Aquaculture, 106 (1992) 301–309
Elsevier Science Publishers B.V., Amsterdam

AQUA 50016

Use of soybean meal and distillers grains with solubles as partial or total replacement of fish meal in diets for channel catfish, *Ictalurus punctatus*

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(Accepted 30 January 1992)

ABSTRACT

Webster, C.D., Tidwell, J.H., Goodgame, L.S., Yancy, D.H. and Mackey, L., 1992. Use of soybean meal and distillers grains with solubles as partial or total replacement of fish meal in diets for channel catfish, *Ictalurus punctatus*. *Aquaculture*, 106: 301–309.

A 12-week feeding trial was conducted in aquaria with juvenile (11 g) channel catfish to examine effects of partially or totally replacing fish meal with a fixed percentage (35%) of distillers grains with solubles (DGS) and a variable percentage (up to 50%) of soybean meal in prepared diets. Four isonitrogenous (33% protein) and isocaloric (2.9 kcal digestible energy/g of diet) diets were formulated to contain 12, 8, 4, and 0% fish meal. Soybean meal was added to assure crude protein levels of 33%. A fifth diet was formulated identical to the diet with 0% fish meal, but with supplemental lysine and methionine added. After 12 weeks, weight gain, individual weight, individual length, food conversion ratio, specific growth rate, and survival were not significantly different ($P > 0.05$) among treatments. These data suggest that a diet with all plant protein sources (soybean meal and distillers grains with solubles) can totally replace fish meal in a channel catfish diet.

INTRODUCTION

Fish meal is the preferred protein source in some finfish diets because of its high protein quality and palatability (Lovell, 1989). Most commercial catfish diets currently contain 5–10% fish meal (Mohsen and Lovell, 1990). However, fish meal is one of the most expensive ingredients in prepared fish diets. Fish nutritionists have long tried to use less expensive plant protein sources to partially or totally replace fish meal (Cowey et al., 1971; Andrews and Page, 1974; Cho et al., 1974; Wee and Wang, 1987; Ng and Wee, 1989).

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Of plant protein feedstuffs, soybean meal is considered to be the most nutritious and is used as the major protein source in many fish diets (Lovell, 1988). However, growth has tended to be reduced in fish fed diets with soybean meal replacing all the fish meal in diets for plaice, *Pieuronectes platessa* (Cowey et al., 1971), tilapia, *Oreochromis mossambicus* (Jackson et al., 1982), rainbow trout (Cho et al., 1974; Dabrowski et al., 1989), and common carp (Viola et al., 1983).

One possible reason for this decreased growth is activity of protease inhibitors in crude soybean meal (Dabrowski and Kozak, 1979; Wilson and Poe, 1985). A second possible reason is amino acid absorption. Dabrowski et al. (1989) reported decreased amino acid absorption in rainbow trout, particularly methionine, as soybean meal is increased above 50% of the total formulation.

Distillers grains with solubles (DGS) are primary fermentation residues from yeast fermentation of cereal grains and are a good protein source without the antinutritional factors present in soybean meal (Wilson and Poe, 1985) or cottonseed meal (gossypol) (Jauncey and Ross, 1982; Martin, 1990). It has been reported that DGS are a nutritious, and possibly beneficial, diet ingredient in channel catfish diets at a 35% level of inclusion (Tidwell et al., 1990; Webster et al., 1991). The purpose of this study was to evaluate the use of a fixed percentage of DGS (35%) and a variable percentage of soybean meal (up to 50%) as a partial or total replacement of fish meal in prepared diets for juvenile channel catfish.

MATERIALS AND METHODS

Experimental diets

Five experimental diets were formulated to contain decreasing percentages of fish meal (FM) and a constant percentage of distillers grains with solubles (DGS, 35%) (Table 1). Diet 1 was similar to a high-quality commercial channel catfish diet with 12% fish meal, soybean meal, corn, and vitamin and mineral premix. Diets 2–5 were similar but contained decreasing percentages (8, 4, and 0%) of FM and 35% DGS. Soybean meal was increased so that the crude protein level was maintained at 33% in all diets. Amino acid composition of the diets was determined from tabular values provided for diet ingredients (NRC, 1983). All diets were formulated isocaloric (2.9 kcal digestible energy/g of diet) (Table 1) (NRC, 1981, NRC, 1983).

In preparing diets, dry ingredients were first ground to a small particle size (approximately 250 μm) in a Wiley mill. Ingredients were thoroughly mixed and water added to obtain a 30% moisture level. Diets were passed through a mincer with die into 0.8-mm diameter strands and were dried (25°C) for 16 h using a convection oven. After drying, the diets were broken up and sieved into convenient pellet sizes. Cod liver oil was sprayed onto the dried pellets

TABLE 1

Composition of experimental diets fed to juvenile channel catfish containing decreasing percentages of fish meal

	Diet (% fish meal)				
	12	8	4	0	0+AA[1]
Ingredient					
Menhaden fish meal (67%)	12.00	8.00	4.00	0.00	0.00
Soybean meal (44%)	48.00	35.00	42.00	49.00	48.50
DGS[2]	0.00	35.00	35.00	35.00	35.00
Ground corn	32.00	15.00	11.50	8.50	8.50
Cod liver oil[3]	3.00	3.00	3.00	3.00	3.00
Premix[4]	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate	1.00	1.00	1.00	1.00	1.00
L-lysine	0.00	0.00	0.00	0.00	0.40
L-methionine	0.00	0.00	0.00	0.00	0.10
CMC[5]	2.00	2.00	2.00	2.00	2.00
Nutrient composition[6]					
Moisture (%)	15.23±0.80	15.30±1.40	14.20±1.49	13.74±1.79	13.81±1.25
Protein (%)[7]	35.82±0.19	36.11±0.59	35.31±0.89	36.04±0.88	35.48±0.32
Fat (%)[7]	6.16±0.07	10.02±0.16	8.43±0.16	8.73±0.12	8.42±0.19
DE[8]	2.88	2.93	2.92	2.90	2.90
Lysine (%)	1.80±0.0	1.71±0.05	1.79±0.01	1.72±0.03	1.81±0.01
Methionine (%)	0.64±0.02	0.63±0.0	0.63±0.02	0.60±0.03	0.63±0.02
Cystine	0.37±0.02	0.34±0.0	0.40±0.03	0.39±0.0	0.46±0.0
Available phosphorus[9]	1.17	1.20	1.16	1.13	1.13

[1]Diet 5 was otherwise identical to diet 4 except 0.4% crystalline L-lysine and 0.1% crystalline L-methionine were added.
[2]DGS=Distillers grains with solubles.
[3]BHT was added at 0.02% of lipid.
[4]Premix supplied vitamins and minerals identical to that in Webster et al. (1991).
[5]CMC=Carboxymethylcellulose.
[6]Percentage moisture, protein, fat, lysine and methionine values are means±s.e. of three replications.
[7]Moisture-free basis.
[8]DE=Digestible energy in kcal/g of diet; based on estimated values of the diet ingredients (NRC, 1981, 1983).
[9]Available phosphorus (% of diet) was calculated from the diet ingredients (NRC, 1983). The available phosphorus for DGS was estimated to be the same value as corn, 25%.

immediately prior to storage. All diets were frozen (−15°C) until immediately prior to feeding.

Percentage protein of diets was determined using a LECO FP-228 nitrogen determinator (LECO Corp., St. Joseph, MI) (Sweeney and Rexroad, 1987), percentage fat was determined by ether extraction (AOAC, 1990), and percentage moisture was determined by drying a 15-g sample in a convection oven at 95°C for 24 h (AOAC, 1990). Digestible energy (DE) values were estimated from DE values of the diet ingredients for channel catfish (NRC,

1983) and trout (for DGS; NRC, 1981). Diets were also analyzed for amino acid composition (Table 1) (AOAC, 1990).

Experimental system and animals

The feeding trial was conducted in 20 37.5-l acrylic aquaria. Water was recirculated through biological and mechanical filters. The recirculating system was a 2000-l vertical screen filter system utilizing high-density polyester screens to remove particulate material and provide substrate for nitrifying bacteria (Red Ewald, Inc., Karnes City, TX). Continuous aeration was provided by a blower and air stones. All aquaria were cleaned once daily to remove feces. Water exchange rate for the system was approximately 6% of total volume per day. Chloride levels were maintained at approximately 500 mg/l (by addition of food-grade NaCl) to minimize potential adverse effects of nitrite (Perrone and Meade, 1977). Each aquarium was supplied with water at a rate of 2.0 l/min. Black plastic covered the back and sides of all aquaria to minimize disturbances (Hale and Carlson, 1972). Continuous illumination was supplied by fluorescent ceiling lights.

Water temperature and dissolved oxygen were measured daily using a YSI Model 57 (YSI Industries, Yellow Springs, OH). Total ammonia and nitrite were measured twice weekly using a DREL/5 spectrophotometer (Hach Company, Loveland, CO). Total alkalinity and chlorides were monitored twice weekly using the DREL/5; pH was monitored twice weekly using an electronic pH meter (pH pen; Fisher Scientific, Cincinatti, OH). Over the duration of the study these water quality parameters averaged ($\pm$S.D.): water temperature, 27.8$\pm$0.9°C; dissolved oxygen, 5.67$\pm$0.83 mg/l; total ammonia, 0.36$\pm$0.19 mg/l; nitrite, 0.27$\pm$0.55 mg/l; total alkalinity, 119.2$\pm$29.7 mg/l; chlorides, 621$\pm$147 mg/l; pH, 7.88$\pm$0.33.

Juvenile channel catfish, *Ictalurus punctatus* (mean individual weight of 11.0 g) were randomly stocked into all aquaria at a rate of 10 fish per aquarium, with four replications per treatment. Fish from each aquarium were weighed at the beginning of the experiment and then every 2 weeks until the conclusion of the feeding trial. Total length of each fish was measured at the beginning and the conclusion of the experiment. All fish were fed twice daily (07.30 and 16.00 h) to satiation for 12 weeks. At the start and conclusion of the feeding trial, a number of fish were sacrificed by decapitation (20 fish at stocking and five fish per aquarium at conclusion), homogenized in a blender, stored in polyethylene bags, and frozen for subsequent protein and lipid analysis as previously described. After homogenization, a 15-g sample was weighed and dried in a drying oven (95°C for 24 h) for moisture determination.

Statistical analysis

Growth performance and food conversion were measured in terms of final individual fish weight (g), total length (mm), survival (%), specific growth

rate (SGR, %/day), food conversion ratio (FCR), and weight gain (%). Growth response parameters were calculated as follows: SGR (%/day) = (log W_t − log W_i/T) × 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 = total dry diet fed (g)/total wet weight gain (g).

Data were analyzed by analysis of variance (ANOVA) using the SAS ANOVA procedure (Statistical Analysis Systems, 1988). Duncan's multiple range 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).

RESULTS

Weight gains were not significantly different ($P > 0.05$) among channel catfish receiving diets containing 12, 8, 4, and 0% fish meal (Table 2). Juvenile channel catfish had an average individual weight gain of 40.2 g. Amino acid supplementation with 0.4% crystalline L-lysine and 0.1% L-methionine in a diet containing 0% fish meal did not significantly ($P > 0.05$) improve channel catfish growth compared to fish fed other diets. Final individual weight was not significantly different ($P > 0.05$) among treatments and averaged 51.7 g overall. Total length of channel catfish averaged 175 mm and was not significantly different ($P > 0.05$) among treatments.

Survival was 97% or better for each treatment and did not differ significantly ($P > 0.05$) among treatments (Table 2). Specific growth rate (SGR) was not significantly different ($P > 0.05$) among treatments and averaged

TABLE 2

Effect of feeding diets with decreasing percentages of fish meal in channel catfish[1]

	Diet (% fish meal)				
	12	8	4	0	0+AA[2]
Initial wt. (g)	11.45 ± 0.14^{ab}	12.05 ± 0.45^{ab}	12.37 ± 0.14^{a}	11.59 ± 0.59^{ab}	10.32 ± 0.58^{b}
Final wt. (g)	53.00 ± 5.00	54.57 ± 4.15	49.09 ± 3.01	49.29 ± 5.57	52.35 ± 4.79
Weight gain (g)	41.55 ± 4.00	42.48 ± 4.12	36.72 ± 2.94	38.03 ± 6.43	42.04 ± 4.36
Weight gain (%)	361.8 ± 39.1	354.0 ± 36.9	296.5 ± 22.4	337.0 ± 54.9	406.0 ± 34.2
Total length (mm)	178.2 ± 5.61	180.4 ± 2.55	171.0 ± 3.23	171.2 ± 5.46	177.0 ± 4.41
Survival (%)	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	97.5 ± 2.5	100.0 ± 0.0
SGR[3]	1.90 ± 0.11	1.88 ± 0.09	1.72 ± 0.07	1.78 ± 0.14	2.02 ± 0.08
FCR[4]	2.16 ± 0.26	2.09 ± 0.11	2.29 ± 0.10	2.36 ± 0.34	2.05 ± 0.13

[1]Values are means ± s.e. for four replications. Means within a row having the same superscript were not significantly different ($P > 0.05$).
[2]Diet 5 was otherwise identical to diet 4 except 0.4% crystalline L-lysine and 0.1% crystalline L-methionine were added.
[3]SGR, specific growth rate (%/day) = 100(log W_t − log W_i)/culture period.
[4]FCR, food conversion ratio = total dry diet fed (g)/total wet weight gain (g).

1.9%/day. Food conversion ratio (FCR) values of fish fed all diets were not significantly different ($P>0.05$) and averaged 2.2:1. All diets were readily consumed.

Whole body proximate composition at the conclusion of the feeding trial resulted in no significant differences ($P>0.05$) in percentage moisture and lipid among fish fed the five diets and averaged 70.3 and 29.1%, respectively. Percentage protein was significantly higher ($P<0.05$) in fish fed diet 1 (12% fish meal), 55.9%, than in fish fed diet 2 (8% fish meal) and diet 4 (0% fish meal), 49.4 and 48.6%, respectively, but not significantly different ($P>0.05$) from fish fed diets 3 and 5, 50.1 and 54.3%, respectively.

DISCUSSION

The present study indicates that a combination of two plant protein sources (distillers grains with solubles and soybean meal) can totally replace fish meal in a channel catfish diet without adverse effects on growth and survival. In this study, growth performances and food conversions of fish fed a diet containing 0% fish meal were not different from fish fed a high-quality diet, similar to commercial formulations, containing a high percentage (12%) of fish meal. Diets used in the present study met all amino acid, vitamin, and mineral requirements of channel catfish (NRC, 1983) and fatty acid requirements (Satoh et al., 1989). Growth rates in fish fed the control diet were similar to published values for channel catfish reared at similar water temperatures (Chappell, 1979; Mohsen and Lovell, 1990; Gannam and Lovell, 1991).

The use of plant protein sources to partially or entirely replace fish meal in diets has been an interest of fish nutritionists for several years. Soybean meal has been the plant protein source most widely used. However, reduced growth in some fish species has been reported as soybean meal level was increased. It has been reported that totally replacing fish meal with soybean meal resulted in lower growth rates in common carp, *Cyprinus carpio* (Viola et al., 1983), tilapia (Shiau et al., 1987), and channel catfish (Lovell et al., 1974; Robinson et al., 1981). This may be due to protease inhibitors present in soybean meal (Wilson and Poe, 1985). Viola et al. (1983) stated that growth in carp was reduced when fed diets with insufficiently heated soybean meal to destroy trypsin inhibitors. When soybean meal was properly heated, growth in carp was similar to fish fed a control diet. Shiau et al. (1987) reported that 30% of fish meal could be replaced by soybean meal when the dietary protein level was 24% for tilapia (*Oreochromis niloticus*×*O. aureus*), but not when the dietary protein level was 32%. Dabrowski et al. (1989) stated that the lower growth rate may be due to reduced amino acid availability in diets with a high percentage (>50%) of soybean meal.

Cottonseed meal (CSM) has been added to channel catfish diets, partially replacing soybean meal (Robinson, 1991). Toxic effects of free gossypol,

found in CSM, are currently not a limiting factor (Robinson and Brent, 1989). However, free gossypol lowers protein quality of CSM by binding lysine during heating and the extrusion process (Robinson and Brent, 1989) requiring lysine supplementation if CSM is added to a channel catfish diet in excess of 30% (Robinson, 1991). Distillers grains with solubles have been shown to be a good diet ingredient for channel catfish at levels up to 35–40% of the diet without lysine supplementation (Tidwell et al., 1990; Webster et al., 1991, and in press).

In the present study, when fish meal was completely replaced by soybean meal and DGS, there may be a trend toward reduced growth. Although growth of fish fed diets with 0% and 4% fish meal was not significantly different from that of fish fed diets with 8% and 12% fish meal, the reduced weight gains may be of note. Fish fed a diet with 0% fish meal and supplemental lysine showed improved weight gain. This is in agreement with other studies that have shown that channel catfish can utilize crystalline lysine (Robinson, 1991; Webster et al., 1991).

Food conversion ratio values (FRC) was not different among treatments, but were slightly higher than reported in the literature (Mohsen and Lovell, 1990; Robinson, 1991); however, they were consistent with FCR values reported in other studies (Tidwell et al., 1990; Webster et al., 1991). The somewhat higher FCR values may be due to the use of small (37.5-l) aquaria. Fish tend to agitate the water during feeding and may break apart diet pellets rapidly. Small particles of diet could then be removed through the standpipe, skewing FCR values upward.

The results of the present study indicate that a diet with 0% fish meal, 35% DGS, and 49% soybean meal may support weight gains in channel catfish juveniles similar to diets with a high percentage (12%) of fish meal. Since fish meal is one of the most expensive diet ingredients in a prepared diet, use of less expensive plant protein sources may allow ingredient flexibility in least-cost diet formulation, and possibly increase profits for producers. Further research to evaluate diets containing DGS and soybean meal as total replacements for fish meal should be conducted in ponds.

ACKNOWLEDGEMENTS

We thank Eddie Reed for his technical assistance and John Sedlacek for use of his laboratory. Distillers grains with solubles were donated by The House of Seagram, Jim Beam, Hiram Walker, Archer Daniels Midland, Midwest Grain Products, Wild Turkey, Grain Processing Corp., and South Point Ethanol. This research was supported in part by a grant from the Distillers Feed Research Council, Des Moines, IA, and a USDA/CSRS grant to Kentucky State University under agreement KYX-89-88-03A.

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