	0.5
Analyzed composition (dry-matter basis)						
Moisture (%)	8.38	9.32	8.19	9.92	8.02	9.36
Protein (%)	36.50	38.42	40.50	39.00	37.76	38.40
Lipid %	9.66	10.83	12.12	9.64	10.21	10.64
Fiber %	3.82	5.18	3.81	3.66	3.70	2.98
Ash %	19.32	16.65	14.60	11.43	8.91	11.14
NFE[3]	30.70	28.92	28.97	36.27	39.42	36.84
Available energy[4]	3.56	3.67	3.87	3.88	4.01	3.97
E:P[5]	9.75	9.55	9.56	9.95	10.62	10.34

[1] Distillers' grains with solubles.
[2] Mineral mix was Rangen trace mineral mix F1 for catfish with 0.3 mg selenium/kg diet added. Vitamin mix was the Abernathy vitamin premix number 2 and supplied the following (mg or IU/kg of diet): biotin, 0.60 mg; B_{12}, 0.06 mg; E, 50 IU; folic acid, 16.5 mg; myo-inositol, 132 mg; K, 9.2 mg; niacin, 221 mg; pantothenic acid, 106 mg; B_6, 31 mg; riboflavin, 53 mg; thiamin, 43 mg; D_3, 440 IU; A, 4,399 IU; ethoxyquin, 99 mg.
[3] NFE = nitrogen-free extract.
[4] Available energy was calculated as 4.0, 4.0, and 9.0 kcal/g of protein, carbohydrate, and lipid, respectively.
[5] Energy-to-protein ratio.

cially-available ingredients and were made at the Abernathy Salmon Culture and Technology Center, Longview, Washington, USA, using a Wenger X85 single-screw cooker-extruder. Diets 1 and 2 contained 0% (FM) and were formulated to contain equal amounts of SBM and meat-and-bone meal (MBM). Diet 2 also contained 10% distillers' grains with solubles (DGS) as a second plant-protein source. Diet 3 contained 32% SBM and 28% poultry by-product meal (PBM). The other three diets (diets 4–6) contained various (7.5, 15, and 30%) percentages of menhaden FM, along with SBM (Table 1). All diets were formulated to be isonitrogenous (40% protein) and isocaloric (4.0 kcal available energy/g of diet). Due to differences in proximate composition of the diet ingredients from tabular values (NRC 1993), diets varied somewhat in actual chemical analysis from calculated values.

Protein content of the diets was determined by macro-Kjeldahl, percentage fat was determined by the acid-hydrolysis method, percentage fiber was determined by using the fritted glass crucible method, percentage ash was determined by placing diets in a muffle furnace (600 C) for 24 h, and moisture was determined by drying (100 C) until constant weight (AOAC 1990). Carbohydrate (NFE) was determined by difference [NFE = 100 − (% protein + % fat + % ash + % fiber)]. Available en-

TABLE 2. *Amino acid composition of practical diets fed to sunshine bass. Values are percentage of the diet.*

Amino acid	Diet number 1	2	3	4	5	6
Alanine	1.94	1.94	2.02	1.64	1.69	1.86
Arginine	2.27	2.27	2.44	2.36	2.26	2.15
Aspartic acid	3.09	3.30	3.58	3.90	3.70	3.46
Cystine	0.38	0.45	0.49	0.46	0.44	0.36
Glutamic acid	5.07	6.77	7.18	7.67	7.30	6.73
Glycine	2.96	2.49	2.53	1.64	1.70	1.93
Histidine	0.85	0.94	0.99	1.00	0.98	0.93
Isoleucine	1.14	1.24	1.42	1.47	1.41	1.36
Leucine	2.19	2.49	2.64	2.61	2.55	2.53
Lysine	1.70	1.83	1.99	2.08	2.09	2.16
Methionine	0.43	0.44	0.55	0.55	0.62	0.71
Met + Cys	0.81	0.89	1.04	1.01	1.06	1.07
Phenylalanine	1.32	1.48	1.58	1.62	1.54	1.45
Proline	2.32	2.25	2.24	1.89	1.76	1.75
Serine	1.50	1.63	1.80	1.74	1.65	1.53
Threonine	1.17	1.29	1.44	1.41	1.39	1.40
Tyrosine	0.77	0.88	0.97	0.96	0.95	0.92
Valine	1.46	1.59	1.71	1.62	1.58	1.58

ergy (AE) was calculated from physiological fuel values of 4.0, 4.0, and 9.0 kcal/g for carbohydrate (NFE), protein, and lipid, respectively (Garling and Wilson 1977). Diets were also analyzed for amino acid composition by a commercial analytical laboratory (Woodson-Tenent Lab, Dayton, Ohio, USA) (Table 2).

Experimental System and Animals

The feeding trial was conducted in 24 110-L glass aquaria. Water was recirculated through biological and mechanical filters. The recirculating system consisted of a 400-L vertical screen filter system utilizing high-density polyester screens (Red Ewald, Inc., Karnes City, Texas, USA) and a propeller-washed bead filter (Aquaculture Technology Systems, New Orleans, Louisiana, USA). These two filter systems removed particulate material and provided substrate for *Nitrosomonas* and *Nitrobacter* bacteria. Continuous aeration was provided by a blower and airstones. Water exchange rate (addition and removal of water in the system) was approximately 3% of total volume per day. Chloride levels were maintained at approximately 100 mg/L, by addition of foodgrade NaCl, to minimize potential adverse effects of nitrite to fish health (Perrone and Meade 1977). Each aquarium was supplied with water at a rate of 6.0 L/min and cleaned daily to remove uneaten feed and feces. All aquaria sides and back were painted black to minimize disturbances. Continuous illumination was supplied by fluorescent ceiling lights. After 3 wk, the bead filter ruptured a seal and was not used. A can filter with "bio-balls" was added to the screen filter to assist in ammonia and nitrite control with no effect on water quality or the health of fish.

Water temperature and dissolved oxygen were measured every other day using a YSI Model 58 oxygen meter (YSI Industries, Yellow Springs, Ohio, USA). Total ammonia and nitrite were measured every other day using a DREL 2000 spectrophotometer (Hach Co., Loveland, Colorado, USA). Total alkalinity and chloride were monitored twice weekly using the titration method of the DREL 2000; pH was monitored three times weekly using an electronic pH meter (pH pen; Fisher Scientific, Cincinnati, Ohio, USA).

Juvenile sunshine bass were obtained

from a commercial supplier (Keo Fish Farm, Keo, Arkansas, USA) and were stocked at an average weight (± SE) of 15.0 ± 4.0 g. Ten fish were batch-weighed to the nearest 0.1 g and were randomly stocked into each aquarium with four replicate aquaria per treatment. To eliminate stress of handling, fish were not weighed until the end of the feeding trial. All fish were fed *ad libitum* twice daily (0730 and 1600 h) for 8 wk. The amount of diet fed to each aquarium was weighed and recorded weekly to the nearest 0.1 g using an analytical scale. At the start and conclusion of the feeding trial, a number of fish were randomly sampled (15 at stocking and 3 fish per aquarium at conclusion), killed by lowering the body temperature, scaled and decapitated with the head being discarded. The body was cut into smaller pieces and homogenized in a blender, stored in polyethylene bags, and frozen for subsequent protein, fat, and moisture analysis. Protein was determined by macro-Kjeldahl, fat was determined by ether extraction, and moisture was determined by placing a 10-g sample in an oven (100 C) to be dried until constant weight (AOAC 1990).

Growth performance and feed conversion were measured in terms of final individual fish weight (g), weight gain (%), survival (%), specific growth rate (SGR, %/d), protein efficiency ratio (PER), net protein utilization (NPU), and feed conversion ratio (FCR). Growth response parameters were calculated as follows: SGR (%/d) = $((\ln W_t - \ln W_i)/T) \times 100$ where W_t is the weight of fish at time t, W_i is the weight of fish at time 0, and T is the culture period in days; PER = weight gain (g)/protein fed (g); NPU = protein gain (g)/protein fed (g); FCR = total dry feed fed (g)/total wet weight gain (g).

Statistical Analysis

Data were analyzed by analysis of variance (ANOVA) using the SAS ANOVA procedure (Statistical Analysis Systems 1988) for significant differences among treatment means. Duncan's multiple-range test was used to compare differences among individual means. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar 1984). Significance was tested at the $P = 0.05$ level.

Results

Over the duration of the study, water-quality parameters averaged (± SD): water temperature, 27.5 ± 0.2 C; dissolved oxygen, 7.36 ± 0.12 mg/L; total ammonia, 0.18 ± 0.04 mg/L; nitrite, 0.458 ± 0.062 mg/L; total alkalinity, 132 ± 8 mg/L; chlorides, 141 ± 6 mg/L; pH, 8.6 ± 0.07 and were within acceptable limits for fish growth and health (Boyd 1979; Mazik et al. 1991).

Final weight and percentage weight gains of sunshine bass fed two of the diets without FM, but with similar levels of an animal-source protein and SBM were similar to final weights and weight gains of fish fed SBM-based diets with either 15% or 30% FM (Table 3). Fish fed diet 2 and diet 3 had no significant differences in final weight (70 g and 72 g, respectively) compared to fish fed diet 5 and diet 6 which had final weights of 71 g and 75 g, respectively. Likewise, percentage weight gains of fish fed diet 2 and diet 3 (356% and 384%, respectively) were not significantly different to weight gains in fish fed diet 5 (354%) or diet 6 (396%). Sunshine bass fed diet 1 and diet 4 had significantly lower final weights (58 g and 51 g, respectively) than fish fed all other diets, while sunshine bass fed diet 4 had significantly lower weight gain (238%) than fish fed diets 2, 3, 5, and 6, but was not different than weight gain of fish fed diet 1 (309%).

Survival was not significantly different. Three fish fed diet 2 died during the fifth week of the study, but no subsequent mortality was observed. Specific growth rate (SGR) of sunshine bass fed diets 1, 2, 3, 5, and 6 were not significantly different from each other and averaged 2.70%/d; however, sunshine bass fed diet 4 had a significantly lower SGR (2.14%/d) compared to fish di-

TABLE 3. *Final weight, percentage weight gain, percentage survival, specific growth rate (SGR), food conversion ratio (FCR), protein efficiency ratio (PER), and net protein utilization (NPU) of juvenile sunshine bass fed diets containing different percentages of fish meal. Values are means ± SE for four replications. Means within a row having the same letter were not significantly different* (P > *0.05).*

	Diet number (% FM)					
	1 (0%)	2 (0%)	3 (0%)	4 (7.5%)	5 (15%)	6 (30%)
Final wt. (g/fish)	57.7 ± 1.8b	69.7 ± 4.8a	71.9 ± 4.0a	51.2 ± 6.5b	71.2 ± 6.5a	74.7 ± 3.2a
Weight gain (%)	309 ± 30bc	356 ± 23ab	384 ± 43a	238 ± 43c	354 ± 37ab	396 ± 45a
Survival (%)	97.5 ± 2.5a	92.5 ± 7.5a	100 ± 0a	100 ± 0a	100 ± 0a	100 ± 0a
SGR[1]	2.50 ± 0.13ab	2.70 ± 0.10a	2.80 ± 0.16a	2.14 ± 0.23b	2.68 ± 0.14a	2.84 ± 0.17a
FCR[2]	2.62 ± 0.17ab	2.19 ± 0.13b	2.12 ± 0.12b	2.92 ± 0.33a	2.06 ± 0.06b	2.09 ± 0.08b
PER[3]	1.06 ± 0.08ab	1.14 ± 0.12ab	1.18 ± 0.06ab	0.92 ± 0.11b	1.29 ± 0.04a	1.25 ± 0.05a
NPU[4]	0.50 ± 0.05a	0.56 ± 0.07a	0.59 ± 0.04a	0.49 ± 0.06a	0.63 ± 0.03a	0.62 ± 0.09a

[1] Specific growth rate (%/d) = 100 [(ln Wt − ln Wi)]/d.
[2] Feed conversion ratio = total diet fed (g)/total wet weight gain (g).
[3] Protein efficiency ratio = weight gain (g)/protein fed (g).
[4] Net protein utilization = protein gain (g)/protein fed (g).

ets 2, 3, 5, and 6, but not different from fish fed diet 1 (Table 3).

Feed conversion ratio (FCR) of fish fed diet 4 was significantly higher (2.9) than that of fish fed diet 2 (2.2), diet 3 (2.1), diet 5 (2.1), and diet 6 (2.1); but was not different from sunshine bass fed diet 1 (2.6). Protein efficiency ratio (PER) of fish fed diet 5 (1.29) and diet 6 (1.25) were significantly higher than the PER for fish fed diet 4 (0.92). There were no differences in PER for fish fed diet 1, 2, 3, and 4. Net protein utilization (NPU) was not different among treatments and averaged 0.57 (Table 3).

Carcass analysis in sunshine bass fed diets containing different levels of FM indicated that fish fed diet 4 had a significantly higher percentage of moisture (69.5%) and protein (53.6%, dry-matter basis) compared to sunshine bass fed all other diets, which averaged 67.5% and 48.7% (dry-matter basis) respectively (Table 4). There was no difference in the percentage lipid in sunshine bass fed any of the diets and this averaged 40.5% (dry-matter basis) for all treatments.

Discussion

Few reports have indicated that a practical diet for sunshine bass can be formulated without FM and still give similar growth compared to fish fed diets with FM. Growth of sunshine bass in the present study was similar to, or higher than, that reported in previous studies (Brown, P. B. et al. 1993; Keembiyehetty and Gatlin 1993; Gallagher 1994; Griffin et al. 1994a, 1994b, 1994c; Keembiyehetty and Gatlin 1997a, 1997b). All diets contained adequate amounts of choline (500 mg/kg of diet;

TABLE 4. *Carcass composition of juvenile sunshine bass fed diets containing different percentages of fish meal. Values are means ± SE for four replications. Means within a row having the same letter were not significantly different* (P > *0.05).*

	Diet number (% FM)					
	1 (0%)	2 (0%)	3 (0%)	4 (7.5%)	5 (15%)	6 (30%)
Moisture (%)	67.5 ± 0.55b	67.12 ± 0.55b	67.58 ± 0.51b	69.45 ± 0.58a	67.89 ± 0.38b	67.35 ± 0.26b
Protein (%)[1]	47.14 ± 1.48b	49.05 ± 1.12b	49.58 ± 0.85b	53.62 ± 2.31a	48.74 ± 0.80b	48.83 ± 0.72b
Lipid (%)[1]	42.10 ± 1.13a	41.22 ± 1.04a	41.56 ± 0.63a	39.03 ± 0.86a	38.49 ± 2.10a	40.72 ± 0.96a

[1] Dry-matter basis.

Griffin et al. 1994c); phosphorus (0.54%; Brown, M. L. et al. 1993), arginine (1.55% of diet/4.4% of dietary protein; Griffin et al. 1994b), threonine (0.9% of diet/2.6% of dietary protein; Keembiyehetty and Gatlin 1997a), and lysine (1.41% of diet/4.0% of dietary protein; Keembiyehetty and Gatlin 1992).

Total sulfur amino acid (TSAA) requirement of 0.73% of the dry diet, with cystine replacing 40% of the methionine, has been reported (Griffin et al. 1994a). However, Keembiyehetty and Gatlin (1993) reported a TSAA requirement of 1.0% of the dry diet. All diets in the present study appeared to meet requirements of Griffin et al. 1994a). Weight gains of sunshine bass fed diet 2 were similar to those of fish fed diet 6, while fish fed diet 1 had lower weight gains compared to fish fed diet 6.

In the present study, average individual weights of sunshine bass fed a diet (diet 1) containing SBM, MBM, and without FM were lower than that of fish fed diets containing SBM and 30% FM, but were not different from fish fed a diet with SBM and 15% FM. This is in partial agreement with Webster et al. (1997) who reported that palmetto bass fed a 42% protein diet with similar percentages of SBM, MBM, and 0% FM had lower growth compared to fish fed diets containing 15, 30, and 45% FM. Differences between the two studies may be due to the higher protein level of diets (42%) used in Webster et al. (1997), compared to the percentage protein of diets used in the present study (36–40%).

It appears that the SBM-based diet with 7.5% FM did not provide for good growth in sunshine bass, even when compared to two diets without FM (diets 2 and 3). In the latter two diets, similar percentages of SBM and another animal-source protein (MBM or PBM) were used. Webster et al. (1997) reported that one possible reason why growth in palmetto bass fed a diet with SBM and MBM was reduced, compared to fish fed diets containing 15, 30, and 45% FM, may have been reduced palatability or attractiveness of the diet, since all diets appeared to meet all nutrient requirements. Brown, P. B. et al. (1993) stated that a diet with 10% FM was needed to elicit a feeding response from sunshine bass. In the present study, when 10% distiller's grains with solubles (DGS) was added to the diet (diet 2) weight gain of fish increased compared to fish fed diet 1. Channel catfish *Ictalurus punctatus* can utilize a diet with 35% DGS (Webster et al. 1991), while Webster et al. (1992a) reported that a combination of two plant-protein sources may have greater success in providing for suitable fish growth when FM is totally replaced, compared to when a diet with one plant-protein source (SBM) is used.

A second possible reason why sunshine bass fed diet 2 had similar weight gains compared to fish fed a diet with 30% FM, but fish fed diet 1 did not, may be due to the lower percentage protein and higher ash values of diet 1. While all diets were formulated to be isonitrogenous and isocaloric, differences in the chemical composition of ingredients from tabular values, and actual compositions of the diet ingredient, resulted in some variation in protein and lipid contents among diets. It may be that reduced protein and higher ash levels of diet 1 did not allow for suitable growth in sunshine bass compared to other diets. Previous studies at our laboratory using practical diets have indicated that diets containing less than 12% ash appear to be suitable for HSB (Webster et al. 1995b; Webster et al. 1997).

A third possibility, not exclusive of the previous two, is that reduced amino acid digestibility of one or more of the diet ingredients could have resulted in some of the ambiguous growth data. Commercially-available ingredients were used, and different ingredient processing methods and temperatures, as well as possible differences in ingredient quality, may affect nutrient digestibility. Sullivan and Reigh (1995) reported that apparent digestibility coefficients for protein in palmetto bass for MBM was 73% while soybean meal was 80%. On the other hand, the same study reported the apparent protein digestibility of fishmeal was 88%, wheat flour was 93%, and corn was 87%. It may be that reduced digestibility of MBM and SBM in diet 1 resulted in reduced digestion of essential amino acids, thereby reducing growth. However, this would not explain the increased growth of fish fed diet 2, which was similar to diet 1 except that 10% DGS was added.

Aquaculture of many carnivorous fish species is dependent upon the use of FM as the major, if not sole, protein source (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 a need to reduce the amount of FM in aquaculture diets to lower diet costs and decrease the reliance on FM. The future of long-term availability of FM appears uncertain, but there is increasing concern that feeding fish and crustaceans, instead of humans, a potential food-quality protein source could be inefficient and unethical (Tacon 1997). Further, since FM is one of the most expensive ingredients in an aquaculture diet, it is important to the aquaculture industry that production diets be formulated that partially or totally reduce the percentage of FM in current diets without adversely affecting the growth and health of the fish.

Studies with other species have indicated that SBM 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. Juvenile palmetto bass fed diets containing SBM replacing 25% and 75% of the FM had growth rates similar to fish fed a diet with FM as the sole protein source; however, all diets with SBM had supplemental methionine added (Gallagher 1994). Keembiyehetty and Gatlin (1997b) reported that a diet containing 14% FM and 55% SBM, without added methionine, did not allow for good growth in sunshine bass compared to a diet with 57% FM, but that addition of 0.3% L-methionine to the first diet did improve growth.

Brown et al. (1997) reported that a diet with 40% SBM and 23% FM can be used for palmetto bass without adversely affecting growth if increased mineral supplementation was added to the diet. Plant protein sources offer lower levels of certain minerals than animal-source proteins, such as fish meal, and contain a high percentage of phytate (phytic acid) which, as a source of phosphorus, is generally unavailable to the fish. However, in the present study, sufficient inorganic phosphorus was added to all diets and phosphorus availability should not have been a limiting factor in growth.

Addition of animal by-products to a SBM-based diet has been reported to improve growth in channel catfish in aquaria; however, the increase in growth was not entirely explained by improved essential amino acid composition or digestible energy levels (Mohsen and Lovell 1990). Fowler (1991) reported that addition of 20% of PBM could replace 50% of the FM in a diet for chinook salmon *O. tshawytcha,* but that when fish were fed a diet with 30% PBM, growth was reduced. Gallagher and LaDouceur (1995) stated that juvenile palmetto bass fed a diet containing 12% FM and 36% low-ash poultry meal had similar weight gains as fish fed a diet containing 47% FM (control). In the present study, sunshine bass fed a diet with 32% SBM and 28% PBM had similar weight gains and SGR as fish fed a diet with 30% FM, indicating that a combination of SBM and PBM may be suitable for use as a total replacement of FM in a diet.

SGR, FCR, and PER in the present study were similar to those reported in other studies. Hughes et al. (1992) reported a range for SGR between 2.2 and 2.5, while FCRs ranged from 2.45 to 3.03, and PER from 0.63 to 0.79. Gallagher (1994) reported an FCR of 1.75 and a PER of 1.80. Nematipour et al. (1992) reported an FCR of 2.3 and a PER range between 0.97 and 1.42. FCR in the present study may have been somewhat higher than in some studies due to overfeeding. Observation of fish indicated that fish had an initial aggressive feeding response, but when feeding stopped, it ceased abruptly. It may have been that excess diet was left after second- or third-rounds of offering diet to the fish, resulting in overfeeding of fish, thereby increasing FCR values.

Carcass analysis of sunshine bass in the present study indicated that fish fed diet 4 had higher protein levels than fish fed all other diets, possibly due to their smaller size. The higher-than-expected lipid deposition in sunshine bass in the present study may have been a result of higher actual available energy values compared to calculated values. Actual energy availability values from protein and carbohydrate in the diet ingredients is poorly known in most fish species and is unpublished for sunshine bass.

In conclusion, a diet with PBM and SBM, or a diet with SBM/MBM/DGS, was consumed by sunshine bass, and fish had weight gains similar to fish fed a diet with 30% FM. However, it should not be stated that PBM is a superior ingredient compared to MBM since differences in ingredient quality and processing methods may affect the suitability of ingredients for fish diets. Further studies should be conducted to evaluate other practical diet formulations and refine formulations used in the present study to produce economical, nutritious diets that can be used by the HSB industry.

Acknowledgments

We would like to thank Mike Freeze and Keo Fish Farms, Keo, Arkansas, USA, for donation of the sunshine bass; Rob Jones, of Jones' Fish Hatcheries, Newtown, Ohio, USA, for transporting the sunshine bass; Devon McClain and Jim Beam Distilleries, Erlanger, Kentucky, USA, for donation of the distillers grains with solubles; Abernathy Salmon Culture & Technology Center for making the diets; and Karla Richardson for typing this manuscript. This study was partially funded by a grant from the USDA/CSRS grant to Kentucky State University under agreement KYX-80-96-07A.

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