REPLACEMENT OF MENHADEN FISHMEAL BY SOYBEAN MEAL FOR THE DIET OF JUVENILE BLACK SEA BASS *Centropristis striata* CULTURE

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According to the proposed principles of organic aquaculture feeds, all fish meal incorporated must be derived from fishery resources certified to be sustainability managed (USDA, NOP 2006). Fish meal is the protein source traditionally used in aquaculture diets, yet it is a limited resource and is expensive (FAO, 2006). Alternate protein sources can lower the cost of aquaculture diets to reduce the amount of wild fish used as protein, and potentially reduce the nutrient levels in effluent waste. However, for most species, there is a limit to how much fish meal can be replaced by alternative protein sources without adversely affecting the fish. Several studies have been done on fresh and saltwater fish to investigate their tolerance for alternative protein sources.

Soybean meal is considered to be one of the most suitable and stable supplies of an alternative ingredient for replacing fishmeal to reduce the cost and to develop organic diets in commercial fish feed industries. Compared to other plant protein sources, soybean is one of the most promising because of its high protein content, very low carbohydrate and fiber, high digestibility and good amino acid profile (Gatlin et al. 2007). Soybean protein has produced encouraging results in diets for species such as common carp, tilapia, channel catfish, salmonids, red drum, striped bass and marine shrimp (O'Keefe, American Soybean Association). However, use of soy protein is technically limited by its amino acid profile and poor palatability (Tacon and Akiyama, 1997). Soybean meal is less expensive than fish meal and is readily available (Hardy, 2006). Furthermore nutrient content in effluent waste from aquaculture can negatively impact local waterways, and soybean meal has significantly less phosphorous than fish meal (NRC, 1993).

Black sea bass, *Centropristis striata* (Linneaus 1758) is a commercially important species found in waters along the Atlantic coast from the Gulf of Maine to Northern Florida, and a subspecies inhabits the eastern Gulf of Mexico. In 2006, the North Carolina commercial black sea bass landings totaled 790,988 lbs (managed quota), valued at $1,740,469 (Division of Marine Fisheries, (www.ncfisheries.net). Their wide acceptance as an excellent food fish and their high market value has led to over-harvesting of wild stocks in many areas [North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries (NCDENR DMF) 2006]. Black sea bass adapt well to captivity have been raised successfully from eggs to marketable stages at the University of North Carolina at Wilmington (Watanabe et al. 2003).

Black sea bass grow rapidly when fed artificial diets consisting largely of marine feedstuffs such as menhaden fish meal or natural diets such as live tilapia. The limited availability and high cost of fish meal and live tilapia may limit their application in practical as well as in organic diets for black sea bass. No published information is available on fish meal replacement with alternative protein sources in black sea bass. The objective of the present study is to develop a less expensive but nutritionally balanced artificial practical diet for maximum growth of black sea bass using soybean meal as a protein source.

Methodology

Test diets

Eleven test diets were prepared containing 44% crude protein and 10% lipid replacing 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100% of menhaden fish meal protein (adding 50, 45, 40, 35, 30, 25, 20, 15, 10, 5 and 0% of menhaden fish meal) by solvent extracted soybean meal protein. All other nutrients were added according to the recent information on nutrient requirements of black sea bass (Alam et al. 2007). All experimental diets also contained 7.5% squid meal and 5% krill meal. Menhaden fish oil and soybean lecithin were used as lipid sources, whereas wheat starch was used as carbohydrate source. High quality Kadai (Kagoshima University, Japan) vitamin and mineral premix for marine fish were used in the diets. One percent feed attractants (alanine, glycine, betaine and taurine) were used as attractants in the diets. Alpha cellulose was used as filler and wheat gluten was used as a binder. Diets were prepared at the UNCW Center for Marine Science (Wilmington, NC) using a Kitchen Aid mixer, meat grinder and a drying oven.

Feeding trial

Two feeding trials were conducted to evaluate the replacement of fishmeal by soybean meal. In trial 1, seven test diets (0, 10, 20, 30, 40, 50, and 60% fishmeal replacement by soybean meal) were fed to triplicate groups of black sea bass (average weight = 5 g) for 6 weeks. In trial 2, six test diets (0, 60, 70, 80, 90, and 100% fishmeal replacement by soybean meal) were fed to triplicate groups of black sea bass (average weight = 10 g) for 10 weeks. In both trials, 15 fish were stocked in each of twenty-one 75-liter recirculating seawater tanks. The fish were fed two times a day to apparent satiation. For both trials, the water quality parameters such as temperature, dissolved oxygen, pH and ammonia levels were monitored routinely and maintained at optimum levels. A 12:12 light: dark photoperiod cycle was provided during the feeding trial.

Evaluated parameters and statistical analysis

After the feeding trial, growth performance including body weight gain, feed intake and feed conversion ratio were evaluated. Proximate composition (crude protein, lipid, ash and moisture) of fish and diets and tissue fatty acid profile will be analyzed and will be presented at the symposium. All data were subjected to statistical verification using one way analysis of variance. Significant differences between means were evaluated by Tukey Kramer test (Kramer, 1956). Probabilities of $P < 0.05$ were considered significant.

Results

After the feeding trial, survival was greater than 96% and 86% in all dietary treatments in trials 1 and 2, respectively, and there were no significant differences ($P > 0.05$) among treatments in both experiments. In trial 1, no significant differences ($P < 0.05$) in body weight gain among fish fed diets replacing 0% to 60% fish meal were observed. In trial 2, no significant differences in body weight gain were observed among fish fed diets replacing 0%, 60%, and 70% of fish meal protein with soybean meal protein. Body weight gain decreased significantly when soybean meal replaced fish meal protein at levels of 70% to 100%. Similar trends were observed for specific growth rate in both trials. In trial 1, there were no significant differences in feed intake and feed conversion ratio among treatments. However, in trial 2, feed conversion ratios were significantly ($P < 0.05$) higher for the diets with more than 70% replacement of fishmeal protein with soybean meal.

Our position regarding the findings in relation to organic feed

Results of this trial indicated that the maximum level of menhaden fish meal protein replacement with solvent extracted soybean meal was 70% (with 7.5% squid meal and 5% krill meal) in the diets of juvenile black sea bass without reducing growth. This means that a diet containing 15% fish meal and 46.7% soybean meal (22% protein) showed the same growth performance as diet containing 50% fish meal (0% replacement) including 1% attractants. However, maximum substitution limits and feed conversion ratios might be different when diets containing non-solvent extracted soybean meal and without attractants are used. We found that the maximum amount of soy protein (22%) that could be used in feeds for black sea bass is much higher than those reported for other marine fish such as red drum, red sea bream (Table 1, O'Keefe, American Soybean Association). To meet organic standards, we are presently conducting research to determine substitution limits of soybean meal without supplementing attractants (synthetic free amino acids). We are also conducting similar research on southern flounder. All of available data will be presented at the symposium. These results could be used to develop environmentally-sound and cost-effective pre-dominantly plant protein based diets for the organic aquaculture of black sea bass. However, hexane solvent extracted soybean meal would disqualify a diet as an organic feed (USDA, NOP 2006). So, in future it is necessary to conduct research using soybean meal that is not solvent extracted.

Specific NOSB issues regarding organic aquaculture standards

Alternative nutritional technology to fish meal (12%) and fish oil (12%) at 24% of total feed.

Protein requirement of carnivorous marine finfish species is about 50% (NRC 1993). Fishmeal contains about 60% protein. If only 12% fishmeal is added in a 50% protein based diet then only 7.2% protein comes from fishmeal. Also, if the fish are fed a diet which is deficient in protein, growth will be reduced and disease may occur which ultimately will affect the organic aquaculture system. Fish reared in a recirculating aquaculture tank system completely depend on artificial diets due to lack of natural feed. So, it is also important to consider the type of culture system before deciding the percentage of protein and lipid in organic diets. We think 12% lipid from fish oil is enough for some herbivorous, omnivorous and carnivorous species but 12% fish meal may not be enough to support good growth of most species of carnivorous fish reared in salt water.

Usually solvent extracted and heat treated soybean meal are used by the fish feed industry to reduce the trypsin inhibitor. If solvent extracted soybean meal is not allowed to be used for organic aquaculture feeds, it is necessary to conduct research using non-solvent extracted soybean meal to determine substitution limits for fish meal on black sea bass. Soybean oil does not contain enough ω-3 fatty acids for marine finfish. If soybean meal which is not solvent extracted is used in the diets, a significant percentage of dietary lipid will come from soybean meal and may affect final product quality. Available data suggested that 12% fish oil in the diet may be adequate for growth of black sea bass and that flesh quality may be comparable to wild fish.

Finally, available data suggested that it may be possible to use farmed fish species such as tilapia for black sea bass culture. Assuming the tilapia have been raised on sustainable feeds, this practice could meet the standard for organic certification.

Table 1. Maximum inclusion rates of soy protein in feeds for aquaculture species (O'Keefe, http://www.soyaqua.org/pdf2/OKeefeFeedIngredientPaper.pdf)

Species	% Maximum soy protein from:	
	Heat Processed Full-Fat Soybeans	Solvent Extracted Soybean meal
Common carp	12	25
Blue tilapia	9.5	20
Channel catfish	9.5	25
Rainbow Trout	17	12
Coho Salmon	9.5	9.5
Atlantic salmon	5	5
Red Drum	6	9.5
Stripped bass	9.5	12
Red sea bream	6	12
Marine shrimp	4	14.5
Black sea bass	-	22 (present study)

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