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Effects of dietary protein and lipid levels on growth and body composition of sunshine bass (*Morone chrysops* × *M. saxatilis*) reared in cages

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Abstract

Juvenile sunshine bass with an average weight of 125 g were stocked into 24 floating cages (1.2×1.2×2.4 m) and fed one of 8 practical diets formulated to contain various percentages (30, 36, 42, and 48%) of protein. Due to differences in composition of feed ingredients, diets were analyzed as having 29, 36, 41, and 46% protein. Each protein level was formulated with two lipid levels: low (between 6.5 and 9.8%) and high (between 13.3 and 17.1%). Fish meal composed a constant percentage (56%) of the dietary protein in all diets. Fish were stocked at a rate of 200 per cage and fed twice daily at 08.00 and 16.30 h. Fish were fed all they would consume in 30 min for approximately 150 days. Percentage weight gains and specific growth rates (SGR) of fish fed diets containing 41 and 46% protein (99 and 116 mg protein/kcal, respectively) were higher ($P<0.05$) than fish fed diets containing 29 and 36% protein, 67 and 82 mg protein/kcal, respectively. No differences ($P>0.05$) in survival or feed conversion ratio (FCR) were found among treatments. Percentage dress-out, abdominal fat, hepatosomatic index, and body composition of sunshine bass was affected by dietary protein and energy level ($P<0.05$). Percentage protein and lipid in carcass and waste (head and viscera) of fish fed diets containing 116 mg protein/kcal had higher ($P<0.05$) protein levels and lower lipid levels than fish fed diets containing 67 and 82 mg protein/kcal. These data suggest that juvenile sunshine bass require a diet containing 41% protein, or a protein to energy ratio greater than 99 mg protein/kcal, when fish meal comprises 56% of the dietary protein.

Keywords: *Morone chrysops* × *M. saxatilis*; Feeding and nutrition—fish; Growth—fish

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1. Introduction

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 a few 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, 1990a,b; Clawson and Lovell, 1992; Tuncer and Harrell, 1992). However, little information on the nutritional requirements of juvenile fish has been reported and commercial production of hybrid striped bass has relied on diets formulated for salmonids or channel catfish.

Millikin (1982) reported that juvenile striped bass required a diet containing 55% protein for optimal growth. However, Brown et al. (1992) reported that juvenile sunshine bass (*M. chrysops* × *M. saxatilis*) required a diet containing 40% protein. This latter value is in agreement with Nematipour et al. (1992) who stated that optimal growth of sunshine bass occurred when fed diets containing 35–45% protein and a protein to energy ratio between 110 and 167 mg protein/kcal. Apparent variations in reported protein requirements may have been caused by differences in culture technique, diet composition, and protein quality.

Protein is the most expensive component in most aquaculture diets. Feed producers want to provide the minimum level of protein that will supply essential amino acids to give acceptable growth of fish. Protein utilization can be improved by replacing protein with lipid or carbohydrate; however, excess energy is undesirable because it may (1) reduce feed consumption (Lovell, 1979), (2) produce fatty fish (Page and Andrews, 1973; Reinitz et al., 1978), and (3) may inhibit optimal utilization of other dietary components (Prather and Lovell, 1973; Winfree and Stickney, 1981). Dietary protein level and the appropriate protein to energy ratio are extremely important when formulating diets to feed fish.

Little information regarding nutritional requirements of juvenile sunshine bass is available in the technical literature. The objective of this study was to evaluate growth and body composition of sunshine bass fed practical diets containing various protein and lipid levels.

2. Materials and methods

Experimental diets

Eight experimental diets with various protein and lipid levels were formulated from practical ingredients (Table 1). Peruvian anchovy meal and soybean meal served as protein sources. Menhaden fish oil was used as the lipid source for energy and to supply essential *n*-3 highly unsaturated fatty acids (HUFA) for the fish (Webster and Lovell, 1990a). Dietary protein/energy ratios were achieved by selecting protein levels of 30, 36, 42, and 48%, and two lipid levels (low, between 6.5 and 9.8%, and high, between 13.3 and 17.1%) within each protein level. These protein and energy levels were selected to be within

Table 1
Compostion of practical diets (containing various percentages of protein and lipid) fed to juvenile sunshine bass

Ingredient	Diet 1	2	3	4	5	6	7	8
Anchovy meal	25.0	25.0	30.0	30.0	35.0	35.0	40.0	40.0
Soybean meal	15.0	17.0	24.5	26.5	33.0	35.0	41.0	43.0
Wheat flour	5.0	13.0	5.0	0.0	0.0	0.0	0.0	0.0
Corn grain	49.7	32.2	35.9	31.4	27.9	18.4	17.4	8.9
Menhaden oil	3.5	11.0	3.0	10.5	2.5	10.0	0.0	6.5
Dicalcium phosphate	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Vitamin mix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mineral mix[2]	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Ascorbic acid	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Proximate analysis								
Moisture (%)	11.97	10.75	11.66	10.88	11.68	9.59	14.87	8.05
Protein (%)[3]	28.29	29.06	33.73	36.33	39.80	42.32	46.32	45.43
Lipid (%)[3]	9.32	15.92	9.79	17.06	9.65	15.25	6.48	13.34
Fiber (%)[3]	1.82	1.73	1.82	1.57	1.59	1.55	1.64	1.53
Ash (%)[3]	7.35	6.98	8.34	8.21	9.74	9.81	11.08	10.86
Arginine	1.31	1.72	1.31	1.22	1.77	1.99	2.05	2.36
Lysine	1.46	1.66	1.80	1.82	2.26	2.38	2.44	2.65
Methionine	0.54	0.51	0.59	0.63	0.74	0.79	0.81	0.85
Met + Cys[4]	0.80	0.76	0.87	0.96	1.09	1.15	1.16	1.25
Energy[5]	4.10	4.44	4.08	4.46	4.03	4.30	3.81	4.17
P/E[6]	69.00	65.45	82.67	81.46	98.76	98.42	121.57	108.94

[1]Vitamin mix supplied the following vitamins (IU or mg/kg of diet): vitamin A, 6000 IU; vitamin D, 2200 IU; vitamin E, 150 IU; vitamin K (as menadione), 10 mg; niacin, 200 mg; pantothenic acid, 60 mg; thiamin, 30 mg; riboflavin, 20 mg; pyridoxine, 20 mg; folic acid, 5 mg; B_{12}, 0.01 mg; biotin, 2 mg; choline, 2500 mg.
[2]Mineral mix supplied the following (mg/kg of diet): manganese, 180 mg; copper, 8 mg; cobalt, 1.5 mg; iron, 66 mg; zinc, 150 mg; iodine, 6 mg; selenium, 0.3 mg.
[3]Moisture-free basis.
[4]Methionine plus cystine.
[5]Available enery in kcal/g of diet.
[6]P/E = protein to energy ratio in mg protein/kcal.

acceptable ranges for hybrid striped bass (Brown et al., 1992; Nematipour et al., 1992). Since digestible energy values for the ingredients have not been determined for hybrid striped bass, 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 into floating pellets by a commercial feed mill (Integral Fish Foods, Inc., Grand Junction, CO 81501, USA). Diets were stored (−40°C) in plastic-lined bags until fed.

Diets were analyzed for crude protein, fat, fiber, ash, and moisture by standard AOAC methods (1990). Crude protein was determined using the Kjeldahl method, crude fat was determined using the acid-hydrolysis method, ash was determined by placing 10 g of sample in a muffle furnace (600°C) for 24 h, crude fiber was determined using the fritted glass crucible method, and moisture was determined by placing a 10-g sample in a drying oven

(95°C) until constant weight. Actual protein levels of the diets were different from formulated values, probably due to differences in feed ingredient compositions from tabular values (NRC, 1983). Actual protein levels were 28.7, 35.5, 41.1, and 45.9%.

Diets were analyzed for amino acid composition (Table 1) by Woodson-Tenent Laboratories, Dayton, OH.

Fish and experimental design

Juvenile sunshine bass, *Morone chrysops* × *M. saxatilis* (average weight, 125 ± 30 g), were obtained from a commercial producer (Nature's Catch, Jamestown, KY) and stocked into 24, 1.2 × 1.2 × 2.4-m (H:W:L) cages on 17 May 1993 at a rate of 200 fish per cage. Fish in each cage were randomly assigned one of 8 experimental diets. Each diet was fed to fish in 3 cages. Fish were fed twice daily (08.00 and 16.30 h) all the diet they would consume in 30 min. Uneaten diet was not removed from the cage because the cage lids prevented this. However, with skillful feeding, very little or no uneaten diet was observed in the cages. For weeks 1–8, a 1/8-inch pellet was fed; thereafter, a 5/32-inch pellet was fed until the conclusion of the study.

Each cage had a frame made of 4.0-cm polyvinylchloride (PVC) tubing with a hinged lid. A 1.0-cm polyethylene mesh covered the frame. A 20-cm panel of polyethylene mesh (5.0-mm) was installed around the top of the inside of each cage to prevent loss of the floating diet. Cages were anchored approximately 2.5-m from the side of a 2.0-ha pond, with an average depth of 2.0 m. There was 1.5 m between cages.

Temperature and dissolved oxygen (DO) were monitored 3 times daily (08.00, 16.30, and 20.30 h) outside the cages, at a depth of 0.75 m, using a YSI Model 58 oxygen meter. If DO was predicted to decline below 4.0 mg/l, aeration was provided using a 10-hp electric paddlewheel. Weekly measurements of pH were recorded using an electronic pH meter. Total ammonia nitrogen, nitrite, and alkalinity were measured weekly using a DR 2000 spectrophotometer (Hach Co., Loveland, CO, USA).

Fish were harvested between 6 and 10 October 1993 and were not fed 16 h prior to harvest. Total number and weight of fish in each cage was determined at harvest. Twenty-five fish were randomly sampled from each cage, individually weighed to the nearest 0.1 g, and measured for total length to the nearest 0.5 cm. Ten fish were randomly sampled from each cage for analysis of dressing percentage, abdominal fat, and body weight. Fish were killed by decapitation and dressed by removing the viscera. Abdominal fat was removed, weighed, and reported as a percentage of total weight. Carcasses and waste (head and viscera) of 3 fish sampled from each cage were homogenized separately in a blender and analyzed for protein, fat, ash, and moisture as previously described for the diets, except that fat was analyzed by ether extraction (AOAC, 1990).

Feed conversion ratio (FCR) and specific growth rate (SGR) were calculated as follows:

$$\text{FCR} = \text{total diet fed (kg)} / \text{total wet weight gain (kg)}$$

$$\text{SGR (\%/day)} = [(\text{Ln } W_t - \text{Ln } W_i)/T] \times 100,$$

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.

Data were analyzed using the SAS General Linear Models (GLM) procedure (Statistical Analysis Systems, 1988) for significant differences among treatment means based on protein level, lipid level, the interaction of protein and lipid, and protein to energy ratio. No significant interaction of protein and lipid was found, so data were presented by individual diet and protein to energy ratio. Means were analyzed by Duncan's multiple range test. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar, 1984).

3. Results

Growth, survival, and feed conversion

When analyzed by individual diets, sunshine bass fed diets containing different protein and lipid levels had different ($P<0.05$) weight gains and specific growth rates, while feed conversion ratios were not different ($P>0.05$) (Table 2). Individual weight was higher ($P<0.05$) for fish fed diets 3 (34% protein:10% lipid), 5 (40% protein:10% lipid), 7 (46% protein:6% lipid), and 8 (45% protein:13% lipid) compared to fish fed diets 1 (28% protein:9% lipid) and 2 (29% protein:16% lipid). Fish fed diet 7 had numerically the highest individual weight (565 g) among all treatments and it was higher ($P<0.05$) than for fish fed diets 1 (447 g), 2 (417 g), 4 (36% protein:17% lipid; 507 g), and 6 (42% protein/15% lipid; 495 g).

Percentage weight gain was higher ($P<0.05$) for fish fed diets 5–8 (average of 346%) compared to fish fed diets 1–3 (average of 271%) (Table 2). Percentage survival of fish

Table 2

Individual weight, percentage weight gain, percentage survival, specific growth rate (SGR), and feed conversion ratio (FCR) of sunshine bass fed diets containing various percentages of protein (P) and lipid (L)[1]

	Indiv. wt. (g)	Weight gain (%)	Survival (%)	SGR[2]	FCR[3]
Diet					
1 (28P:9L)	446.9±5.3[cd]	279.7±14.1[c]	91.5±3.5[ab]	0.96±0.03[c]	2.67±0.09[a]
2 (29P:16L)	416.5±6.5[d]	239.7±4.9[d]	88.8±1.5[ab]	0.88±0.01[d]	2.32±0.24[a]
3 (34P:10L)	532.4±25.8[ab]	294.3±10.4[bc]	83.3±5.9[ab]	0.98±0.02[bc]	2.44±0.20[a]
4 (36P:17L)	506.7±23.4[b]	319.7±11.1[ab]	93.3±1.9[a]	1.03±0.02[ab]	1.93±0.12[a]
5 (40P:10L)	549.7±18.4[ab]	347.3±3.5[a]	92.2±4.2[a]	1.08±0.01[a]	1.83±0.12[a]
6 (42P:15L)	494.6±5.0[cb]	344.7±19.8[a]	73.8±10.9[b]	1.07±0.03[a]	2.67±0.60[a]
7 (46P:6L)	564.8±17.0[a]	343.0±7.6[a]	92.0±3.3[ab]	1.07±0.01[a]	1.86±0.12[a]
8 (45P:13L)	549.4±19.7[ab]	347.0±14.4[a]	89.2±3.4[ab]	1.08±0.02[a]	1.99±0.15[a]
P/E (mg protein/kcal)					
67	431.7±7.8[b]	259.7±11.2[c]	90.2±1.8[a]	0.92±0.02[c]	2.50±0.14[a]
82	519.6±16.6[a]	307.0±8.8[b]	88.3±3.5[a]	1.01±0.02[b]	2.19±0.15[a]
99	522.2±15.0[a]	346.0±9.0[a]	83.0±6.7[a]	1.08±0.01[a]	2.25±0.33[a]
116	557.1±12.2[a]	345.0±7.3[a]	90.6±2.2[a]	1.07±0.01[a]	1.93±0.09[a]

[1]Values are means ± s.e. of 3 replications. Means in the same column with different superscripts are significantly different ($P<0.05$).

[2]SGR = specific growth rate.

[3]FCR = feed conversion ratio.

fed diet 6 was lower ($P<0.05$) than of fish fed diets 4 and 5; however, this was due to mortality resulting from a localized oxygen depletion after one of the cages in the treatment was cleaned. Cages were not cleaned subsequent to that occurrence.

Specific growth rate (SGR) was higher ($P<0.05$) for fish fed diets 5–8 (average of 1.08%/day) than for fish fed diets 1–3 (average of 0.94%/day), but not different ($P>0.05$) from fish fed diet 4 (Table 2). Feed conversion ratio (FCR) values were not different ($P>0.05$) among treatments. Diets with protein to energy ratios of 99 and 116 mg protein/kcal had higher ($P<0.05$) percentage weight gains and SGR than fish fed diets containing 67 and 82 mg protein/kcal (Table 2).

Percentage dress-out, abdominal fat, and HSI

Data from individual diets indicated that percentage dress-out (carcass with head and viscera removed) of sunshine bass fed diet 7 (60.9%) was higher ($P<0.05$) than in fish fed diets 1–6, but not different ($P>0.05$) from fish fed diet 8 (Table 3). Percentage of abdominal fat in fish fed diets 1, 2, 4, and 6 was higher ($P<0.05$) than fish fed diets 7 and 8. Hepatosomatic index (HSI) was higher ($P<0.05$) for fish fed diets 1–4 (average of 4.8%) than for fish fed diets 7 and 8 (average of 3.2%).

When data were analyzed by protein to energy ratio, fish fed diets containing 116 mg protein/kcal had a higher ($P<0.05$) percentage dress-out (60.3%) and a lower percentage of abdominal fat (3.0%) than fish fed diets containing 67, 82, and 99 mg protein/kcal (Table 3). Fish fed diets containing 99 and 116 mg protein/kcal had higher ($P<0.05$) HSI than fish fed diets containing 67 and 82 mg protein/kcal.

Table 3
Percentage dress-out, percentage abdominal fat, and hepatosomatic index (HSI) of sunshine bass fed diets containing various percentages of protein (P) and lipid (L)[1]

	Percentage dress-out	Abdominal fat (%)	HSI[2]
Diet			
1 (28P:9L)	57.9 ± 0.2^{bc}	4.2 ± 0.2^{abc}	5.2 ± 0.2^{a}
2 (29P:16L)	57.1 ± 0.9^{c}	4.4 ± 0.1^{ab}	5.1 ± 0.2^{a}
3 (34P:10L)	58.7 ± 0.8^{bc}	3.3 ± 0.2^{cd}	4.1 ± 0.2^{bc}
4 (36P:17L)	56.9 ± 0.3^{c}	4.8 ± 0.4^{a}	4.6 ± 0.4^{ab}
5 (40P:10L)	59.0 ± 0.4^{b}	3.6 ± 0.1^{bcd}	3.5 ± 0.1^{cd}
6 (42P:15L)	57.9 ± 0.3^{bc}	4.2 ± 0.5^{abc}	3.5 ± 0.5^{cd}
7 (46P:6L)	60.9 ± 0.6^{a}	3.0 ± 0.4^{d}	3.2 ± 0.1^{d}
8 (45P:13L)	59.6 ± 0.3^{ab}	3.1 ± 0.2^{d}	3.1 ± 0.1^{d}
P/E (mg protein/kcal)			
67	57.5 ± 0.4^{b}	4.3 ± 0.1^{a}	5.1 ± 0.1^{a}
82	57.8 ± 0.6^{b}	4.0 ± 0.4^{a}	4.3 ± 0.2^{b}
99	58.5 ± 0.3^{b}	3.9 ± 0.3^{a}	3.5 ± 0.2^{c}
116	60.3 ± 0.4^{a}	3.0 ± 0.2^{b}	3.2 ± 0.1^{c}

[1]Values are means ± s.e. of 3 replications. Means within the same column with different superscripts are significantly different ($P<0.05$).
[2]HSI = hepatosomatic index.

Table 4
Percentage moisture, protein, fat, and ash of dressed carcass of sunshine bass fed diets containing various percentages of protein (P) and lipid (L)[1]

	Moisture	Protein (%)[2]	Lipid (%)[2]	Ash (%)[2]
Diet				
1 (28P:9L)	67.7±0.7[b]	61.6±0.7[bcd]	30.7±0.5[ab]	8.4±0.8[a]
2 (29P:16L)	67.1±0.6[b]	58.4±1.4[d]	32.1±1.6[a]	8.8±0.3[a]
3 (34P:10L)	68.2±0.3[b]	61.9±1.4[bcd]	30.6±1.4[ab]	7.4±0.4[a]
4 (36P:17L)	67.5±0.4[b]	59.3±1.3[cd]	31.5±1.1[ab]	8.7±0.5[a]
5 (40P:10L)	68.8±0.7[ab]	63.6±2.2[abc]	28.7±1.5[abc]	8.0±0.3[a]
6 (42P:15L)	68.0±0.3[b]	62.1±1.6[bcd]	28.9±1.1[abc]	8.8±0.5[a]
7 (46P:6L)	70.3±0.2[a]	69.4±1.1[a]	25.4±1.4[c]	8.6±0.9[a]
8 (45P:13L)	68.7±0.7[b]	64.3±1.5[ab]	27.5±1.8[bc]	8.6±0.6[a]
P/E (mg protein/kcal)				
67	67.4±0.4[b]	60.0±1.0[b]	31.4±0.8[a]	8.6±0.4[a]
82	67.9±0.3[b]	60.6±1.0[b]	31.1±0.8[a]	8.0±0.4[a]
99	68.4±0.4[b]	62.8±1.2[b]	28.8±0.8[ab]	8.4±0.3[a]
116	69.5±0.5[a]	65.9±1.1[a]	26.5±1.1[b]	8.6±0.5[a]

[1]Values are means ± s.e. of 3 replications. Means within the same column with different superscripts are significantly different ($P < 0.05$).
[2]Moisture-free basis.

Table 5
Percentage moisture, protein, fat, and ash of waste (head and viscera) of sunshine bass fed diets containing various percentages of protein (P) and lipid (L)[1]

	Moisture	Protein (%)[2]	Lipid (%)[2]	Ash (%)[2]
Diet				
1 (28P:9L)	59.7±0.9[bc]	33.8±0.8[bc]	47.4±1.4[a]	10.0±0.2[ab]
2 (29P:16L)	58.0±0.4[c]	32.2±0.9[c]	45.9±0.4[ab]	9.9±0.2[ab]
3 (34P:10L)	58.8±0.8[bc]	34.4±1.4[bc]	47.6±0.5[a]	9.9±0.1[ab]
4 (36P:17L)	58.8±0.2[bc]	32.0±0.7[c]	48.0±1.3[a]	9.2±0.1[b]
5 (40P:10L)	59.6±0.8[bc]	35.6±1.0[b]	47.9±1.1[a]	10.4±0.8[ab]
6 (42P:15L)	59.0±0.4[bc]	34.4±1.1[bc]	47.2±0.6[a]	9.8±0.4[ab]
7 (46P:6L)	60.9±0.3[ab]	39.5±0.8[a]	43.7±2.0[b]	11.3±1.0[a]
8 (45P:13L)	61.7±0.7[a]	38.8±0.4[a]	43.3±0.7[b]	11.1±0.7[a]
P/E (mg protein/kcal)				
67	58.9±0.6[b]	33.0±0.7[b]	46.7±0.7[a]	9.9±0.1[b]
82	58.8±0.4[b]	33.2±0.9[b]	47.8±0.6[a]	9.5±0.2[b]
99	59.3±0.4[b]	35.0±0.7[b]	47.5±0.6[a]	10.1±0.4[ab]
116	61.3±0.4[a]	39.1±0.4[a]	43.5±1.0[b]	11.2±0.5[a]

[1]Values are means ± s.e. of 3 replications. Means within the same column with different superscripts are significantly different ($P < 0.05$).
[2]Moisture-free basis.

Body composition

Sunshine bass fed diet 7 had a higher ($P<0.05$) percentage of moisture (70.3%) than in fish fed diets 1–4, 6, and 8, but it was not different ($P>0.05$) from fish fed diet 5 (Table 4). Percentage of carcass protein was higher ($P<0.05$) in fish fed diet 7 (69.4%) than in fish fed diets 1–4, while fish fed diets 1–4 had higher ($P<0.05$) percentages of fat than fish fed diets 7 and 8. No difference ($P>0.05$) in percentage ash was found among treatments. Fish fed a diet containing 116 mg protein/kcal had higher ($P<0.05$) percentage of moisture and protein than fish fed all other diets, while having a lower percentage of lipid (26.5%) than fish fed 67 mg protein/kcal (31.4%) and 82 mg protein/kcal (31.1%).

Percentage moisture, protein, fat, and ash in waste (head and viscera) of sunshine bass fed the various diets were different ($P<0.05$). Fish fed diets 7 and 8 had higher ($P<0.05$) protein (38.8%), and lower fat (43.3%) ($P<0.05$) than fish fed diets 1, 3, 4, 5, and 6 (Table 5). Fish fed a diet containing 116 mg protein/kcal had higher ($P<0.05$) percentages of moisture and protein (61.3 and 39.1%, respectively), and a lower percentage of lipid (43.5%) than fish fed all other diets.

4. Discussion

In the present study, weight gain of sunshine bass was highest when fish were fed diets containing between 99 and 116 mg protein/kcal. This is within the ranges reported in other studies. Nematipour et al. (1992) reported that optimal growth of sunshine bass was achieved with diets containing between 110 and 167 mg protein/kcal. Optimum dietary protein to energy (P/E) ratio for rapid growth of juvenile blue tilapia has been reported to be 108 and 123 mg protein/kcal (Winfree and Stickney, 1981); 88 and 147 mg protein/kcal for channel catfish (Garling and Wilson, 1976; Reis et al., 1989); and 105 mg protein/kcal for brook trout (Ringrose, 1971).

Protein requirements of juvenile carnivorous fish species have varied. Smallmouth bass have been reported to require diets containing 45% protein, while largemouth bass require 40% protein (Anderson et al., 1981); rainbow trout, between 40 and 45% protein (Halver et al., 1964; Satia, 1974); coho salmon, 40% protein (Zeitoun et al., 1974); yellowtail, a minimum of 50% protein (Shimeno, 1991); and red drum, between 35 and 50% protein (Daniels and Robinson, 1986; Serrano et al., 1992). Dietary protein requirements among and within species may differ due to differences in water temperature, salinity, diet composition, quality and biological value of protein sources, and sources of non-protein energy (NRC, 1983). Protein quality depends upon palatability, essential amino acid composition, and digestibility. Since all diets were composed of the same ingredients, no differences in palatability or digestibility should be observed.

Amino acid composition of the diets was important to the growth of sunshine bass in the present study. Total sulfur amino acid requirements for juvenile (53 g) sunshine bass were determined to be 1.0% of dry diet or 2.9% of dietary protein with cystine sparing less than 40% of methionine (Keembiyehetty and Gatlin, 1993). Dietary lysine requirement of sunshine bass has been reported to be 1.4% of the dry diet or 4.0% of dietary protein when fed semipurified (Keembiyehetty and Gatlin, 1992) and purified (Griffin et al., 1992) diets.

Dietary arginine requirement is reportedly 1.55% of dry diet or 4.4% of dietary protein for juvenile (3–7 g) sunshine bass (Griffin et al., 1994a).

Based on the requirements of sunshine bass, all diets in the present study appeared to meet the requirement for lysine, and all diets (except diets 1, 3, and 4) met the requirement for arginine. Total sulfur amino acid levels in diets 1–6 may have been limiting compared to literature values using smaller fish (Keembiyehetty and Gatlin, 1993); however, sunshine bass fed diets 5 and 6 had growth similar to fish fed diets 7 and 8. Griffin et al. (1994b) reported that the total sulfur amino acid requirement for sunshine bass is 0.73%. This value is below the levels of sulfur amino acids in all diets in the present study, indicating that diets met the sulfur amino acid requirement. However, this could depend upon the amino acid availability (especially cystine) of the dietary protein.

Survival and specific growth rate (SGR) data for sunshine bass reared in cages in the present study are in agreement with data from Woods et al. (1985) who reported that palmetto bass had survival between 70 and 95% and a SGR value of 0.80%/day after approximately 8 months growth in circular tanks. Average survival values from the present study were 88% and SGR was 1.02. Feed conversion values in the present study were somewhat higher than reported for channel catfish (1.4) (Li and Lovell, 1992; Robinson and Robinette, 1993). This may have been due to feeding a small pellet for the first 6–8 weeks of the study. It was noticed afterwards that approximately 50% of the pellets sank when placed in water. This may have resulted in overfeeding of fish. However, FCR values from the present study are in agreement with Hughes et al. (1992) who reported FCR values between 2.5 and 3.0, and lower than those reported by Klar and Parker (1989).

Since fish can meet a substantial part of their energy requirement from dietary protein, the protein to energy (P/E) ratio is extremely influential on the efficiency of protein and energy utilization. Fish in the present study fed diets containing 116 mg protein/kcal had a higher percentage dress-out (dressed carcass), a lower percentage of abdominal lipid, a higher percentage of body protein, and a lower percentage of body lipid than fish fed the other diets. The level of digestible energy in a diet affects the amount of food consumed by fish and the P/E ratio of the diet will influence conversion efficiency of the diet (Reis et al., 1989). A P/E ratio lower than 116 mg protein/kcal tended to increase lipid deposition and decrease protein levels in sunshine bass. However, growth of fish fed diets containing 99 and 116 mg protein/kcal (with 41 and 46% protein, respectively) was similar.

The present study indicates that a diet with 41% protein and a P/E ratio of 99 mg protein/kcal produced growth (weight gain and SGR) and feed conversion values in sunshine bass similar to fish fed diets containing 46% protein and 116 mg protein/kcal. However, fish fed diets containing 41% protein did have lower dress-out percentages, an increase in abdominal fat, a decrease in carcass protein, and an increase in carcass lipid levels compared with fish fed diets containing 46% protein. Thus producers may need to determine if similar growth (weight gain), but decreased dress-out and increased lipid levels in fish fed diets with 41% protein (99 mg protein/kcal) are outweighed by the potentially lower cost of the diet. Results suggest that carbohydrate and lipid were utilized equally by sunshine bass. Thus, diets 5 and 7, with lower added lipid levels, may be used since less added lipid may reduce storage and spoilage concerns.

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