

Red Drum, *Sciaenops ocellatus*,  
Production Diets:  
Replacement of Fish Meal  
with Soybean Meal

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**ABSTRACT.** The replacement of fish meal with soybean meal in fish diets has met with varying degrees of success. Quite often, poor responses to high soybean meal diets are due to a reduced palatability of the diet when fish meal is removed. Recent work has demonstrated that poultry by-product meal can be used as a substitute for fish meal in practical diets for juvenile red drum (*Sciaenops ocellatus*), indicating it may have favorable palatability characteristics for this species. The present research was designed to evaluate the replacement of menhaden fish meal with solvent-extracted soybean meal in practical diets containing 20% poultry by-product meal and formulated to contain 44% protein and 10% lipid. Test diets were adjusted for phosphorus and methionine content to ensure that minimal dietary requirements were maintained. The response of red drum (mean initial weight 179 g) to diets containing fish meal ranging from 40 to 5% of the diet, as well as the response to a low fish meal diet supplemented with krill hydrolysate, were evaluated over a 14-week growth period. Final weights (percent gain) ranged from 588 g (237.8%) to 651 g (258.5%), with feed conversion efficiencies

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ranging from 62.1% to 69.9% and protein conversion efficiencies ranging from 27.8% to 30%. No significant differences ( $P > 0.05$ ) were observed for diet intake, feed conversion efficiency, protein conversion efficiency, intraperitoneal fat ratio, or weight gain. Significant differences in protein intake and the hepatosomatic index were observed. The present findings suggest that fish meal can be reduced to 5% of the diet by replacing it with solvent-extracted soybean meal as well as methionine and phosphorus supplements. Although diets without poultry by-product meal were not tested, it is presumed that the poultry meal enhanced the palatability of the diets, allowing the replacement of fish meal with soybean meal. [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <<http://www.HaworthPress.com>> © 2004 by The Haworth Press, Inc. All rights reserved.]

**KEYWORDS.** Nutrition, fish meal, poultry meal, growout, red drum, *Sciaenops ocellatus*

### INTRODUCTION

World aquaculture production has experienced a steady expansion that is expected to continue as world population increases. Paralleling the growth of aquatic animal production systems has been an increase in diet production which often relies on fish meal as a source of high quality protein, highly unsaturated fatty acids, minerals and attractants. Given the limited supply of fish meal and other marine protein sources, we must find alternative ingredients to include in production diets for fish. Considerable research has been conducted with red drum, *Sciaenops ocellatus*, with respect to nutritional requirements and the use of non-marine protein sources. The replacement of fish meal with soybean meal in juvenile diets has met with varying degrees of success (Reigh and Ellis 1992; Davis et al. 1995; Meilahn et al. 1996; McGoogan and Gatlin 1997). Although various nutritional factors could be implicated, quite often poor fish performance has been due to a reduced palatability of the diet when fish meal and other marine protein sources are removed. Kureshy et al. (2000) demonstrated that poultry by-product meal can be used as a substitute for fish meal in practical diets for juvenile red drum. Based on these results, it may be possible to reduce fish meal levels in production diets that contain poultry by-product meals. The majority of diet inputs, and hence fish meal usage, occurs during

the growout stage of production. Hence, it is important that we develop diet formulations for large fish that contain reduced levels of fish meal. The present research was designed to evaluate the iso-nitrogenous replacement of menhaden fish meal with solvent extracted soybean meal in practical diets containing 20% poultry by-product meal.

## **MATERIALS AND METHODS**

### ***Experimental Conditions***

This research was conducted at the University of Texas at Austin, Marine Science Institute in Port Aransas, Texas. The 14-week growth trial was conducted in a semi-closed recirculating system, consisting of 18 semi-square polyethylene tanks (designed to hold 570 L of water), a 970-L reservoir tank containing two trickling towers and submerged biological filtration, two 2.0-kW submersible heaters, a circulation pump, and sand filtration. Supplemental aeration was provided to each tank, and the system makeup water was exchanged at a rate of approximately 19 L/min throughout the experiment. A 16 hour light: 8 hour dark photoperiod was established using fluorescent lamps with timers.

Tanks were initially stocked with an excess of size-sorted fish which were allowed to acclimate to the culture system for one week. Tanks were then cleaned and individually restocked with eight fish having a mean initial weight of 179 g. A sub-sample of the population was frozen for subsequent biochemical analyses. Water quality was evaluated twice weekly for pH, total ammonia nitrogen (TAN) and nitrite-nitrogen ( $\text{NO}_2\text{-N}$ ) using methods described by Spotte (1979). Water quality parameters were maintained at: (mean $\pm$ standard deviation) pH,  $7.7\pm 0.1$ ; TAN,  $0.16\pm 0.06$  ppm;  $\text{NO}_2\text{-N}$ ,  $0.06\pm 0.02$  ppm. Salinity and dissolved oxygen (DO) were monitored daily and maintained at  $29.6\pm 4.0$  ppt and  $6.1\pm 0.9$  ppm, respectively. Temperature was also measured daily. Due to a heater failure, temperature was maintained at  $26.2\pm 0.7^\circ\text{C}$  during the first 12 days of the experiment and  $28.5\pm 1.0^\circ\text{C}$  for the duration of the experiment, resulting in an overall mean of  $27.7^\circ\text{C}$ .

### ***Experimental Diets***

Six experimental diets (Table 1), containing fish meal ranging from 40% to 5% of the diet, were prepared to contain 44% protein and 10%

lipid. Each diet was randomly assigned to three tanks. Feed was prepared by first homogenizing ingredients in a food mixer (Hobart Corp., Troy, Ohio<sup>1</sup>). Boiling water was then added to obtain a consistency appropriate for pelleting. The mash was cold-extruded through a meat grinder (4-mm die), and dried for 5 hours at 40°C in a forced-air convection oven. Extruded pellets were air-cooled overnight in order to obtain an approximate moisture content of 8-10%. Diet was then crumbled to an appropriate length (approximately 6 mm). Protein content was confirmed using the micro-Kjeldahl method (Ma and Zuazago 1942) and percent dry matter of the feed was determined by drying the sample to a constant weight at 95°C.

### ***Growth Trial***

Following initial stocking, the fish were weighed every 14 days at which time the tanks were cleaned. To prevent *Amyloodinium ocellatum* infections, the make up water was treated with copper (0.3 ppm Cu) prior to weighing the fish and fish were dipped in freshwater during the weighing process. Feed was offered twice daily (0800 and 1700 h) throughout the experiment and was withheld on weighing days. After weighing, feeding rates were adjusted according to weight gain (final wet weight – initial wet weight), feed efficiency values for the previous two weeks (FE; wet weight gain  $\times$  100/dry diet fed) as well as apparent consumption and feeding activity. Feeding rates at the start of the experiment were 2.8 g dry diet/100g wet fish and were slowly reduced to 1.8 g dry diet/100g wet fish at the conclusion of the experiment.

Upon termination of the growth trial, fish were enumerated and the total biomass in each tank determined. Additionally, three randomly selected fish from each tank were sacrificed and weighed. The liver and intraperitoneal fat from each fish were then removed and weighed in order to determine hepatosomatic index (HSI; wet liver weight  $\times$  100/wet body weight) and intraperitoneal fat ratio (IPF; wet weight of fat  $\times$  100/wet body weight). The liver and intraperitoneal fat were then homogenized with the de-scaled fish carcass. After homogenizing, a sub-sample was collected for whole body dry matter and protein analysis. Dry matter was determined in duplicate by drying the sample to a constant weight at 95°C. Whole body protein was determined in triplicate. Pro-

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TABLE 1. Composition of experimental diets (g/100 g dry weight).

Ingredient	D40	D30	D20	D10	D5	D5K
Fish meal <sup>1</sup>	40.00	30.00	20.00	10.00	5.00	5.00
Poultry meal <sup>2</sup>	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal <sup>3</sup>	-	12.79	25.58	38.37	44.76	43.50
Krill <sup>4</sup>	-	-	-	-	-	1.00
Menhaden fish oil <sup>5</sup>	3.14	4.07	5.01	5.94	6.41	6.42
Wheat gluten <sup>6</sup>	4.00	4.00	4.00	4.00	4.00	4.00
Wheat starch <sup>6</sup>	20.81	17.02	12.42	7.63	5.23	5.49
Nutribinder <sup>7</sup>	8.00	8.00	8.00	8.00	8.00	8.00
Trace mineral premix <sup>8</sup>	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix <sup>9</sup>	3.00	3.00	3.00	3.00	3.00	3.00
Stay C 250 mg/kg <sup>10</sup>	0.10	0.10	0.10	0.10	0.10	0.10
KH <sub>2</sub> PO <sub>4</sub> <sup>6</sup>	0.20	0.20	1.00	2.00	2.50	2.50
Lecithin <sup>11</sup>	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine <sup>6</sup>	-	0.07	0.14	0.21	0.25	0.24

<sup>1</sup>Special Select™, Omega Protein Inc., Hammond, LA, USA.

<sup>2</sup>Flashed dried poultry by-product meal, Griffin Industries, Inc., Cold Spring, KY, USA.

<sup>3</sup>Solvent extracted, Producers Co-Operative Association, Bryan, TX, USA.

<sup>4</sup>Krill hydrolysate, American Dehydrated Foods, Inc., Verona, MO, USA.

<sup>5</sup>Omega Protein Inc., Reedville, VA, USA.

<sup>6</sup>United States Biochemical Corporation, Cleveland, OH, USA.

<sup>7</sup>Processed sorghum, Industrial Grain Products Inc., Lubbock, TX, USA.

<sup>8</sup>g/100 g premix: cobalt chloride, 0.004; cupric sulfate pentahydrate, 0.250; ferrous sulfate, 4.0; magnesium sulfate heptahydrate, 28.398; manganous sulfate monohydrate, 0.650; potassium iodide, 0.067; sodium selenite, 0.010; zinc sulfate heptahydrate, 13.193; filler, 53.428.

<sup>9</sup>g/kg premix: thiamin HCl, 0.5; riboflavin, 3; pyroxidine HCl, 1.0; DL Ca-pantothenate, 5.0; nicotinic acid, 5.0; biotin, 0.05; folic acid, 0.18; vitamin B<sub>12</sub>, 0.002; choline chloride, 100; inositol, 5.0; menadione, 2.0; vitamin A acetate (20,000 IU/g), 5.0; vitamin D<sub>3</sub> (400,000 IU/g), 0.002; dL-alpha-tocopherol acetate (250 IU/g), 8.0; alpha-cellulose 856.266.

<sup>10</sup>Stay C, L-ascorbyl-2-polyphosphate, Hoffman-LaRoche, Inc., Nutley, NJ, USA.

<sup>11</sup>Aqualipid 95, Central Soya Chemurgy Division, Fort Wayne, IN, USA.

tein conversion efficiency (PCE; protein gain  $\times$  100/protein fed) was then calculated.

### Analyses

Data was analyzed using one-way analysis of variance to determine significant differences ( $P < 0.05$ ) among treatment means. Student-Neuman-Keuls multiple comparison test was used to determine significant differences between treatment means (Steel and Torrie 1980). All statistical analyses were conducted using the Statistical Analysis System (v6.12, SAS Institute Inc., Cary, North Carolina).

### **RESULTS AND DISCUSSION**

The present research was designed to evaluate the replacement of menhaden fish meal with solvent-extracted soybean meal as well as evaluate the response of red drum to krill hydrolysate as a potential attractant in low fish meal diets. The growth trial was initiated with advanced juveniles (179.1 g) and was conducted over a 14 week period without significant water quality or disease problems. At the termination of the experiment the fish were of marketable size (~600 g). Mean values for final mean weight, percent gain, survival, FE, PCE, HSI and IPFR are presented in Table 2.

Mortality was minimal with no significant differences in survival observed between treatment means. Although some differences were detected in total protein intake and HSI, there was no clear relationship between these variables and the dietary treatments. In general, there were no notable differences among any of the parameters that were tested. These results would indicate that the low fish meal diets were acceptable in terms of nutritional quality and palatability to the red drum. The lack of a response is similar to findings of Kureshy et al. (2000) who replaced fish meal with poultry by-product meals in practical diet for juveniles. It should be noted that the lack of response of the red drum to the removal of fish meal from the diet could be due either to positive palatability attributes of poultry by-product meal or to a reduction in palatability requirements of larger fish, as proposed by McGoogan and Gatlin (1997).

Quite often, the replacement of marine protein sources not only changes the nutritional profile of the diet but it also effects palatability. For this research, crystalline methionine and phosphorus were supplemented to the diets to maintain minimal levels of these nutrients. When similar procedures and diets were used in research with juvenile red drum, poor performance has been reported, presumably due to shifts in palatability (Reigh and Ellis 1992; Davis et al. 1995; Meilahn et al. 1996) as fish meal was replaced with other protein sources. Consequently, in the present study the low fish meal diet was also supplemented with 1% (dry weight basis) krill hydrolysate. Krill meal is considered an excellent attractant that is used to enhance palatability and is often used for feed training fish (Kubitza and Lovshin 1997; Moura et al. 2000). Although krill is considered a highly palatable ingredient, supplementation did not appear to influence growth. However, since there was no apparent reduction in growth or feed consumption as

TABLE 2. Response of red drum (mean initial weight 179.1g) offered test diets with varying levels of fish meal ranging from 40 (D40) to 5% (D5) of the diet and a low fish meal diet with krill hydrolysates (D5K) over a 14-week growth trial.<sup>1</sup>

Diet	Mean weight (g)	Weight gain (%)	Consumed feed (g)	Protein fed (g)	Survival (%)	FE <sup>2</sup> (%)	PCE <sup>3</sup> (%)	HSI <sup>4</sup>	IPFR <sup>5</sup>
D40	629.7	248.6	701.9	306.5 <sup>ab</sup>	100.0	69.9	27.8	1.6 <sup>ab</sup>	0.8
D30	588.1	237.8	665.5	284.5 <sup>b</sup>	100.0	62.1	30.0	1.8 <sup>a</sup>	1.7
D20	651.5	258.6	710.7	313.3 <sup>a</sup>	100.0	65.8	29.5	1.3 <sup>ab</sup>	0.9
D10	614.6	242.1	669.9	288.5 <sup>b</sup>	100.0	64.7	28.6	1.2 <sup>ab</sup>	1.0
D5	638.1	258.5	696.9	319.7 <sup>a</sup>	95.8	66.0	29.3	1.1 <sup>b</sup>	0.5
D5K	598.5	232.7	664.5	287.4 <sup>b</sup>	100.0	62.9	28.3	1.5 <sup>ab</sup>	1.5
PSE <sup>6</sup>	29.69	16.22	13.58	5.91	1.70	2.72	1.45	0.12	0.31
Pr > F	0.4783	0.8130	0.1106	0.0038	0.4582	0.8815	0.8923	0.0213	0.1453

<sup>1</sup> Means of three replicates. Numbers in the same column with different superscripts are significantly different ( $P < 0.05$ ).

<sup>2</sup> Feed efficiency (FE) = wet weight gain  $\times$  100/dry weight of feed offered.

<sup>3</sup> Protein conversion efficiency (PCE) = dry protein gain  $\times$  100/dry protein offered.

<sup>4</sup> Hepatosomatic index (HSI) = (wet liver weight  $\times$  100/wet body weight).

<sup>5</sup> Intra-peritoneal fat ratio (IPFR) = (wet weight of fat  $\times$  100/wet body weight).

<sup>6</sup> Pooled standard error.

fish meal was replaced with soybean meal, the addition of an attractant probably was not necessary.

Results of the present study demonstrate that fish meal can be replaced with other non-marine protein sources as long as the nutritional value and palatability of the diet is maintained. The combination of soybean meal and poultry by-product meal utilized in the present study would be expected to result in significant cost savings in ingredients without compromising growth and feed conversion efficiencies. Investments in diet and diet usage are highest during the final stages of production. Hence, if we are to reduce feed costs and our dependence on marine resources, further research with regards to ingredient substitution, nutritional value and palatability of growout diets are needed.

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