



ELSEVIER

Aquaculture 188 (2000) 299–309

Aquaculture

www.elsevier.nl/locate/aqua-online

Use of hempseed meal, poultry by-product meal, and canola meal in practical diets without fish meal for sunshine bass (*Morone chrysops* × *M. saxatilis*)

Carl D. Webster^{a,*}, Kenneth R. Thompson^a, Ann M. Morgan^a,
Ebony J. Grisby^a, Ann L. Gannam^b

^a Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601, USA

^b Abernathy Fish Technology Center, US Fish and Wildlife Service, Longview, WA 98632, USA

Received 22 November 1999; received in revised form 21 January 2000; accepted 21 January 2000

Abstract

In an effort to reduce fish meal (FM) use in diets for sunshine bass, a feeding trial was conducted. Four practical floating diets were formulated to contain 40% protein, similar energy levels, and without FM. A fifth diet was formulated to contain 30% FM and served as the control diet. Ten fish were stocked into each of 20 110-l aquaria and were fed twice daily (0730 and 1600 h) amounts of diet similar to that of the aquarium consuming the most diet at that feeding. Diets were formulated to contain as major protein sources: Diet 1, 35% soybean meal (SBM) and 35% meat-and-bone meal (MBM); Diet 2, 27% SBM + 27% MBM + 20% hempseed meal (HSM); Diet 3, 30% SBM and 30% poultry by-product meal (PBM); Diet 4, 27% SBM + 27% MBM + 20% canola meal (CM). The control diet (Diet 5) had 30% SBM and 30% FM.

At the conclusion of the feeding trial, percentage weight gain of sunshine bass fed Diet 1 was significantly ($P < 0.05$) higher (299%) compared to fish fed Diet 3 (197%) and Diet 4 (226%), but not different from fish fed Diets 2 and 5. Specific growth rate (SGR) of fish fed Diet 1 was significantly higher (1.97%/day) compared to fish fed Diet 3 (1.52%/day), but not different compared to fish fed all other diets. Percentage survival and the amount of diet fed were not significantly different among all treatments and averaged 95% and 111 g diet/fish, respectively. Feed conversion ratios (FCRs) of fish fed Diets 3 and 4 were significantly higher (2.71 and 2.88, respectively) compared to fish fed the other diets. Percentage fillet weight and hepatosomatic index (HSI) were not significantly different among treatments and averaged 22.7% and 2.04%,

* Corresponding author. Tel.: +1-502-564-9109; fax: +1-502-564-9118.

E-mail address: cwebster@dcrc.net (C.D. Webster).

respectively. Proximate compositions of fillets were not different among fish fed all diets and averaged 23.9%, 19.6%, and 2.0% for moisture, protein (wet weight basis), and lipid (wet weight basis), respectively.

Results from the present study indicate that diets without FM can be fed to juvenile sunshine bass without adverse effects on growth, survival, and body composition. Further research needs to be conducted in ponds on the diet formulations used in the present study to verify results. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Sunshine bass; Diet; Fish meal; Growth

1. Introduction

The culture of hybrid striped bass has rapidly increased in the past few years with annual production of 636,000 kg in 1990 to 3.8 million kg in 1997, with projections indicating that US production could be 5.9 million kg in 1999. With this rapid increase in the amount of hybrid striped bass produced, economical nutritious diets are required for the continuing development of this industry. However, cost is not the most important consideration for feeding a diet to fish. It is imperative that a practical diet contain all the essential amino acids, fatty acids, vitamins, and minerals required by a fish because if these requirements are not met, fish growth and health could be compromised, adversely affecting profitability.

One approach to reduce feed cost is to partially or totally substitute more expensive animal protein sources with less expensive plant 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. Use of less expensive animal and/or plant protein sources as total replacements for FM is an important research area in aquaculture nutrition.

Soybean meal (SBM) is considered to be one of the most nutritious of all plant protein ingredients (Lovell, 1988). However, the growth of hybrid striped bass is inconsistent when SBM is added in high percentages to a diet. Gallagher (1994) determined that juvenile hybrid striped bass 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. (1997) reported that growth in sunshine bass fed diets containing 15%, 30%, and 45% FM was not significantly different among treatments, but fish fed a diet without FM were significantly smaller.

Poultry by-product meal (PBM) has been reported to partially replace FM in Pacific salmon diets (Fowler, 1981) and in chinook salmon (Fowler, 1991) at levels of up to 20% of the diet; however, when PBM was used in chinook salmon diets at 30% of the diet, reduced growth of fish was observed, possibly due to reduced palatability (Fowler, 1991).

Canola is the name given to varieties of rapeseed (*Brassica napus* and *B. campestris*) that are low in both glucosinolates (antithyroid factors) and erucic acid (Higgs et al., 1983). Higgs et al. (1990) reported that the protein quality of canola meal (CM) is

equivalent to that of herring meal and higher than that for SBM and cottonseed meal based on the essential amino acid index. However, CM does contain phenolic compounds (such as sinapine and tannins) that may reduce palatability (McCurdy and March, 1992) and protein digestibility (Krogdahl, 1989), has a high fiber content which reduces protein and energy digestibility (Higgs et al., 1983), and has some glucosinolates.

Hempseed meal (HSM) is the meal left after oil has been extracted from the seed and has moderate protein levels ranging from 30% to 40%, depending upon the variety of hemp used. Little research has been conducted on the use of HSM; however, it appears to be a suitable ingredient for use in aquaculture diets. Unpublished data from our laboratory indicate that 20% HSM can be added to a channel catfish diet without adverse effects on growth.

As the hybrid striped bass industry expands, there is a need to formulate nutritious diets that are economical and do not rely on 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 without FM and using various animal and plant protein sources.

2. Materials and methods

2.1. Experimental diets

Five floating diets (pellet size = 2.0 mm) were formulated with practical, commercially available ingredients and were produced at the Abernathy Fish Technology Center, Longview, WA, using a Wenger X85 single-screw cooker-extruder (Table 1). All diets were formulated isonitrogenous (40% protein), isocaloric (4.0 kcal available energy (AE)/g of diet) and to contain total sulfur amino acids (TSAA; methionine and cystine) as 1.0% of the diet.

Percentage protein of the diets was determined by macro-Kjeldahl, percentage lipid 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 has been attained (AOAC, 1990). Carbohydrate (NFE) was determined by difference [NFE = 100 - (% protein + % fat + % ash + % fiber)]. 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, OH) (Table 2).

2.2. Experimental system and animals

The feeding trial was conducted in 24 110-l glass aquaria at the Aquaculture Research Center, Kentucky State University. Dechlorinated city (tap) water was recirculated through biological and mechanical filters. The recirculating system consisted of a 1500-l vertical screen filter system utilizing high-density polyester screens (Red Ewald,

Table 1

Formulations (percentage of total) of five practical diets fed to juvenile sunshine bass and the analyzed composition of the diets

| Ingredient | Diet number | | | | |
|--|-------------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 |
| Menhaden fish meal | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 |
| SBM | 35.0 | 27.0 | 30.0 | 27.0 | 30.0 |
| MBM | 35.0 | 27.0 | 0.0 | 27.0 | 0.0 |
| PBM | 0.0 | 0.0 | 30.0 | 0.0 | 0.0 |
| HSM | 0.0 | 20.0 | 0.0 | 0.0 | 0.0 |
| CM | 0.0 | 0.0 | 0.0 | 20.0 | 0.0 |
| Red wheat flour (mids) | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Corn meal | 8.2 | 4.2 | 18.2 | 4.2 | 19.2 |
| Menhaden fish oil | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 |
| Vitamin and mineral mix ^a | 1.95 | 1.95 | 1.95 | 1.95 | 1.95 |
| Monocalcium phosphate | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Ascorbic acid (Stay-C) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Choline chloride | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| <i>Analyzed composition (dry matter basis)</i> | | | | | |
| Moisture (%) | 7.7 | 8.8 | 8.3 | 8.8 | 10.5 |
| Crude protein (%) | 43.8 | 40.0 | 42.5 | 41.7 | 41.8 |
| Crude lipid (%) | 5.9 | 6.0 | 6.0 | 5.8 | 4.1 |
| Fiber (%) | 2.1 | 6.5 | 2.1 | 4.3 | 1.8 |
| Ash (%) | 13.0 | 11.4 | 8.3 | 12.1 | 9.1 |
| NFE ^b | 35.5 | 36.1 | 41.1 | 36.1 | 43.2 |
| Available energy ^c | 3.69 | 3.58 | 3.88 | 3.63 | 3.77 |
| E:P ^d | 8.42 | 8.95 | 9.13 | 8.71 | 9.02 |

^aMineral 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; B₁₂, 0.06 mg; E (as alpha-tocopheryl acetate), 50 IU; folic acid, 16.5 mg; myo-inositol, 132 mg; K (as menadione sodium bisulfate complex), 9.2 mg; niacin, 221 mg; pantothenic acid, 106 mg; B₆, 31 mg; riboflavin, 53 mg; thiamin, 43 mg; D₃, 440 IU; A (as vitamin A palmitate), 4399 IU; ethoxyquin, 99 mg.

^bNFE = nitrogen-free extract.

^cAvailable energy was calculated as 4.0, 4.0, and 9.0 kcal/g of protein, carbohydrate, and lipid, respectively.

^dEnergy-to-protein ratio.

Karnes City, TX). This filter system removed particulate material and provided substrate for *Nitrosomonas* and *Nitrobacter* bacteria. Continuous aeration was provided by a blower and airstones. Water exchange rate for 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 4 l/min and cleaned daily to remove uneaten feed and feces. All aquaria sides and back were covered in black plastic to minimize disturbances which resulted when personnel were present in the laboratory. Continuous illumination was supplied by fluorescent ceiling lights.

Water temperature and dissolved oxygen were measured every other day using a YSI Model 58 oxygen meter (YSI Industries, Yellow Springs, OH). Total ammonia and

Table 2

Amino acid composition of practical diets fed to sunshine bass

Values are percentage of the diet, except where indicated in parentheses, which are percentage of dietary protein.

| Amino acid | Requirement ^a | Diet number | | | | |
|---------------|--------------------------|-------------|------------|------------|------------|------------|
| | | 1 | 2 | 3 | 4 | 5 |
| Alanine | | 2.20 | 1.88 | 2.01 | 1.99 | 1.85 |
| Arginine | 1.55 (4.4) | 2.60 (5.9) | 2.57 (6.4) | 2.51 (5.9) | 2.39 (5.7) | 2.28 (5.5) |
| Aspartic acid | | 3.86 | 3.55 | 3.79 | 3.57 | 3.64 |
| Cystine | | 0.40 | 0.38 | 0.52 | 0.46 | 0.57 |
| Glutamic acid | | 6.28 | 5.78 | 6.19 | 6.17 | 5.87 |
| Glycine | | 3.06 | 2.56 | 2.52 | 2.73 | 2.02 |
| Histidine | | 0.88 | 0.79 | 0.83 | 0.85 | 0.84 |
| Isoleucine | | 1.44 | 1.32 | 1.55 | 1.37 | 1.55 |
| Leucine | | 2.74 | 2.43 | 2.79 | 2.57 | 2.75 |
| Lysine | 1.41 (4.0) | 2.17 (5.0) | 1.82 (4.6) | 2.14 (5.0) | 2.03 (4.9) | 2.07 (5.0) |
| Methionine | | 0.55 | 0.56 | 0.66 | 0.57 | 0.67 |
| TSAA | 0.73 (2.1) 1.00 (2.9) | 0.95 (2.2) | 0.94 (2.4) | 1.18 (2.8) | 1.03 (2.5) | 1.24 (3.0) |
| Phenylalanine | | 1.63 | 1.52 | 1.67 | 1.52 | 1.65 |
| Proline | | 2.56 | 2.16 | 2.31 | 2.47 | 2.24 |
| Serine | | 1.83 | 1.66 | 1.89 | 1.71 | 2.06 |
| Threonine | 0.9 (2.6) | 1.49 (3.4) | 1.32 (3.3) | 1.55 (3.7) | 1.46 (3.5) | 1.55 (3.7) |
| Tyrosine | | 0.97 | 0.85 | 0.99 | 0.92 | 0.94 |
| Valine | | 1.80 | 1.64 | 1.84 | 1.74 | 1.88 |

^aWebster (1998).

nitrite were measured three times weekly using a DREL 2000 spectrophotometer (Hach, Loveland, CO). Total alkalinity and chloride were monitored three times 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, OH). Over the duration of the study, these water quality parameters averaged (\pm SD): water temperature, $27.4 \pm 0.9^\circ\text{C}$; dissolved oxygen, 6.6 ± 0.5 mg/l; total ammonia nitrogen, 0.33 ± 0.19 mg/l; nitrite, 0.065 ± 0.117 mg/l; alkalinity, 109 ± 41 mg/l; chlorides, 103 ± 19 mg/l; pH, 8.1 ± 0.2 . During the study, these averages were within acceptable limits for fish growth and health (Boyd, 1979; Mazik et al., 1991).

Juvenile sunshine bass (*M. chrysops* \times *M. saxatilis*) were purchased from a commercial supplier (Keo Fish Farm, Keo, AR) and had an average weight (\pm SE) of 20.4 ± 2.6 g. Ten fish were randomly stocked into each aquarium with four replications per treatment. After stocking, to eliminate stress of handling, fish were not weighed for the duration of the feeding trial. To ensure that all fish had equal opportunity to eat all they could consume, all fish were fed the same amount of diet as the fish in the aquarium consuming the most food for that particular feeding in each treatment. Fish were fed twice daily (0730 and 1600 h) for 10 weeks. At the conclusion of the feeding trial, three fish were randomly sampled, killed by lowering the body temperature in a freezer, whole body weight was measured to the nearest 0.01 g, abdominal fat was gently teased away from the connective tissue and weighed, the liver was removed and weighed, and

the fillets were removed from the backbone and skin and weighed. Fillets from these three fish, from each aquarium, were homogenized in a blender, stored in polyethylene bags, and frozen for subsequent protein, lipid, 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 has been achieved (AOAC, 1990).

Growth performance, feed conversion, and body analysis were measured in terms of percentage weight gain, survival (%), specific growth rate (SGR, %/day), feed conversion ratio (FCR), percentage abdominal fat, percentage fillet weight, and hepatosomatic index (HSI). Growth response parameters were calculated as follows: $SGR (\%/day) = ((\ln W_t - \ln W_i)/T) \times 100$ 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; $FCR = \text{total dry feed fed (g)}/\text{total wet weight gain (g)}$; and $HSI = \text{wet weight liver (g)}/\text{wet weight fish (g)} \times 100$.

2.3. Statistical analysis

Data were analyzed by analysis of variance (ANOVA) using the Statistix Version 4.1 (Analytical Software, 1994) for significant differences among treatment means. The least significant difference (LSD) 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.

3. Results

The percentage weight gain of sunshine bass fed Diet 1 (35% SBM and 35% meat-and-bone meal, MBM) was significantly ($P < 0.05$) higher (299%) compared to

Table 3

Percentage weight gain, SGR, percentage survival, amount of diet fed, FCR, percentage of abdominal fat, percentage fillet, and HSI of juvenile sunshine bass fed practical diets^w

| | Diet number | | | | |
|-------------------|----------------------------|----------------------------|--------------------------|----------------------------|----------------------------|
| | 1 | 2 | 3 | 4 | 5 |
| Weight gain (%) | 299 ± 26 ^a | 251 ± 9 ^{a,b} | 197 ± 36 ^b | 226 ± 15 ^b | 251 ± 21 ^{a,b} |
| SGR ^x | 1.97 ± 0.09 ^a | 1.79 ± 0.03 ^{a,b} | 1.52 ± 0.20 ^b | 1.68 ± 0.07 ^{a,b} | 1.79 ± 0.09 ^{a,b} |
| Survival (%) | 100 ± 0.0 | 95.0 ± 2.9 | 90.0 ± 4.1 | 92.5 ± 4.8 | 97.5 ± 2.5 |
| Diet fed (g/fish) | 108.3 ± 2.2 | 105.9 ± 3.6 | 108.1 ± 9.4 | 122.1 ± 10.7 | 109.9 ± 7.1 |
| FCR ^y | 1.97 ± 0.10 ^b | 2.24 ± 0.21 ^b | 2.71 ± 0.05 ^a | 2.88 ± 0.13 ^a | 2.00 ± 0.02 ^b |
| Abdominal fat (%) | 5.04 ± 0.35 ^{a,b} | 4.69 ± 0.42 ^{a,b} | 5.49 ± 0.45 ^a | 4.29 ± 0.31 ^b | 4.67 ± 0.47 ^{a,b} |
| Fillet (%) | 23.41 ± 0.83 | 21.83 ± 0.74 | 23.14 ± 0.89 | 21.58 ± 1.28 | 23.82 ± 1.11 |
| HSI ^z | 2.15 ± 0.15 | 2.07 ± 0.16 | 2.08 ± 0.22 | 1.77 ± 0.24 | 2.13 ± 0.13 |

^w Values are means ± SE for four replications. Means within a row having different letters were significantly different ($P < 0.05$).

^x Specific growth rate (%/day) = $100 \times [(\ln W_t - \ln W_i)]/\text{day}$.

^y FCR = total diet fed (g)/total wet weight gain (g).

^z HSI = liver weight (g)/whole body weight (g) × 100.

Table 4
 Fillet composition of juvenile sunshine bass fed practical diets^a

| | Diet number | | | | |
|--------------------------|--------------|--------------|--------------|--------------|--------------|
| | 1 | 2 | 3 | 4 | 5 |
| Moisture (%) | 23.92 ± 0.24 | 24.67 ± 0.30 | 23.55 ± 0.42 | 23.22 ± 0.74 | 23.95 ± 0.54 |
| Protein (%) ^b | 19.94 ± 0.32 | 20.01 ± 0.43 | 19.42 ± 0.22 | 19.05 ± 0.28 | 19.51 ± 0.65 |
| Lipid (%) ^b | 2.04 ± 0.51 | 2.27 ± 0.55 | 1.85 ± 0.08 | 1.54 ± 0.20 | 2.43 ± 0.78 |

^aValues are means ± SE for four replications. There were no significant differences ($P > 0.05$) in percentage moisture, protein and lipid among treatments.

^bWet weight basis.

fish fed Diets 3 (30% SBM and 30% PBM) and 4 (27% SBM and 27% MBM, and 20% CM), but not different from fish fed Diets 2 (27% SBM, 27% MBM, 20% HSM) and 5 (30% SBM, 30% FM) (Table 3). SGR of fish fed Diet 1 was significantly higher (1.97%/day) compared to fish fed Diet 3 (1.52%/day), but not different from fish fed all other diets. Percentage survival was not significantly different among all treatments and averaged 95%.

The average amount of diet fed per fish was not significantly different among treatments and averaged 111 g/fish for the duration of the study. However, FCRs of fish fed Diets 3 and 4 were significantly higher (2.71 and 2.88, respectively) compared to fish fed the other three diets (Table 3).

The percentage of whole body weight of abdominal fat in sunshine bass fed Diet 3 was significantly higher (5.5%) than for fish fed Diet 4 (4.3%), but not significantly different from fish fed all other diets (Table 3). Percentage fillet of sunshine bass fed all diets was not significantly different among treatments and averaged 22.7% of body weight. HSI was not significantly different among all treatments and averaged 2.04% of whole body weight.

There were no significant differences in percentage moisture, percentage protein (wet weight basis), and percentage lipid (wet weight basis) of fillets among any treatment and these values averaged 23.86%, 19.59%, and 2.03%, respectively (Table 4).

4. Discussion

In the present study, individual weight, percentage weight gain, and SGR of sunshine bass fed a diet containing SBM and MBM (Diet 1) and a diet with SBM, MBM, and HSM (Diet 2), both without FM, were similar to those of fish fed a diet with 30% FM. This may allow for less expensive diet formulations for sunshine bass and may reduce diet costs for producers, thereby increasing profitability. As production of hybrid striped bass has increased during the past 10 years, producers have seen the price paid per kilogram decrease from US\$6.00 in 1993 to approximately US\$5.00/kg in 1999. However, while producers have received less money for their product, diet costs have not decreased, thereby reducing producer's profits for their fish. It has been estimated

that for every decrease (or increase) of 10% in the cost of diet, net returns to producers increase (or decrease) by approximately US\$250/acre (Dunning, 1998). One factor for the continued expansion of the hybrid striped bass industry is to reduce diet costs, and one means to accomplish this goal is to reduce FM usage since it is one of the most expensive ingredients in an aquaculture diet.

Information on numerous aspects of the nutritional requirements of juvenile hybrid striped bass have been described and it appears that all diets used in the present study met requirements (Webster, 1998). SBM can partially replace FM in some aquaculture diets. 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 (1997) 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.

The 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, 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, the growth of sunshine bass fed a diet containing 27% SBM, 27% MBM, and 20% HSM had similar weight gain as fish fed the control diet. HSM is the meal after the oil has been pressed and is fairly high in protein (> 35%) and has a moderate lipid level (10–15%). However, hemp is currently illegal to grow in some countries and the meal has to be imported, which makes the price of the ingredient prohibitively high. It is unclear why growth of sunshine bass fed a diet with PBM or CM was not similar to that of fish fed a diet with 30% FM. Diets with PBM and CM were similar in chemical composition and proximate analyses as the other diets used in the feeding trial. Webster et al. (1999) reported that sunshine bass fed a diet with PBM, and a formulation similar to the diet used in the present study, had similar growth to fish fed a control diet.

It may be that a different source of PBM was used in the present study. Different sources of ingredients may have varied nutrient compositions, processing methods, different amounts of constituents (bone, offal, meat, blood, etc.), and digestibility. Dong et al. (1993) found differences in proximate composition and protein digestibility among samples of PBM from different manufacturers that varied from reported tabular values (NRC, 1993). However, the diet appeared to meet nutrient requirements of sunshine bass. A second plausible reason for the reduced weight gains of sunshine bass fed diets containing PBM and CM could be that the sunshine bass did not initially find the diets palatable. Larger fish were used in the present study and may have been fed diets with a

high percentage of FM. When the feeding trial began, fish may have not consumed Diets 3 and 4 as readily as the others and thus, did not increase their weight as rapidly as fish fed the other diets.

Percentage weight gain, SGR, and FCR in the present study were similar to those reported in other studies (Hughes et al., 1992; Nematipour et al., 1992; Webster et al., 1995; 1997; 1999; Keembiyehetty and Gatlin, 1997). SGR in the present study may have been somewhat lower than some studies due to stocking of larger fish. FCR for some of the diets used in the present study may have been somewhat higher than in some studies due to overfeeding or the diets may not have been as palatable as some of the other diets used in this study. It is felt that overfeeding is preferable to underfeeding when evaluating practical diets fed to fish in aquaria because overfeeding ensures that growth data will be accurate and not be biased by a lack of a sufficient quantity of diet to achieve optimal growth.

The percentage of abdominal fat and HSI of sunshine bass in the present study were similar to reported values. Nematipour et al. (1992) reported that abdominal fat comprised between 3.5% and 6.4% of whole body weight and HSI to be between 1.5% and 3.4%. Keembiyehetty and Gatlin (1997) reported abdominal fat in sunshine bass to comprise between 4% and 5% of body weight and HSI to be 1.5%. Keembiyehetty and Wilson (1998) reported abdominal fat values of between 3.1% and 7.2% in sunshine bass fed diets containing various protein:energy ratios, while HSI was reported between 2.4% and 4.6%.

The percentage fillet of sunshine bass in the present study was lower (22.7%) than other reports, probably due to differences in techniques of obtaining fillets used in the various studies. Nematipour et al. (1992) reported that percentage fillet weight was between 40% and 45% of whole body weight, while Gallagher (1994) reported a fillet weight of 34%. In the latter study, larger (100–150 g) palmetto bass were used. In the present study, while the values for percentage fillet weight may be lower than some reports, the same individual filleted all fish so there should be no variation in terms of technique used and portion of muscle obtained for the fillet. Proximate composition of fillets of sunshine bass fed practical diets in the present study was not different and was in agreement with Zhang et al. (1994), who reported that fillets of palmetto bass had 82% protein (dry matter basis) and 10% lipid (dry matter basis).

It appears that sunshine bass can utilize practical diets without FM if TSAA levels are 0.89% of the diet (2.2% of dietary protein) and the fish consume the diet readily. While sunshine bass fed a diet with 20% HSM, SBM, and MBM had similar growth and body composition compared to fish fed a diet with 30% FM, the current price of HSM does not allow for its use in aquaculture diets in the US. If the price is reduced to be competitive with other plant protein sources, HSM appears to be a suitable ingredient for use in sunshine bass diets.

Acknowledgements

We would like to thank Rob Jones, of Jones' Fish Hatcheries, Newtown, OH for transporting the sunshine bass; Madison Hemp and Flax 1806, Lexington, KY for donation of the HSM, Ebony Grisby, Kentale Morris, and B.R. Lee for technical

assistance; and Ebony Grisby for typing this manuscript. This study was partially funded by a grant from the USDA/CSRS grant to KY State University under agreement KYX-80-96-07A.

References

- Analytical Software, 1994. Statistix User's Guide. Version 4.1. Analytical Software, Tallahassee, FL.
- AOAC, 1990. Official Methods of Analysis of the Association of Official Analytical Chemists. 15th edn. AOAC, Arlington, VA.
- Boyd, C.E., 1979. Water Quality in Warmwater Fish Ponds. Auburn University Agricultural Experiment Station, Auburn, AL.
- Brown, P.B., Twibell, R., Jonker, Y., Wilson, K.A., 1997. Evaluation of three soybean products in dits fed to juvenile hybrid striped bass *Morone saxatilis* × *M. chrysops*. J. World Aquacult. Soc. 28, 215–223.
- Dong, F.M., Hardy, R.W., Haard, N.F., Barrows, F.T., Rasco, B.A., Fairgrieve, W.T., Forster, I.P., 1993. Chemical composition and protein digestibility of poultry by-product meals for salmonid diets. Aquaculture 116, 149–158.
- Dunning, R., 1998. Aquaculture in North Carolina. Hybrid Striped Bass: Inputs, Outputs, and Economics. North Carolina Department of Agriculture, Plymouth, NC.
- Fowler, L.G., 1981. Tests of vegetable protein replacements and alternate ingredients in Abernathy diet. Abernathy Salmon Cultural Development Center Tech. Transfer Ser. No. 81-1, 14 pp.
- Fowler, L.G., 1991. Poultry by-product meal as a dietary protein source in full chinook salmon diets. Aquaculture 99, 309–321.
- Gallagher, M.L., 1994. The use of soybean meal as a replacement for fish meal in diets for hybrid striped bass (*Morone saxatilis* × *M. chrysops*). Aquaculture 126, 114–127.
- Gallagher, M.L., LaDouceur, M., 1995. The use of blood meal and poultry products as partial replacements for fish meal in diets for juvenile palmetto bass (*Morone saxatilis* × *M. chrysops*). J. Appl. Aquacult. 5 (3), 57–65.
- Garling, D.L., Wilson, R.P., 1977. Effect of dietary carbohydrate on growth and body composition of fingerling channel catfish. Prog. Fish-Cult. 39, 43–47.
- Higgs, D.A., Fagerlund, U.H.M., McBride, J.R., Plotnikoff, M.D., Dosanjh, B.S., Markert, J.R., Davidson, J., 1983. Protein quality of Altex canola meal for chinook salmon (*Oncorhynchus tshawytscha*) considering dietary protein and 3, 5, 3"-triiodo-L-thyronine content. Aquaculture 34, 213–238.
- Higgs, D.A., McBride, J.R., Dosanjh, B.S., Fagerlund, U.H.M., 1990. Potential for using canola meal and oil in fish diets. In: Fish Physiology, Fish Toxicology, and Fisheries Management. Ryans, R.C. (Ed.), Proc. Intl. Symp. Guangzhou, Chinapp. 88–107.
- Hughes, S.G., Lemm, C.A., Herman, R.L., 1992. Development of a practical diet for juvenile striped bass. Trans. Am. Fish. Soc. 121, 802–809.
- Keembiyehetty, C.N., Gatlin, D.M., 1997. Performance of sunshine bass fed soybean meal based diets supplemented with different methionine compounds. Prog. Fish-Cult. 59, 25–30.
- Keembiyehetty, C.N., Wilson, R.P., 1998. Effect of water temperature on growth and nutrient utilization on sunshine bass (*Morone chrysops* × *M. saxatilis*) fed diets containing different energy/protein ratios. Aquaculture 166, 151–162.
- Krogdahl, A., 1989. Alternative protein sources from plants contain antinutrients affecting digestion in salmonids. In: Takeda, M., Watanabe, T. (Eds.), Proc. Of the 3rd Intl. Symp. on Feeding and Nutrition in Fish, Laboratory of Fish Nutrition, Tokyo University of Fisheries, Tokyo, Japan. pp. 253–261.
- Lovell, R.T., 1988. Use of soybean products in diets for aquaculture species. J. Aquat. Prod. 2, 27–52.
- Mazik, P.M., Hinman, M.L., Winkleman, D.A., Kleine, S.J., Simco, B.A., 1991. Influence of nitrite and chloride concentrations on survival and hematological profiles of striped bass. Trans. Am. Fish. Soc. 120, 247–254.
- McCurdy, S.M., March, B.E., 1992. Processing of canola meal for incorporation in trout and salmon diets. J. Am. Oil Chem. Soc. 69, 213–220.

- Mohsen, A.A., Lovell, R.T., 1990. Partial substitution of soybean meal with animal protein sources in diets for channel catfish. *Aquaculture* 90, 303–311.
- Nematipour, G.R., Brown, M.L., Gatlin, D.M., 1992. Effects of dietary energy:protein ratio on growth characteristics and body composition of hybrid striped bass *Morone chrysops* × *M. saxatilis*. *Aquaculture* 107, 359–368.
- NRC, 1993. *Nutrient Requirements of Fish*. National Academy Press, Washington, DC.
- Perrone, S.J., Meade, T.L., 1977. Protective effect of chloride on nitrite toxicity to coho salmon (*Oncorhynchus kisutch*). *J. Fish Res. Board Can.* 34, 486–492.
- Webster, C.D., 1998. Feeding hybrid striped bass. In: Lovell, T. (Ed.), *Nutrition and Feeding of Fish*. 2nd edn. Kluwer Academic Publishing, Boston, MA, pp. 199–214.
- Webster, C.D., Tiu, L.G., Morgan, A.M., Gannam, A.L., 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. *J. World Aquacult. Soc.* 30, 443–453.
- Webster, C.D., Tiu, L.G., Tidwell, J.H., 1997. Effects of replacing fish meal in diets on growth and body composition of palmetto bass (*Morone saxatilis* × *M. chrysops*) raised in cages. *J. Appl. Aquacult.* 7 (1), 53–67.
- Webster, C.D., Tiu, L.G., Tidwell, J.H., Van Wyk, P., Howerton, R.D., 1995. Effects of dietary protein and lipid levels on growth and body composition of sunshine bass (*Morone chrysops* × *M. saxatilis*) reared in cages. *Aquaculture* 131, 291–301.
- Zar, J.H., 1984. *Biostatistical Analysis*. Prentice-Hall, Englewood Cliff, NJ.
- Zhang, Q., Reigh, R.C., Wolters, W.R., 1994. Growth and body composition of pond-raised hybrid striped basses, *Morone saxatilis* × *M. chrysops* and *M. saxatilis* × *M. mississippiensis*, fed low and moderate levels of dietary lipid. *Aquaculture* 125, 119–129.