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[Article]

Growth Response and Feed Utilization of Juvenile Hybrid Catfish Fed Diets Containing Distiller's Dried Grains with Solubles to Replace a Combination of Soybean Meal and Corn Meal

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Abstract.—A feeding trial was conducted in aquaria with juvenile hybrid catfish (channel catfish *Ictalurus punctatus* × blue catfish *I. furcatus*) to evaluate distiller's dried grains with solubles (DDGS) as a replacement for a combination of soybean meal (SBM) and corn meal (CM). Twenty-five 75-L glass aquaria were each stocked with 30 juvenile hybrid catfish (initial weight = 1.16–1.25 g). Five replicates were randomly assigned to each of five dietary treatments. Diet 1, the basal diet, contained 32% SBM and 20% CM (no DDGS and no lysine supplementation) and was based on a practical diet formulated for channel catfish. Diet 2 contained 20% DDGS and 0% lysine supplementation; diet 3 contained 20% DDGS and 0.10% lysine supplementation; diet 4 contained 30% DDGS and 0% lysine supplementation; and diet 5 contained 30% DDGS and 0.20% lysine supplementation. Fish were fed at a restricted rate equaling 5% of wet body weight twice daily for 8 weeks. There were no significant differences in percent weight gain or final weight among the four treatments with DDGS supplements. However, weight gain and final weights of fish offered diet 1 were significantly poorer than those of fish offered diets 3–5. These diets also produced significantly lower feed conversion ratios and higher protein efficiency ratios than diet 1. Results of the present study indicate that the diets formulated with 30% DDGS using the reported combination of other protein sources were not deficient in lysine and supported good growth and feed utilization in juvenile hybrid catfish.

Feed is generally the largest expenditure in semi-intensive and intensive fish culture operations, and protein is the most expensive component of feeds. Efforts to reduce feed costs have resulted in increased use of plant proteins as replacements for expensive animal ingredients, especially fish meal, in diet formulations. Because of its high protein content, high digestibility, relatively well-balanced amino acid profile, reasonable price, and steady supply, soybean meal (SBM) is widely used as a cost-effective feed ingredient for many aquaculture animals (Storebakken et al. 2000). However, other plant protein sources generally cost less than both fish meal and SBM; thus, replacing SBM with less-expensive plant protein sources would be beneficial in reducing feed costs.

Distiller's dried grains with solubles (DDGS) constitute a coproduct of the ethanol distillery industry. As a result of the recent expansion and increase in ethanol production for fuels and to reduce pollution, the production of DDGS in the USA increased to more than 7 million metric tons in 2006 (Shurson 2006). This product has a relatively high protein content (~30% crude protein) without the presence of antinutritional factors commonly found in most plant protein sources. Results of earlier studies have shown that based on growth performance and feed utilization efficiency, the DDGS product is a promising feed ingredient for several fish species, including rainbow trout *Oncorhynchus mykiss* (Cheng and Hardy 2004),

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tilapias *Oreochromis* spp. (Wu et al. 1996), and channel catfish *Ictalurus punctatus* (Lovell 1980; Tidwell et al. 1990; Webster et al. 1991, 1992, 1993).

At least four species of ictalurid catfishes have been considered as candidates for commercial aquaculture in the USA. Channel catfish and blue catfish *I. furcatus* are the best two species for aquaculture (Tucker and Robinson 1990; Dunham et al. 1993). Compared with blue catfish, the channel catfish has faster growth-to-market size, better tolerance for low dissolved oxygen, and superior resistance to some diseases (e.g., columnaris). However, the blue catfish also has superior resistance to certain diseases (e.g., enteric septicemia of catfish), has better carcass traits, and is easier to harvest by seine (Dunham and Argue 2000). Research on hybrids of female channel catfish × male blue catfish has demonstrated that they exhibit many commercially desirable characteristics. Compared with most commercially cultured strains of channel catfish, this hybrid exhibits superior characteristics for the following traits: faster growth, tolerance of low dissolved oxygen, increased resistance to many diseases, tolerance to crowded growth conditions in ponds, uniformity in size and shape, higher dress-out percentages, and increased harvestability by seining (Wolters et al. 1996; Masser and Dunham 1998). Published data on the nutrition of channel catfish × blue catfish hybrids are limited. The objective of this study was to investigate the growth response and feed utilization of juvenile channel catfish × blue catfish hybrids (hereafter, hybrid catfish) fed diets containing 20% and 30% DDGS with and without lysine supplementation as replacements for a combination of SBM and corn meal (CM) in the basal diet.

Methods

Diet preparation.—Due to a lack of basic data on nutrient requirements for hybrid catfish, a practical diet formula for channel catfish was used as the basal diet in the present study. Five isonitrogenous experimental diets were formulated to contain 32% protein and 6% lipid (as fed). The upper limit to DDGS was set at 30% due to processing considerations and possible degradation of pellet quality when using higher inclusion levels. Treatments (diets 1–5) consisted of the basal diet and four diets containing 20% or 30% DDGS with and without the addition of lysine as partial replacements for a mixture of SBM and CM on an equal protein basis (Table 1). Diet 1 (basal diet) contained no DDGS and no lysine supplementation; diet 2 contained 20% DDGS and 0% lysine supplementation; diet 3 contained 20% DDGS and 0.10% lysine supplementation; diet 4 contained 30% DDGS and 0% lysine supplementation; and diet 5 contained 30% DDGS and 0.20% lysine supplementation. Fish oil was added to keep lipid levels consistent in all diets. Diets were extruded into floating pellets by Zeigler Brothers, Inc. (Gardners, Pennsylvania). The proximate composition and amino acid composition of the diets were analyzed by the New Jersey Feed Laboratory, Inc., Trenton, following procedures of the Association of Official Analytical Chemists (AOAC 1995) and are presented in Tables 1 and 2, respectively.

Fish rearing.—Juvenile hybrid catfish were obtained from a mix of spawns. Before the start of the feeding trial, fish were acclimated to the experimental conditions and fed the basal diet for 3 weeks in an indoor recirculating water system. Fish (average weight = 1.16–1.25 g) were randomly stocked into twenty-five 75-L glass aquaria at a density of 30 fish/aquarium. Aquaria were supplied with flow-through dechlorinated tap water with continuous aeration to maintain the dissolved oxygen level above saturation. Fish in quintuplicate aquaria were randomly assigned to each of the five experimental diets and were fed at a daily rate of 5% of body weight divided into two daily offerings (between 0800 and 0900 hours and between 1400 and 1500 hours) for 8 weeks. Fish in each aquarium were group weighed and counted every 2 weeks. During the feeding trial, water temperature was maintained at 24–29°C and pH was maintained at 7.2–8.5. Dissolved oxygen was not less than 5 mg/L, and levels of free ammonia and nitrite were negligible.

Data calculations and statistical analysis.—At the termination of the 8-week feeding trial, fish in each aquarium were weighed (each replicate was group weighed) and counted. Growth and feed utilization were calculated and expressed as follows:

$$\text{percent weight gain (\% WG)} = 100 \times [(\text{final weight} - \text{intial weight})/\text{initial weight}],$$

$$\text{feed conversion ratio (FCR)} = \text{feed offered (g)}/\text{weight gain (g)},$$

and

$$\text{protein efficiency ratio (PER)} = \text{weight gain (g)}/\text{protein offered (g)}.$$

The Statistical Analysis System version 8.01 (SAS Institute, Inc., Cary, North Carolina) was used for all statistical evaluations. All data were analyzed using one-way analysis of variance followed by Duncan's multiple-range test when appropriate to identify specific differences in treatment means. The level of significance was set at 0.05.

TABLE 1.—Ingredient and proximate composition (% dry matter) of five experimental diets for juvenile hybrid catfish.

Ingredient or proximate component	0% DDGS	20% DDGS	20% DDGS + lysine	30% DDGS	30% DDGS + lysine
Ingredient (% dry matter)					
Soybean meal	32.00	24.00	24.00	20.00	20.00
DDGS[a]	0.00	20.00	20.00	30.00	30.00
Wheat middlings	21.79	16.00	16.00	9.99	9.79
Corn meal	20.00	15.00	15.00	16.00	16.00
Cottonseed meal	15.00	14.99	14.89	15.00	15.00
Poultry by-product meal (67% protein)	5.60	5.40	5.40	5.40	5.40
Blood meal (92% protein)	2.00	2.00	2.00	2.00	2.00
Fish oil	2.00	1.00	1.00	0.00	0.00
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00
Calcium propionate	0.25	0.25	0.25	0.25	0.25
Vitamin premix[b]	0.20	0.20	0.20	0.20	0.20
Mineral premix[b]	0.10	0.10	0.10	0.10	0.10
Stay-C (35% active)	0.06	0.06	0.06	0.06	0.06
Lysine	0.00	0.00	0.10	0.00	0.20
Proximate composition (% dry weight)					
Crude protein	35.0	34.2	34.8	35.0	34.0
Crude lipid	6.8	6.6	6.6	7.1	6.6
Fiber	5.5	5.7	5.8	5.8	5.9
Ash	6.3	6.2	6.2	6.1	5.7
Lysine (% protein)	5.4	5.0	5.1	4.7	4.8
Methionine + cysteine (% protein)	3.4	3.6	3.5	3.5	3.3

[a] DDGS = distiller's dried grains with solubles.
[b] Vitamin and mineral premixes (DSM, Inc., Parsippany, New Jersey).

Results

The proximate composition and amino acid composition of experimental diets are presented in Tables 1 and 2, respectively. Lysine levels ranged from 1.58% to 1.81% of the diet (dry weight basis), and methionine ranged from 0.58% to 0.62%.

At the conclusion of the 8-week growth trial, survival ranged from 97.3% to 100.0%, but the

TABLE 2.—Amino acid composition in experimental diets used for juvenile hybrid catfish. Diets contained various percentages of distiller's dried grain with solubles (DDGS).

Amino acid	0% DDGS	20% DDGS	20% DDGS + lysine	30% DDGS	30% DDGS + lysine
As % dry diet					
Methionine	0.60	0.62	0.62	0.61	0.58
Cysteine	0.55	0.55	0.55	0.55	0.51
Lysine	1.81	1.63	1.67	1.58	1.58
Phenylalanine	1.69	1.65	1.69	1.67	1.67
Leucine	2.63	2.73	2.85	2.90	3.00
Isoleucine	1.28	1.22	1.36	1.30	1.29
Threonine	1.32	1.28	1.28	1.32	1.28
Valine	1.52	1.48	1.59	1.57	1.50
Histidine	0.88	0.89	0.87	0.88	0.87
Arginine	2.56	2.28	2.41	2.31	2.33
Glycine	1.82	1.71	1.72	1.77	1.68
Aspartic acid	3.61	3.34	3.35	3.33	3.22
Serine	1.77	1.71	1.68	1.72	1.66
Glutamic acid	6.49	6.54	6.19	6.59	6.36
Proline	1.81	1.95	1.91	2.08	1.97
Hydroxyproline	0.20	0.22	0.23	0.23	0.24
Alanine	2.07	2.00	2.19	2.31	2.04
Tyrosine	0.84	0.87	0.90	0.86	0.89
Total	33.45	32.67	33.06	33.58	32.67
As % protein					
Lysine	5.41	4.99	5.05	4.71	4.84
Methionine	1.79	1.90	1.88	1.82	1.78
Methionine + cysteine	3.44	3.58	3.54	3.45	3.34

TABLE 3.—Growth performance and feed utilization in juvenile channel catfish × blue catfish hybrids given five experimental diets containing various percentages of distiller's dried grains with solubles (DDGS). Within a row, different letters indicate significant differences ($P < 0.05$).

	Experimental diet						
Variable	0% DDGS	20% DDGS	20% DDGS + lysine	30% DDGS	30% DDGS + lysine	PSE[a]	*P*
Survival (%)	100.0	100.0	98.0	97.3	98.7	0.42	0.174
Initial weight (g)	1.25	1.17	1.18	1.16	1.17	0.02	0.600
Final weight (g)	7.42 z	7.54 zy	8.21 yx	8.39 x	8.67 x	0.14	0.006
WG (%)[b]	500.8 z	546.7 zy	597.9 y	624.1 y	643.2 y	16.34	0.021
FCR[c]	2.07 x	1.97 yx	1.78 zy	1.73 z	1.74 z	0.04	0.009
PER[d]	1.40 z	1.49 zy	1.62 yx	1.66 yx	1.69 x	0.03	0.007

[a] PSE = pooled SE = $\sqrt{\text{MSE}/n}$ (where MSE = mean-squared error).
[b] WG = weight gain (%) = 100 × [(final weight – initial weight)/initial weight].
[c] FCR = feed conversion ratio = feed offered (g)/weight gain (g).
[d] PER = protein efficiency ratio = weight gain (g)/protein offered (g).

differences were not significant among the dietary treatments ($P = 0.174$) (Table 3). Compared with fish offered diet 1 (basal) and diet 2 (20% DDGS, no lysine supplementation), the hybrid catfish that received diet 4 (30% DDGS, no lysine supplementation) and diet 5 (30% DDGS, 0.20% lysine supplementation) had significantly ($P = 0.006$) higher final body weights. There were no significant differences in %WG among fish offered diets 2–5. However, %WG of fish fed diets 4 and 5 was significantly ($P = 0.021$) higher than that of fish fed diet 1. Furthermore, fish fed diet 5 had the highest %WG (643.17%).

There were no significant differences in FCR among fish maintained on diets 3–5. However, FCRs of fish that were fed diets 4 and 5 were significantly ($P = 0.009$) lower than those of fish that received diets 1 and 2. Diet 5 also produced the best PER value, which was significantly higher than the PERs obtained from diets 1 and 2 but did not differ from the PERs produced by diets 3 and 4.

Discussion

Most of the published data about channel catfish × blue catfish hybrids focus on spawning, reproduction, and disease resistance (e.g., Wolters et al. 1996; Dunham and Argue 2000; Phelps et al. 2007). Available information on nutrition of this hybrid is limited. Bosworth et al. (1998) fed diets containing 25% and 45% protein to channel catfish × blue catfish hybrids for 10 weeks and found that hybrids receiving the low-protein diet had better growth and feed efficiency than hybrids receiving the high-protein diet. Li et al. (2007) evaluated the response of channel catfish × blue catfish hybrids to three levels of protein under practical pond production conditions. They observed no difference in production, although fillet yield was higher in fish offered a 36% protein diet compared with fish that were offered 28% and 32% protein diets. Because of a lack of basic data on nutrient requirements for hybrid catfish, a practical diet for channel catfish was used as the basal diet in the present study. Results of this study indicated that even though the differences were not always significant, hybrid catfish growth performance (final weight and %WG) and feed utilization efficiency (FCR and PER) appeared to increase with increasing inclusion of DDGS to replace SBM and CM. These performance measures, however, significantly improved relative to the basal (control) diet when the dietary DDGS level was increased to 30%, regardless of lysine supplementation level. This generally agrees with previous studies showing that 30–35% DDGS could be used to partially replace SBM in channel catfish diets (Tidwell et al. 1990; Webster et al. 1991, 1992, 1993; Robinson and Li 2008). Concentrations of lysine (1.58–1.81% of the diet or 5.41–4.71% of protein), methionine (0.58–0.62% of the diet or 1.71–1.88% of protein), and total sulfur amino acids (1.09–1.17% of the diet or 3.34–3.58% of protein) in our five experimental diets are presented in Table 2. Channel catfish requirements for lysine (about 1.5% of the diet or 5.0% of protein: Robinson et al. 1980) and methionine in the absence of cystine (about 0.56% of the diet or 2.35% of protein: Harding et al. 1977) have been reported. Clearly, methionine or total sulfur amino acids in our experimental diets are not limiting, but lysine could be limiting. Based on growth performance and feed utilization efficiency obtained in the present study, both lysine and methionine (total sulfur amino acids) were not limiting amino acids in hybrid catfish diets containing up to 30% DDGS.

Improved utilization efficiency (FCR and PER) of

diets containing 30% DDGS with or without lysine supplementation (diets 4 and 5) generally agreed with the results of Robinson and Li (2008), who obtained significantly better FCRs in channel catfish fed an SBM plus DDGS diet compared with those fed an SBM basal diet. However, this has not been seen in previous studies (Webster et al. 1991, 1992, 1993; Robinson and Li 2005; Lim et al. 2009). Robinson and Li (2008) ascribed this difference to the underestimation of digestible energy for DDGS. The reason for the increased PER and decreased FCR associated with the hybrid catfish diets containing DDGS in the present study cannot be ascertained. Ingledew (1999) estimated that 3.9% of the total biomass of DDGS was yeast, with 5.3% of the protein content contributed by yeast protein. Yeasts are rich in protein, B-complex vitamins, and β-glucans. Therefore, fermentation could increase the digestibility of plant dietary protein sources. However, comparative studies on the digestibility of some dietary protein sources, such as DDGS, SBM, CM, and cottonseed meal, are needed to improve the feed formula for hybrid catfish.

In conclusion, DDGS (at least at levels up to 30%) appear to be suitable for replacing SBM and CM in hybrid catfish diets without the need for lysine supplementation. Future research should evaluate the nutritional influence of higher inclusion levels of DDGS and their effects on diet processing and potential negative effects on pellet quality.

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