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[Article]

Pond Demonstration of Production Diets Using High Levels of Distiller's Dried Grains with Solubles with or without Lysine Supplementation for Channel Catfish

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Abstract.—Due to the increased availability and potential price advantage of distiller's dried grains with solubles (DDGS), there is considerable interest in utilizing this product in aquaculture diets. The response of channel catfish *Ictalurus punctatus* to practical diets containing 20% and 30% DDGS with and without lysine supplementation was evaluated over a 150-d pond trial. Twenty earthen ponds were stocked with 650 juvenile channel catfish. The basal diet contained 35% soybean meal, 15% cottonseed meal, and 23.7% corn meal and was based on a typical practical diet formulation for channel catfish. The experimental diets, which were formulated to contain 32% protein and 6% lipid, were as follows: diet 1 (control [basal] diet) contained 0% DDGS and 0% lysine; diet 2 included 20% DDGS and 0% lysine; diet 3 contained 20% DDGS and 0.10% lysine; diet 4 contained 30% DDGS and 0% lysine; and diet 5 included 30% DDGS and 0.20% lysine. There were no significant differences in the measured variables (i.e., final weight, weight gain, yield, survival, and feed conversion ratio) among the dietary treatments, indicating that diets containing a soybean meal–corn meal mixture and 30% DDGS without lysine supplementation allow for good growth and feed utilization in pond-produced channel catfish.

Feed is generally the largest expenditure in semi-intensive and intensive catfish culture operations, and protein is the most expensive component of feeds. Efforts to reduce feed costs have resulted in increased use of plant proteins in diet formulations as replacements of expensive animal ingredients. Because of its low cost, consistent quality, availability, and high nutritional value, soybean meal (SBM) is the most commonly used plant protein source in fish feeds. Currently, SBM comprises 30–40% of the formulation in commercial grow-out feeds for catfish. Replacement of SBM with less-expensive protein sources would be beneficial in reducing feed costs. Distiller's dried grains with solubles (DDGS) are a co-product of the ethanol distillery industry and are typically less expensive than SBM on a per-unit-protein basis. In 2001, about 2.8 million metric tons of DDGS were produced in the United States. The recent expansion and increase in fuel ethanol production (i.e., due to the shortage and rising cost of petroleum-based fuel and to reduce pollution) have resulted in higher DDGS production; United States DDGS production was approximately 8 million tons in 2006 (Shurson 2006).

The DDGS product has a moderate protein content (~30% crude protein) with fewer antinutritional factors but a higher fiber content than is found in commonly used plant protein sources. At present, DDGS are widely used as a protein supplement in terrestrial animal feeds, but the use of DDGS in fish feed is limited due to the product's low content of essential amino acids, most notably lysine (NRC 1993). Results of earlier studies, however, have shown that based on growth performance and feed utilization efficiency, DDGS constitute a promising ingredient in feeds for several fish species, including rainbow trout *Oncorhynchus mykiss* (Cheng and Hardy 2004), channel catfish *Ictalurus punctatus* (Lovell 1980; Tidwell et al. 1990; Webster et al. 1991, 1992a, 1992b; 1993; Lim et al. 2009), and tilapias *Oreochromis* spp. (Wu et al. 1996; Lim et al. 2007; Lim and Yildirim-Aksoy 2008; Shelby et al. 2008). A recent laboratory study by Lim et al. (2009) showed that with lysine supplementation,

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TABLE 1.—Ingredient and analyzed composition of experimental diets for channel catfish. See Methods for additional description of diets.

Ingredient or component	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Ingredient (g/kg)					
Soybean meal	320.0	240.0	240.0	200.0	200.0
DDGS[a]	0.00	200.0	200.0	300.0	300.0
Wheat middlings	217.9	160.0	160.0	99.9	97.9
Corn meal	200.0	150.0	150.0	160.0	160.0
Cottonseed meal	150.0	149.9	148.9	150.0	150.0
Poultry by-product meal, 67% protein	56.0	54.0	54.0	54.0	54.0
Blood meal, 92% protein	20.0	20.0	20.0	20.0	20.0
Herring fish oil	20.0	10.0	10.0	0.00	0.00
Dicalcium phosphate	10.0	10.0	10.0	10.0	10.0
Calcium propionate	2.50	2.50	2.50	2.50	2.50
Vitamin premix[b]	2.00	2.00	2.00	2.00	2.00
Mineral premix[b]	1.00	1.00	1.00	1.00	1.00
Stay-C, 35% active	0.60	0.60	0.60	0.60	0.60
Lysine	0.00	0.00	1.00	0.00	2.00
Proximate component (% as-is basis)					
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[c]	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).
[c] (Amino acid content/total amino acids) × 100.

DDGS at dietary levels ranging from 10% to 40% can be used to replace an SBM–corn meal mixture without affecting the growth or feed utilization efficiency of channel catfish. The cost of feed can be further reduced if lysine supplementation can be omitted from the formulation.

Currently, there is considerable interest in the use of DDGS in commercial catfish feeds. However, there is limited information on the use of high levels of DDGS and the need for lysine supplementation. In addition, although a number of cage and laboratory studies have evaluated the use of DDGS, there are few pond production studies verifying the use of high levels of DDGS in channel catfish diets. Hence, the objective of this study was to determine whether lysine supplementation is required in commercial channel catfish grow-out diets containing high levels of DDGS (20% and 30%) to replace a mixture of SBM and corn meal.

Methods

This trial was conducted at the E. W. Shell Fisheries Station, Auburn, Alabama, using twenty 0.04-ha (0.1-acre), rectangular earthen ponds with sloping bottoms and depths ranging from 0.6 to 1.2 m. Each pond had two separate water supply lines for independent filling from the catch basin or the shallow end of the pond. Ponds were sun-dried for 1 week before stocking; they were then filled with 0.6 m of water, and copper sulfate was applied for 4 d to prevent the growth of aquatic weeds. The ponds were then drained, dried for 2 d, filled, and treated with quick lime to increase water alkalinity. Water originating from a hillside reservoir pond that receives runoff from the station's watershed was used as the water supply.

Five experimental diets were formulated to contain 32% protein and 6% lipid (Table 1). The upper limit of DDGS supplementation was set at 30% due to processing considerations and possible degradation of pellet quality when using higher inclusion levels (Lim 2007). The diets consisted of a basal (control) diet and four test diets containing 20% or 30% DDGS with or without the addition of lysine. The DDGS component was used on an equal protein basis to replace a mixture of SBM and corn meal (Table 1). The diets were designated as follows: diet 1 was the basal diet; diet 2 contained 20% DDGS without lysine supplementation; diet 3 contained 20% DDGS with 0.10% lysine; diet 4 included 30% DDGS without lysine supplementation; and diet 5 included 30% DDGS with 0.20% lysine. Fish oil was adjusted to maintain lipid at the same level in all diets. Soybean meal was used to add protein; corn meal was added as a source of starch and to improve pellet stability. Wheat middlings were also varied to allow for DDGS addition. Diets were extruded into floating pellets by Zeigler Brothers, Inc. (Gardners, Pennsylvania), and were transported and stored in plastic-lined paper bags. A pooled sample from over 15 bags of each diet was collected, and the proximate

TABLE 2.—Amino acid composition (g/kg) of the experimental diets (see Methods) for channel catfish.

Amino acid	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Methionine	6.00	6.20	6.20	6.10	5.80
Cysteine	5.50	5.50	5.50	5.50	5.10
Lysine	18.1	16.3	16.7	15.8	15.8
Phenylalanine	16.9	16.5	16.9	16.7	16.7
Leucine	26.3	27.3	28.5	29.0	30.0
Isoleucine	12.8	12.2	13.6	13.0	12.9
Threonine	13.2	12.8	12.8	13.2	12.8
Valine	15.2	14.8	15.9	15.7	15.0
Histidine	8.80	8.90	8.70	8.80	8.70
Arginine	25.6	22.8	24.1	23.1	23.3
Glycine	18.2	17.1	17.2	17.7	16.8
Aspartic acid	36.1	33.4	33.5	33.3	32.2
Serine	17.7	17.1	16.8	17.2	16.6
Glutamic acid	60.5	65.4	61.9	65.9	63.6
Proline	18.1	19.5	19.1	20.8	19.7
Hydroxyproline	2.00	2.20	2.30	2.30	2.40
Alanine	20.7	20.0	21.9	23.1	20.4
Tyrosine	8.40	8.70	9.00	8.60	8.90
Total	334.5	326.7	330.6	335.8	326.7

composition (Table 1) and amino acid composition (Table 2) of the diets were analyzed by the New Jersey Feed Laboratory, Inc. (Trenton, New Jersey), according to standard procedures (AOAC 1995). A pellet binder containing nitrogen was also included in the diets, resulting in a 2% increase of the analyzed protein.

Channel catfish juveniles were obtained from a commercial fingerling producer in Mississippi. Before juveniles were stocked into experimental ponds, they were treated with formalin to reduce disease transmission. An initial sample of 60 fingerlings was randomly collected to determine the average initial weight, total length, and size distribution. Based on the relationship between length and weight, all juveniles were judged as thin; the condition factor (100 × [weight, g]/[length, cm]^3) of every fish was less than 1.0. The standard length–weight relationship comes from the published values by Tucker et al. (2004). Juvenile channel catfish were manually sorted into three groups based on length: (1) less than 12.7 cm (<5 in); (2) 12.7–15.2 cm (5–6 in); and (3) greater than 15.2 cm (>6 in). Equal numbers of fish from each group were then stocked into 20 ponds at a rate of 650 fish/pond (16,250 fish/ha [6,500 fish/acre]). During the first 5 d after stocking, mortalities were collected and replaced with similar-sized fish.

Feed was offered once daily in the afternoon. A fixed quantity of feed was preweighed for each pond based on estimated feed intake. Feed was then offered slowly to satiation, with daily rations adjusted as needed based on (1) fish behavior or response and (2) the desire to avoid overfeeding. Water temperature and dissolved oxygen (DO) concentrations were monitored twice daily (at about 0600 and 1700 hours) using a YSI Model 55 DO meter (Yellow Springs Instruments, Inc., Yellow Springs, Ohio). Water samples were collected every 2 weeks for total ammonia nitrogen (TAN) analysis, and pH was checked once weekly using pH test strips. Morning DO levels in ponds were maintained above 3 mg/L by using 0.5-hp floating vertical pump aerators.

The fish were cultured from May 22 to October 21, 2008, with feed being offered throughout the entire 150-d period. Prior to harvest, the water level was lowered to 0.6 m in all ponds. The harvest process included counting and group weighing of the fish. Samples of 40 fish were randomly collected from each pond for the determination of individual weights and lengths. Fish were first removed by seining the ponds, followed by drain-harvesting of fish concentrated into the catch basin. After harvest, five fish from each pond were also collected for determination of fillet proximate composition (AOAC 1995). Survival (%), final weight, final biomass, final average length, weight gain (100 × [final weight − initial weight]/initial weight), feed conversion ratio (FCR), and yield were determined for each pond.

The collected data were analyzed for statistical differences using the Statistical Analysis System (SAS Institute, Inc., Cary, North Carolina). Data were analyzed by one-way analysis of variance and the Student–Newman–Keuls test to determine significant ($P \leq 0.05$) differences among treatment means.

Results

Throughout the study, the means (±SD) of water quality variables (temperature: 26.5 ± 2.63°C; DO: 4.73 ± 1.08 mg/L; pH: 7.8 ± 0.3; TAN: 0.12 ± 0.12 mg/L) remained within acceptable limits for channel

TABLE 3.—Growth performance of channel catfish fed experimental diets (see Methods) containing various levels of distiller's dried grains with solubles, with or without lysine supplementation, for 150 d.

Variable	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	PSE[a]	*P*
Initial weight (g)	86.7	87.5	85.7	86.7	86.1	1.03	0.786
Yield (kg/ha)	5,838	5,661	6,220	5,779	5,766	238.1	0.535
Survival (%)	73.5	73.2	80.2	73.3	77.0	0.035	0.548
Final weight (g)	498.8	481.7	482.2	491.4	468.6	17.78	0.799
Weight gain (%)	474.8	450.7	461.4	467.1	444.5	8.59	0.732
Final biomass (kg)	236.3	229.2	251.8	234.0	233.4	9.64	0.535
Feed conversion ratio	1.7	1.9	1.7	1.9	1.9	0.077	0.151

[a] PSE = pooled SE.

catfish grow out in ponds (Tucker et al. 2004). Overall, growth performance of channel catfish was very similar among all dietary treatments (Table 3). There were no significant differences noted in survival, final weight, weight gain (%), FCR, or yield after 150 d of culture. Survival ranged from 73.2% to 80.2% in all treatments. Fish offered diets 1 (basal diet) and 3 (20% DDGS with 0.10% lysine) had a slightly lower FCR (1.7) than fish offered diets 2, 4, and 5 (1.9), but the values were not significantly different. Fish offered diet 3 had the highest yield (6,220 kg/ha), survival (80.2%), and weight gain (351.8%) among the treatment groups.

Analysis of fillet proximate composition of channel catfish did not reveal any significant differences among dietary treatments (Table 4). On a wet weight basis, percentages of lipid, ash, and protein were statistically similar across all dietary treatments.

Discussion

Dietary protein requirements for channel catfish have been determined in various studies and range from 24% to 55% (NRC 1993). There are many factors that influence the protein requirements of channel catfish, including differences in size and life stages, digestible energy content of diets, and feed rate. Li and Lovell (1992) reported that 26% dietary protein was adequate for optimum weight gain when channel catfish were fed to satiation, whereas a minimum dietary protein level of 32% was necessary for optimum growth when fish were fed at a predetermined maximum level of 60 kg/ha per day. In the present study, all diets were formulated to contain 32% protein, as this is the protein level currently used by the majority of commercial catfish farms in Alabama.

TABLE 4.—Fillet proximate composition of channel catfish fed diets (see Methods) containing various levels of distiller's dried grains with solubles, with or without lysine supplementation, for 150 d.

		Percent, wet weight basis		
Diet	Moisture (%)	Lipid	Ash	Protein
1	74.85	6.11	1.18	17.75
2	75.46	5.26	1.15	17.60
3	74.89	5.82	1.17	17.54
4	75.53	5.44	1.18	17.53
5	74.51	6.35	1.18	17.83
PSE[a]	0.577	0.573	0.023	0.23
P	0.689	0.653	0.791	0.85

[a] PSE = pooled SE.

To reduce the cost of catfish production diets, some producers have utilized ingredients with a lower-cost protein. Distiller's dried grains with solubles provide a lower-cost protein alternative that has showed promise not only for use with channel catfish, but also for the poultry and swine industries (Whitney et al. 2006; Schilling et al. 2010; Xu et al. 2010). The present study was conducted over 150 d of culture and resulted in a final biomass of approximately 5,550 kg/ha. These yields are typical for channel catfish culture in the southern United States (Tucker et al. 2004). Under the conditions of this study, there were no differences in net yield, final weight, or FCR for fish reared on a typical catfish feed (control diet) or feeds containing 20% and 30% DDGS with or without lysine supplementation in replacement of SBM and corn meal. These results are supported by other studies of various fish species under a variety of culture conditions. A number of laboratory-based studies have evaluated the use of DDGS as an alternative protein source. In a study evaluating the growth response of Nile tilapia *Oreochromis niloticus* fry fed all-plant-protein diets, Wu et al. (1996) reported that incorporation of 16–49% DDGS in diets containing 32, 36, and 40% crude protein resulted in acceptable weight gain. In growth trials conducted in aquaria, Tidwell et al. (1990) and Webster et al. (1991) found that 40% and 35% DDGS, respectively, could be used in channel catfish diets as substitutes for SBM and corn meal on an equal protein basis without requiring lysine supplementation. In a laboratory study of Nile tilapia, Lim et al. (2007) reported that in diets containing 8% menhaden fish meal, increasing the dietary levels of DDGS to 40% without addition of lysine significantly reduced weight gain compared with diets containing lower DDGS levels (0, 10, and 20%). In the same study, FCR of fish offered the 40% DDGS diet was also significantly lower than the FCR of fish offered the control diet. Another laboratory study by Lim et al. (2009) suggested that if lysine is supplemented at a level equal to that in the control diet, 40% DDGS could be included in channel catfish diets containing 8% fish meal without affecting growth and feed efficiency. Li et al. (2009) reported that channel catfish offered a diet containing 300-g/kg DDGS in a 9-week laboratory study had greater diet consumption, weight gain, and feed efficiency ratio compared with a control diet.

There have been relatively few pond trials verifying the use of DDGS in diets for channel catfish over an entire production cycle. Lovell (1980) reported that a DDGS inclusion level of up to 30% in combination with 10% fish meal was successfully used in channel catfish diets under pond culture conditions. In a 110-d cage study conducted in a 1.0-ha pond, Webster et al. (1993) found that 30% DDGS could be used in replacement of an SBM–corn meal mixture in channel catfish diets containing 8% fish meal. Robinson and Li (2008) reported that DDGS levels of up to 22.5% could be used to replace a portion of SBM in diets fed to pond-raised channel catfish. In a pond production trial conducted in Mississippi, Robinson and Li (2008) reported that DDGS levels up to 30% could be used when the diet was supplemented with lysine. In that study (Robinson and Li 2008), channel catfish that were offered diets containing SBM and DDGS had slightly better FCRs but no differences in survival or weight gain when compared with fish offered the control diet that contained only SBM. Our results indicated that even though the animal proteins in experimental diets were supplied by poultry by-product meal and blood meal instead of fish meal, it was possible to incorporate 30% DDGS into pond grow-out diets for channel catfish as a substitute for an SBM–corn meal mixture without requiring lysine supplementation.

Lysine is generally considered to be the first limiting amino acid in diets of channel catfish. If feeds are formulated to meet a minimum lysine requirement, then the requirements for all other amino acids will be met or exceeded if traditional feed ingredients are used. Lysine will probably be the only supplemental amino acid needed in commercial channel catfish feeds (Li et al. 2004). Lysine requirement for optimum growth of juvenile channel catfish was reported as 5.1% of total protein (NRC 1993). In the present study, three diets had lower than the recommended lysine level of 5.1% (diet 2: 5.0%; diet 4: 4.7%; diet 5: 4.8%) and thus would probably have a higher potential to be associated with a lysine deficiency in fish (Table 2). However, in the present study, there were no evident signs of a dietary lysine deficiency.

There are several possible reasons why a deficiency was not observed. One possible explanation is that the fermentation process and the presence of yeast may improve the digestibility of DDGS, thereby improving lysine availability. Ingledew (1999) estimated that 3.9% of the total biomass of DDGS was yeast, with 5.3% of the protein content of this product being contributed by yeast protein. Yeasts are rich in protein, B-complex vitamins, and β-glucans. Therefore, it would be wise for feed mills to analyze micronutrients and other components of DDGS prior to inclusion in commercial diets.

In the present study and the studies by Tidwell et al. (1990) and Webster et al. (1991), it was demonstrated that at least 30% DDGS can be used in channel catfish diets as a substitute for the combination of SBM and corn meal on an equal protein basis without requiring lysine supplementation. In addition to the lack of influence on growth and production in our study, the shift in protein sources caused no differences in fish proximate composition (Table 4). In another study by Webster et al. (1993), no significant differences in carcass proximate composition were observed among channel catfish fed diets containing 0, 10, 20, and 30% DDGS.

Fish that are fed diets containing high levels of DDGS may contain yellow pigments. Li et al. (2009) reported that channel catfish offered diets containing 300-g/kg DDGS and 200-g/kg high-protein distiller's dried grains had 14–17-mg/kg yellow pigments (lutein and zeaxanthin), a level that was higher than the 11-mg/kg threshold for yellow coloration recommended by Lovell (1989). In the study by Li et al. (2009), it was also noted that channel catfish offered 300-g/kg DDGS and 200-g/kg high-protein distiller's dried grains had a yellow color both on their skin and in their fillets when compared with the grayish color of channel catfish offered the control diet. In our study, we did not observe yellow coloration on the skin or fillets of the channel catfish. However, if DDGS or other distiller by-products are utilized by feed manufacturers in commercial diets, the xanthophyll content of the DDGS and the finished feed should be determined. The fish should be closely monitored to ensure that the DDGS levels used do not negatively affect the channel catfish products.

With continued expansion of fermentation processes, the availability of DDGS at cost-effective levels is likely to continue. The inclusion of DDGS in commercial diets for channel catfish appears to be quite promising. Despite the effectiveness of DDGS as a lower-cost alternative protein source, care needs to be taken with regards to monitoring the carotenoid content and amino acid levels of the final diet. The primary disadvantages of DDGS include the low level of lysine and the presence of xanthophylls, which can lead to yellow fillet problems.

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