FINAL REPORT Final Report Submission Date: September 20, 2001

Submitted to: FATS AND PROTEIN RESEARCH FOUNDATION, INC.
RR #2 Box 298
BLOOMINGTON, IL 61704

Project Title: Use of Meat and Bone Meal in Diets fed to Hybrid Striped Bass

Investigator: Dr. P. B. Brown
Purdue University
1159-Forestry Building
West Lafayette, IN 47907-1159
765-494-4968
765-496-2422 (FAX)
pb@fnr.purdue.edu

Project Started: July 1, 2000 Project Completed: June 30, 2001

Industry Summary

Introduction

If we want to eat fish in the future, we must grow them. Commercial harvest from the oceans of the world has not increased significantly since 1989 and is unlikely to exceed the 80 mmt currently harvested. According to the United Nations Food and Agriculture Organization, just to keep pace with population growth, we need to produce 40 mmt of new aquaculture production by 2035. If per capita consumption of fish and shellfish increases by 1% per year, then new production must be over 100 mmt in the same time period. In 1995, global swine production was 83 mmt and global chicken production was 46 mmt. Thus, it appears that significant new industries are poised for rapid growth in the 21^{st} century. Increases in animal production of this magnitude increase demand for high-quality feedstuffs. Fish require comparatively high levels of crude protein in diets; thus, the protein feedstuffs are critical for realization of this new growth.

The hybrid striped bass is one of the new aquacultural production industries in the US and one of the most rapidly growing. Further, production is located across the country, not centered in any particular region. However, dietary formulations are not standardized and significant opportunities exist for evaluation of new feedstuffs and realizing incorporation into production diets. In this study, we will build upon our previous research with this new hybrid and continue development of diets specifically for the hybrid striped bass.

Detailed nutritional research with the hybrid striped bass began in the late 1980's. To date, nutritional requirements for lysine, arginine, methionine, choline, and phosphorus have been quantified. Further, estimates of the remaining essential amino acids are available and have been found appropriate. Given several of the critical nutritional requirements for this hybrid, practical diets were developed and are currently available. Additionally, this level of knowledge provided for meaningful evaluations of protein feedstuffs in practical diets fed to this hybrid. To date, only soy products have been evaluated.

Objectives

Evaluate meat and bone meal in diets fed to hybrid striped bass by incorporating the ingredient in graded levels into a practical diet.

Industry Summary

Mean consumption of diets containing meat and bone meal was higher than consumption of the control diet containing no meat and bone meal and weight gain was also higher in all treatments containing meat and bone meal compared to the control. Feed conversion ratio was lower in all but one treatment fed meat and bone meal and protein efficiency ratios were higher in all but one treatment. Meat and bone meal exerted no significant effects on lipid accumulation in the body cavity or liver. Additionally, fillet composition was not affected by meat and bone meal in the diet. Apparent crude protein digestibility and apparent phosphorus and amino acid availabilities were lower in fish fed the highest level of meat and bone meal (45% of diet) compared to fish fed all other diets, but there were no differences in nutrient availability in fish fed 15, 20, 25, 30, 35 or 40% of the diet as meat and bone meal compared to fish fed the control diet. These data clearly indicate that meat and bone meal can be used as the primary source of crude protein and essential amino acids in diets fed to hybrid striped bass. Using the highest level of incorporation, changes in dietary formulation could reduce feed prices by 20% if feed manufacturers used meat and bone meal.

Scientific Abstract

We fed juvenile hybrid striped bass one of eight diets to evaluate meat and bone meal as a source of crude protein and essential amino acids. Diets contained either 0, 15, 20, 25, 30, 35, 40 or 45% meat and bone meal substituted for an isonitrogenous amount of soybean meal and fish meal. All diets were fed for a seven week growth trial which was followed by a 2-week digestibility trial. Mean consumption, weight gain and feed conversion ratio were not significantly affected by addition of meat and bone meal into diets. Intraperitoneal and liver lipid concentrations were not significantly affected by meat and bone meal. Fillet proximate composition was not significantly different among treatments. Apparent crude protein, phosphorus and amino acid availabilities were generally lower in fish fed the highest level of meat and bone meal, but those values were not significantly different in other dietary treatments. Based on these data, it appears meat and bone meal can be used as the primary source of crude protein and essential amino acids in practical growout diets for hybrid striped bass.

Key Words: hybrid striped bass, meat and bone meal, crude protein digestibility, amino acid availability

Introduction

If we want to eat fish in the future, we must grow them. Commercial harvest from the oceans of the world has not increased significantly since 1989 and is unlikely to exceed the 80 mmt currently harvested (New 1997). According to the United Nations Food and Agriculture Organization, just to keep pace with population growth, we need to produce 40 mmt of new aquaculture production by 2035 (New 1997). If per capita consumption of fish and shellfish increases by 1% per year, then new production must be over 100 mmt in the same time period. In 1995, global swine production was 83 mmt and global chicken production was 46 mmt. Thus, it appears that significant new industries are poised for rapid growth in the 21st century. Increases in animal production of this magnitude increase demand for high-quality feedstuffs. Fish require comparatively high levels of crude protein in diets; thus, the protein feedstuffs are critical for realization of this new growth.

The hybrid striped bass is one of the new aquacultural production industries in the US and one of the most rapidly growing. Further, production is located across the country, not centered in any particular region. However, dietary formulations are not standardized and significant opportunities exist for evaluation of new feedstuffs and realizing incorporation into production diets. In this study, we will build upon our previous research with this new hybrid and continue development of diets specifically for the hybrid striped bass.

The hybrid striped bass is a cross between the freshwater white bass (Morone chrysops) and the saltwater striped bass (M. saxatilis). Females of both species have been used in the crosses, with the striped bass female x white bass male considered the original hybrid. More recently, the white bass female x striped bass male has been used to make the crosses and that reciprocal hybrid is now the more commonly cultured of the two crosses.

The hybrid was initially developed as a sport fish in the southeastern US (Kerby 1986; 1993). The hybrid was desirable because it grew faster than either parent in the first 2-3 years of life. However, shortly after development and initial stocking into reservoirs, the striped bass was declared rare and endangered. The striped bass fishery along the East Coast supported both a recreational and commercial fishery and both were curtailed during the late 1970's through early 1990's. Since then, wild populations rebounded to levels that support a reduced recreational harvest. Because of the loss of supply and stable, if not increasing demand, aquaculture of hybrid striped bass began in the 1970s and has steadily grown since then. According to the first census of aquaculture in the US, culture of hybrid striped bass totaled $28 million is sales in 1998, producing approximately 9 million pounds of food size fish and 27 million juvenile fish. Culture of this hybrid is clearly one of the most rapidly growing new aquaculture industries in the US and the one in which meat and bone meals have not been evaluated.

Detailed nutritional research with the hybrid striped bass began in the late 1980's. To date, nutritional requirements for lysine, arginine, methionine, choline, and phosphorus have been quantified. Further, estimates of the remaining essential amino acids are available (Brown, 1995) and have been found appropriate (unpublished data from our laboratory). Given several of the critical nutritional requirements for this hybrid, practical diets were developed and are currently available. Additionally, this level of knowledge provided for meaningful evaluations of protein feedstuffs in practical diets fed to this hybrid (Twibell et al., 1998). To date, only soy products have been evaluated. Also, some level of fish meal is considered important in practical diets as a flavor component (Brown et al., 1993; Webster et al., 1997). It is important to note that before development of several of the critical nutritional requirements for this hybrid, practical dietary evaluations were conducted with selected feedstuffs, yet responses were not consistent with graded levels of incorporation of the test feedstuff into diets (Gallagher 1992).

Experimental Procedures

Meat and bone meal (33% beef, 29% pork and 38% poultry; 38% offal, 8% bone, 12% trimming and 42% deadstock) was supplied by Fats and Protein Research Foundation Inc. (Bloomington, IL). Proximate analyses of the meat and bone meal is presented in Table 1. Soybean meal, corn grain and dicalcium phosphate were obtained from local sources (Cargill, Inc., Lafayette, IN). Menhaden oil and reagent grade minerals were obtained from commercial suppliers (Omega Protein, Reedville,VA and Sigma Chemical, St. Louis, MO, respectively). Vitamins were acquired from U.S. Biochemical (Cleveland, OH). L-ascorbyl 2-polyphosphate was obtained from Roche Inc. (Nutley, NJ). Purified soybean lecithin, containing 90% phosphatidylcholine and 3% lysophosphatidylcholine, was provided by the American Lecithin Company (Oxford, CT). Vitamins (with the exception of ascorbic acid and choline chloride) and minerals were added to the diets as nutritionally complete premixes. Diets were mixed and pelleted as previously reported (Twibell et al., 2000).

Proximate composition and amino acid concentrations of meat and bone meal, soybean meal, corn grain and fish meal were analyzed prior to dietary formulation by standard methods (AOAC 1990; Folch et al. 1957). All diets were formulated to contain 44% crude protein and 10% lipid. Additionally, all diets met the established and predicted essential amino acid requirements for this hybrid (Brown 1995). Dietary formulations are in Table 2.

Juvenile hybrid striped bass (Morone chrysops x M. saxatilis) were obtained from a commercial producer (Keo Fish Farms, Keo, AR) and transported to the Purdue University Aquaculture Research Facility. Procedures used during transport, quarantine and experimental period were approved by the Purdue Animal Care and Use Committee (PACUC No. 89-060-98, "Nutritional Studies with Aquatic Animals," Principal Investigator Qualification No. BRO-249).

The closed recirculating system used contained 24 individual 38-L aquaria. The experimental system was equipped with two submerged filtration tanks for solid material removal and denitrification of the water. Water was pumped through a sand filter to each aquarium at a rate of ~1 L/min. Water temperature was maintained at 28 ± 2°C throughout the experiments. The diurnal light:dark cycle of the aquaculture facility remained at 16 h light:8 h dark throughout the study.

Groups of 15 randomly chosen fish were stocked into each of 24 aquaria. Fish were acclimated to the experimental system and their respective diets for 2 wk prior to each experiment. Following the acclimation period, the number of fish in each tank was reduced to 10 so that the total weight of fish in each tank was 550 ± 8.0 g. Dietary treatments were randomly assigned to triplicate aquaria. All fish were fed to satiation. The experiment lasted 7 wk.

Water quality was monitored daily and was within acceptable limits throughout the study. Dissolved oxygen concentrations were not below 5.0 mg/L at any time. Ammonia-N and nitrite-N concentrations did not exceed 0.38 mg/L and 0.18 mg/L, respectively.

At the conclusion of the experiment, all fish were anesthetized (tricaine methanesulfonate, Argent Chemical, Redmond, WA) and weighed 24 h after the final feeding. Weight gain, feed efficiency (FE) and survival were determined. All fish were then placed back into their respective aquaria. All fish were fed for an additional two weeks. Diets fed during this period were the same as those used during the 7-wk growth trial, but each diet contained 0.5% barium carbonate as an indicator of nutrient availability (Riche et al. 1995). At the end of the 2-wk digestibility trial, all fish were euthanized and fecal samples collected from the posterior 10% of the gastrointestinal tract by dissection. Additionally, various tissue samples were collected.

Three randomly chosen fish were collected from each dietary replicate and frozen at -20°C for subsequent determination of carcass and fillet proximate composition. Visceral fat was dissected from those fish for calculation of intraperitoneal fat (IPF) ratio (IPF x 100/body weight), livers were removed and weighed, then stored at –20C for subsequent lipid determinations.

All data were analyzed as a completely randomized design using each aquarium as an experimental unit. Data were subjected to one-way ANOVA. All data were analyzed using the Statistical Analysis System (SAS Institute Inc., Cary, NC). Student-Newman-Keuls test separated mean values when significant differences were detected by ANOVA. Accepted level of significance was 0.05.

Results

Mean consumption of the diet containing 30% meat and bone meal (MBM) was significantly higher than mean consumption of the control diet or the diet containing 20% MBM (Table 3). No other significant differences were detected. Mean weight gain of fish fed the control diet was significantly lower than fish fed any level of MBM. Weight gains of fish fed the diets containing MBM were not significantly different. Feed conversion ratio of fish fed 30% MBM was significantly higher than in fish fed 20% MBM, but other values were not significantly different. Protein efficiency ratios were not significantly different among dietary treatments. Mean intraperitoneal fat, hepatosomatic indices and liver lipid concentrations were not significantly affected by dietary additions of MBM (Table 4). Similarly, proximate composition of whole bodies (Table 5) and fillet samples from dietary treatments were not significantly different (Table 6).

Apparent crude protein digestibility in fish fed 45% MBM was significantly lower than in fish fed other dietary treatments (Table 7). No other significant differences were detected. Apparent phosphorus availability values were not significantly affected by addition of MBM to practical diets. Apparent availability of all amino acids was significantly lower in fish fed 45% MBM compared to fish fed other treatments (Table 8). No other significant differences were detected.

Discussion

Whole animal responses were not significantly affected by feeding MBM up to 45% of the dry diet. Those diets contained 27% soybean meal and 2.75% fish meal compared to the control diet that contained 54% soybean meal and 16% fish meal. Thus, it appears MBM can be used as the primary source of crude protein and essential amino acids in diets fed to hybrid striped bass. It is unclear if higher levels of MBM can be used or if MBM can serve as the sole source of crude protein and essential amino acids. However, it is clear the hybrid striped bass grows maximally when fed high levels of MBM.

MBM has been identified as an appropriate ingredient in diets fed to Nile tilapia (Wu et al., 1999; El-Sayed, 1998), Indian carp (Paul et al., 1997), African catfish (Rao et al. 1997), yellowtail (Shimeno et al., 1993), channel catfish (Mohsen and Lovell, 1990), milkfish (Alava and Lim, 1988) and rainbow trout (Rehulka, 1985). However, most of these evaluations incorporated MBM at relatively low levels in the diet (6-12% of dry diet), or were simply a complete replacement of fish meal with MBM (El-Sayed, 1998). Bureau et al. (2000) fed either 12 or 24% of the diet as MBM and reported no significant differences in weight gain, feed efficiency or retention of nitrogen, lipid or energy in fish fed either of 3 sources of MBM compared to fish fed a control diet. Kikuchi et al. (1997) evaluated MBM levels of 9, 18, 36 or 44% of the diet and determined that levels up to 18% were efficacious in diets fed to Japanese flounder. Robaina et al. (1997) determined that MBM could be safely used in diets for gilthead seabream at levels of 20% of the dietary protein. Additionally, feed efficiency and protein efficiency ratio of fish fed 20% of the protein as MBM were higher than in fish fed the control diet. Tacon et al. (1983) determined that MBM could be used in place of 75% of the dietary crude protein in diets fed to Nile tilapia. Channel catfish consumed more feed, converted that food to tissue better, and gained more weight than catfish fed no MBM (Mohsen and Lovell, 1990). However, dietary concentrations of 5 and 10% of the dietary crude protein were the only levels evaluated. Thus, it is clear the hybrid striped bass can utilize MBM as efficiently as any other species tested to date, more efficiently than those evaluated in a systematic manner.

Processing characteristics of hybrid striped bass fed MBM were not significantly affected. There were no significant increases in visceral lipid deposits or liver weight that would decrease dressout percentage. Further, liver health does not appear to have been impacted as liver lipid concentrations were not significantly altered as dietary MBM increased in the diet. Carcass and fillet proximate composition were not significantly affected by dietary treatments; thus, the nutritional benefits of consuming hybrid striped bass appear to have been maintained. Fillets from hybrid striped bass remain a good source of protein.

As the dietary concentration of MBM reached 45% of the diet, several nutrient availability values decreased significantly. The reason for this decrease is unclear and it did not impart a significant impact on whole-animal production characteristics. The decreases in nutrient availability may simply be a situation in which the intake of those nutrients measured was in excess of the animals' needs and absorption mechanisms from the gastrointestinal tract were overwhelmed. Additional research into this situation may prove useful. However, it is clear that hybrid striped bass can efficiently use MBM as a source of nutrients. Brown et al. (1985) reported the apparent crude protein digestibility (ACPD) of MBM was 82% in channel catfish, while Cruz (1975) reported ACPD of 72%. Cho et al. reported ACPD values for rainbow trout of 82% and apparent lipid digestibility of 77%. Hajen et al. (1993) reported ACPD value of 85% for chinook salmon fed MBM. True amino acid availability from MBM has been reported for channel catfish (Wilson et al., 1981). Those values ranged 76-88%. Values determined in this study are well within the range of previously reported nutrient availability values for fishes.

Conclusions

Production of hybrid striped bass is one of the newest and most rapidly growing aquaculture industries in the US. Based on these data, meat and bone meal can serve as the primary source of crude protein and essential amino acids in diets fed to this hybrid.

Based on the cost of ingredients, a change from current formulations to those containing high levels of meat and bone meal could reduce feed costs by approximately 20% opening a new market for meat and bone meal and helping this new aquaculture industry grow.

Literature Cited

Alava, V.R. and C. Lim. 1988. Artificial diets for milkfish, Chanos chanos (Forsskal), fry reared in seawater. Aquaculture 71:339-346.

AOAC (Association of Official Analytical Chemists). 1990. Official methods of Analysis. Association of Official Analytical Chemists, Inc. Arlington, Virginia, USA.

Brown, P.B. 1993. Comparison of fecal collection methods for determining phosphorus absorption in rainbow trout. **In**: Fish Nutrition in Practice, IVth International Symposium on Fish Nutrition and Feeding, (S.J. Kaushik and P. Luquet, editors). Institute National de la Recherche Agronomique, Paris, Les Colloques n° 61, pp. 443-448.

Brown, P.B. 1995. Using whole-body amino acid patterns and quantitative requirements to rapidly develop diets for new species such as striped bass (Morone saxatilis). Journal of Applied Ichthyology 11:342-346.

Brown, P.B., R.J. Strange, and K.R. Robbins. 1985. Protein digestibility coefficients for yearling channel catfish fed various high-protein feedstuffs. Progressive Fish-Culturist 47:94-97.

Brown, P.B., A. Emery, A.L. Lawrence, and E.H. Robinson. 1989. Digestible energy values for red swamp crayfish and evaluation of dietary associative effects in practical feeds. Journal of the World Aquaculture Society 20:122-126.

Brown, P.B., M.E. Griffin and M.R. White. 1993. Experimental and practical diet evaluations with juvenile hybrid striped bass. Journal of the World Aquaculture Society 24:80-89.

Brown, P.B., R. Twibell, Y. Jonker and K.A. Wilson. 1997. Evaluation of three soybean products in diets fed to juvenile hybrid striped bass Morone saxatilis x M. chrysops. Journal of the World Aquaculture Society 28:215-223.

Bureau, D.P., A.M. Harris, D.J. Bevan, L.A. Simmons, P.A. Azevedo and C.Y. Cho. 2000. Feather meals and meat and bone meals from different origins as protein sources in rainbow trout (Oncorhynchus mykiss) diets. Aquaculture 181:281-291.

Cho, C.Y., S.J. Slinger and H.S. Bayley. 1982. Bioenergetics of salmonid fishes: Energy intake, expenditure and productivity. Comparative Biochemistry and Physiology 73B:25-41.

Cruz, E.M. 1975. Determination of nutrient digestibility in various feedstuffs for channel catfish. Ph.D. dissertation. Auburn University, Alabama.

El-Sayed, A.-FM. 1998. Total replacement of fish meal with animal protein sources in Nile tilapia, Oreochromis niloticus (L.), feeds. Aquaculture Research 29:275-280.

Folch, J., Lees, M., Sloan Stanley, G.H., 1957. A simple method for the isolation and purification of total lipides from animal tissues. Journal of Biological Chemistry 226: 497-509.

Forster, I. 1999. A note on the method of calculating digestibility coefficients of nutrients provided by single ingredients to feeds of aquatic animals. Aquaculture Nutrition 5:143-145.

Gallagher, M.L. 1994. The use of soybean meal as a replacement for fish meal in diets for hybrid striped bass (Morone saxatilis x M. chrysops). Aquaculture 126:119-127.

Griffin, M.E., P.B. Brown and A. Grant. 1992. Dietary lysine requirement of juvenile hybrid striped bass. Journal of Nutrition 122:1332-1337.

Griffin, M.E., M.R. White and P.B. Brown. 1994a. Total sulfur amino acid requirement and cysteine replacement value for juvenile hybrid striped bass (Morone saxatilis x M. chrysops). Comparative Biochemistry and Physiology 108A:423-429.

Griffin, M.E., K.A. Wilson and P.B. Brown. 1994b. Dietary arginine requirement of juvenile hybrid striped bass. Journal of Nutrition 124:888-893.

Griffin, M.E., K.A. Wilson, M.R. White and P.B. Brown. 1994c. Dietary choline requirement of juvenile hybrid striped bass. Journal of Nutrition 124:1685-1689.

Hajen, W.E., R.M. Beames, D.A. Higgs and B.S. Dosanijh. 1993. Digestibility of various feedstuffs by post-juvenile chinook salmon (Oncorhynchus tshawytscha) in sea water. 2. Measurement of digestibility. Aquaculture 112:333-348.

Kerby, J.H. 1986. Striped bass and striped bass hybrids. Pages 127-147 in R.R. Stickney, editor. Culture of nonsalmonid freshwater fishes. CRC Press, Boca Raton, FL.

Kerby, J.H. 1993. Striped bass and striped bass hybrids. Pages 251-306 in R.R. Stickney, editor. Culture of nonsalmonid freshwater fishes, second edition. CRC Press, Boca Raton, FL.

Kikuchi, K., T. Sato, T. Furuta, I. Sakaguchi and Y. Deguchi. 1997. Use of meat and bone meal as a protein source in the diet of juvenile Japanese flounder. Fisheries Science, Tokyo 63:29-32.

Mohsen, A.A. and R.T. Lovell. 1990. Partial substitution of soybean meal with animal protein sources in diets for channel catfish. Aquaculture 90:303-311.

Nematipour, G.R., M.L. Brown and D.M. Gatlin. 1992. Effects of dietary carbohydrate:lipid ratio on growth and body composition of hybrid striped bass. Journal of the World Aquaculture Society 23:128-132.

New, M.B. 1997. Aquaculture and the capture fisheries - balancing the scales. World Aquaculture 28:11-32.

Paul, B.N., S. Nandi, S. Sarkar and P.K. Mukhopadhyay. 1997. Effects of feeding unconventional animal protein sources on the nitrogen metabolism in rohu, Labeo rohita (Hamilton). Israeli Journal of Aquaculture 49:183-192.

Rao, A.S., P.K. Mukhopadhyay, G.R.M. Rao and S.K. Sahoo. 1997. Effects of some nonconventional animal proteins on growth and certain tissue biochemical response in Clarias batrachus fingerlings. Indian Journal of Fisheries 44:57-62.

Riche, M., M.R. White, and P.B. Brown. 1995. Barium carbonate as an alternative indicator to chromic oxide for use in digestibility experiments with rainbow trout. Nutrition Research 15:1323-1331.

Riche, M. and P.B. Brown. 1996. Absorption of phosphorus from feedstuffs fed to rainbow trout. Aquaculture 142:269-282.

Rehulka, J. 1985. Replacement of fish and meat and bone meal by sulphite yeast and poultry meal in the rainbow trout feed mixture. Bulletin of the Department of Hydrobiology, Vodnany 21:13-17.

Robaina, L., F.J. Moyano, M.S. Izquierdo, J. Socorro, J.M. Vergara, and D. Montero. 1997. Corn gluten and meat and bone meals as protein sources in diets for gilthead seabream (Sparus aurata): nutritional and histological implications. Aquaculture 157:347-359.

SAS. 1990. SAS/STAT User's Guide, version 6, 4th ed. SAS Institute, Cary, NC.

Shimeno, S., T. Masumoto, T. Hujita, T. Mima and S. Ueno. 1993. Alternative protein sources for fish meal in diets of young yellowtail. Bulletin of the Japanese Society of Scientific Fisheries 59:137-143.

Smith, R.R., M.C. Peterson and A.C. Allred. 1980. The effect of leaching on apparent digestion coefficient in determining digestibility and metabolizable energy of feedstuffs for salmonids. Progressive Fish-Culturist 42:195-199.

Tacon, A.G.J., K. Jauncey, A. Falaye, M. Pantha, I. MacGowan, E.A. Stafford, L. Fishelson and Z. Yaron. 1983. The use of meat and bone meal, hydrolysed feather meal and soybean meal in practical fry and fingerling diets for Oreochromis niloticus. Pages 356-365 in International Symposium on Tilapia in Aquaculture, Nazareth, Israel

Webster, C.D., L.G. Tiu and J.H. Tidwell. 1997. Effects of replacing fish meal in diets on growth and body composition of palmetto bass (Morone saxatilis x M. chrysops) raised in cages. Journal of Applied Aquaculture 7:53-68.

Wilson, R.P., E.H. Robinson and W.E. Poe. 1981. Apparent and true availability of amino acids from common feed ingredients for channel catfish. Journal of Nutrition 111:923-929.

Windell, J.T., J.W. Folz and J.A. Sarokon. 1978. Methods of fecal collection and nutrient leaching in digestibility studies. Progressive Fish-Culturist 40:51-55.

Wu, Y.V., K.W. Tudor, P.B. Brown and R.R. Rosati. 1999. Substitution of plant proteins or meat and bone meal for fish meal in diets of Nile tilapia. North American Journal of Aquaculture 61:58-63.

Table 1. Proximate composition of the meat and bone meal fed to hybrid striped bass. Crude protein, ash, and fat are expressed on an as-is basis.

Crude Protein	52.4%
Ash	22.6%
Fat	11.0%
Moisture	3.4%

Table 2. Composition of diets fed to hybrid striped bass for evaluation of meat and bone meal.

	%							
Ingredient	MBM0	MBM15	MBM20	MBM25	MBM30	MBM35	MBM40	MBM45
Soybean Meal	54.34	41.76	39.35	36.93	34.52	32.10	29.69	27.28
Fish Meal (Menhaden)	16.00	15.01	12.96	10.92	8.88	6.84	4.79	2.75
Meat & Bone Meal	0.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00
Corn Grain	20.30	20.30	20.30	20.30	20.30	20.30	20.30	20.30
Fish Oil (w/- ethoxyquin)	6.78	5.08	4.68	4.28	3.88	3.48	3.07	2.67
Dicalcium Phosphate	1.31	1.57	1.40	1.24	1.07	0.90	0.73	0.57
Ascorbic Acid - PP	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Vitamin Premix (Trt. Comp.)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-Methionine	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Choline Chloride	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Mineral Premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Table 3. Mean weight gain, feed consumption, feed conversion ratio, and protein efficiency ratio (PER) of hybrid striped bass fed graded additions of meat and bone meal.

Diet	% Wt. Gain	Feed Consumption g	FCR	PER
MBM0	108.9±8.2a	1372.9±43.6b	1.45ab	1.71
MBM15	139.6±4.0b	1594.4±56.8ab	1.31ab	1.82
MBM20	136.2±6.3b	1444.7±99.8b	1.21b	2.02
MBM25	139.2±1.9b	1608.0±41.2ab	1.32ab	1.81
MBM30	135.7±4.6b	1825.2±100.1a	1.54a	1.62
MBM35	137.1±6.4b	1633.7±28.2ab	1.36ab	1.82
MBM40	140.0±5.9b	1639.5±74.8ab	1.33ab	1.79
MBM45	137.8±9.6b	1619.2±105.7ab	1.33ab	1.86

Table 4. Mean intraperitoneal fat (IPF), hepatosomatic index (HSI), and liver lipid concentrations of hybrid striped bass fed graded additions of meat and bone meal.

Diet	IPF%	HSI %	Liver Lipid
MBM0	2.02	0.96	54.28
MBM15	1.63	0.94	49.97
MBM20	1.85	0.92	53.15
MBM25	1.74	0.91	53.54
MBM30	1.92	1.00	50.98
MBM35	1.40	1.26	50.02
MBM40	1.67	0.95	56.01
MBM45	1.29	0.91	57.31

Table 5. Mean proximate composition of whole hybrid striped bass fed graded additions of meat and bone meal.

Diets	% Moisture	% Crude Protein	% Crude Fat	% Ash
MBM0	63.40	57.45	33.33	13.88
MBM15	67.76	54.66	28.61	14.37
MBM20	68.02	58.29	28.87	13.86
MBM25	66.46	55.32	28.55	13.69
MBM30	67.58	56.39	28.33	13.56
MBM35	66.67	57.06	28.65	13.94
MBM40	64.60	56.96	29.15	14.20
MBM45	66.19	58.50	27.59	14.37

Table 6. Mean proximate composition of fillets from hybrid striped bass fed graded additions of meat and bone meal.

Diets	% Moisture	% Crude Protein	% Crude Fat	% Ash
MBM0	76.96	82.06	9.84	7.65
MBM15	76.56	80.18	14.33	7.22
MBM20	76.31	80.33	12.54	7.57
MBM25	76.64	80.98	12.37	7.45
MBM30	76.69	80.38	14.45	7.34
MBM35	76.72	80.26	14.01	7.36
MBM40	76.77	80.95	12.69	7.32
MBM45	76.72	81.86	10.87	7.59

Table 7. Mean apparent crude protein digestibility and phosphorus availability of hybrid striped bass fed graded additions of meat and bone meal.

Diet	Crude Protein	Phosphorus
MBM0	80.89a	42.99
MBM15	84.30a	37.55
MBM20	84.28a	36.13
MBM25	80.56a	40.93
MBM30	80.83a	44.42
MBM35	73.96a	38.89
MBM40	81.20a	39.96
MBM45	68.62b	34.86

Table 8. Mean amino acid availability from hybrid striped bass fed graded additions of meat and bone meal.

Diets	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val
MBM0	86.62	85.71	82.36	82.12	81.50	80.47	84.05	78.04	77.14	80.54
MBM15	90.16	87.88	84.70	85.88	87.25	85.27	87.57	80.75	77.07	83.39
MBM20	89.55	86.88	83.38	84.99	87.29	85.41	86.56	78.88	74.55	82.45
MBM25	84.47	81.14	76.81	78.58	78.56	78.98	80.52	73.86	67.89	75.73
MBM30	89.35	85.26	81.25	84.12	86.33	83.91	85.64	78.15	73.36	81.16
MBM35	78.49	74.22	67.28	70.97	67.18	70.84	72.36	65.83	55.77	67.58
MBM40	87.98	84.74	80.49	83.44	83.63	84.36	84.69	78.63	73.61	80.13
MBM45	73.58a	67.30a	62.00a	64.65a	58.51a	62.79a	66.50a	57.98a	41.90a	62.64a