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Evaluation of corn distillers dried grains with solubles and brewers yeast in diets for channel catfish *Ictalurus punctatus* (Rafinesque)

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Abstract

A study was conducted to examine the use of distillers grains with solubles (DDGS), ethanol extracted DDGS (EDDGS), and brewers yeast in channel catfish, *Ictalurus punctatus*, diets. Diets containing these ingredients were compared with all-plant and fish meal control diets. Juvenile channel catfish (initial weight: 9.1 ± 0.2 g fish^{-1}) were stocked in flow-through aquaria and fed one of six practical diets for 8 weeks. Diets containing 1% brewers yeast or 30% DDGS supported the same level of growth and feed efficiency ratio (FER) as the diet containing 5% fish meal. Ethanol extraction effectively removed most of the fat and yellow pigments in DDGS. The diet containing 30% EDDGS resulted in significantly lower growth and FER compared with the diet containing DDGS. However, the weight gain of fish fed the EDDGS diet was intermediate compared with fish fed the all-plant control, fish meal control, and 1% and 2% brewers yeast diets. The EDDGS could potentially be used at high levels as a substitution for soybean meal without causing yellow pigment deposition in catfish flesh, provided that the ethanol extraction process is proven economical. Brewers yeast, used at 1–2% of the diet, appears to be effective at improving weight gain and FER of channel catfish over the all-plant diet.

Keywords: channel catfish, distillers dried grains, brewers yeast, growth, feed efficiency

Introduction

Distillers dried grains with solubles (DDGS) from corn is a by-product of ethanol production. It is relatively high in protein (27%) and highly palatable to channel catfish, *Ictalurus punctatus*. With the rapid expansion of ethanol production in the United States, the prices for DDGS have become more competitive compared with soybean meal and other plant protein sources. Use of this by-product in catfish feeds would reduce feed cost.

Several studies have been reported on the use of DDGS in channel catfish diets. Early studies demonstrated that up to 35% DDGS without lysine supplementation (Webster, Tidwell & Yancey 1991; Webster, Tidwell, Goodgame, Yancey & Mackey 1992; Webster, Tidwell, Goodgame & Johnsen 1993) and up to 70% with lysine supplementation (Webster *et al.* 1991) could be used to partially replace soybean meal and fish meal in channel catfish diets without affecting fish growth. Recently, Lim, Yildirim-Aksoy and Klesius (2009) also reported no differences in the growth of juvenile channel catfish fed diets containing up to 40% DDGS with supplemental lysine. In a pond study with channel catfish, Robinson and Li (2008) found that up to 30–40% DDGS with supplemental lysine could be used in food fish diets. They noted that feed efficiency ratio (FER) was improved in fish fed diets containing 30–40% DDGS. However, it was not clear whether the improved FER of fish fed diets containing DDGS was caused by the increased dietary fat level, because of high levels of fat (about 9%) contained in the DDGS, or by other compounds present in the product.

Li, Robinson, Oberle and Lucas (2010) examined the use of several corn distillers by-products including DDGS, distillers solubles and high-protein DDGS in diets and the effects of additional dietary fat on juvenile channel catfish performance. They found that elevated fat levels in diets containing distillers

by-products were only partially responsible for the improvement in FER of fish fed the distillers by-products. The presence of the distillers solubles in the diet, possibly due to the brewers yeast, *Saccharomyces cerevisiae*, further improved FER, and also improved weight gain over the control diets with or without additional fat.

Distillers grains with solubles contain up to three times of the amount yellow pigments lutein and zeaxanthin found in yellow corn. The high level of yellow pigments may limit its use in catfish diets because high dietary yellow pigment levels can result in pigment deposition in the flesh, rendering it less appealing to the general consumer in the United States (Lee 1987; Li, Robinson & Oberle 2009). If levels of pigmented compounds in DDGS can be reduced, more DDGS could be used without adversely affecting marketability of the catfish product. Therefore, the present study was conducted to examine the effect of DDGS, de-pigmented DDGS and brewers yeast in the diet on the growth, FER and body proximate composition of juvenile channel catfish.

Materials and methods

Six practical diets containing 28% crude protein and 5% crude fat (Table 1) were formulated to meet or exceed all known nutrient requirements of channel catfish (National Research Council 1993). Diet descriptions follow:

Diet 1 – all-plant control diet.
Diet 2 – fish meal control diet (similar to Diet 1 except with 5% menhaden fish meal in replacement of part of soybean meal).
Diet 3 – 30% ethanol extracted DDGS (EDDGS).
Diet 4 – 30% DDGS.
Diet 5 – 1% brewers yeast (similar to Diet 1 except with brewers yeast in replacement of part of soybean meal).
Diet 6 – 2% brewers yeast (similar to Diet 1 except with brewers yeast in replacement of part of soybean meal).

The DDGS was provided by Poet, LLC (Sioux Falls, SD, USA) and Brewtech® dried brewers yeast was provided by International Ingredient Corporation (St Louis, MO, USA). Remaining dietary ingredients were obtained from the Delta Western Feed Mill (Indianola, MS, USA) and were from commercial sources. The DDGS was extracted with hexane and ethanol, respectively, in a manner similar to the ether extraction method described by Association of Official Analytical Chemists International (AOAC) (2000) using the Soxtec System (Foss North America, Eden Prairie, MN, USA). The resulting material was dried at 60 °C for 60 min to evaporate the solvent residue. The hexane extracted DDGS was not used in the feeding study because only a small amount of yellow pigment was removed during the process. The experimental diets were prepared as sinking pellets according to procedures described previously (Li, Johnson & Robinson 1993).

Juvenile channel catfish were obtained from the USDA Agriculture Research Service's Catfish Genetics Research Unit (Stoneville, MS, USA). Thirty fish were stocked into each of thirty 110 L flow-through aquaria at the Thad Cochran National Warmwater Aquaculture Center (NWAC), Mississippi State University (Stoneville, MS, USA). The aquaria were supplied with well water (flow rate: approximately 1 L min^{-1}) and continuous aeration. Water temperature and dissolved oxygen were monitored in the system once daily using a YSI oxygen meter (Yellow Springs Instruments, Yellow Springs, OH, USA) and averaged at 29.8 ± 0.2 °C and 6.8 ± 0.2 mg L^{-1} respectively. A diurnal light:dark cycle was regulated at 14:10 h.

Before initiation of the experiment, the fish were acclimated for 2 weeks and fed an all-plant conditioning diet once daily to apparent satiation at 08:00 hours. After acclimation, all fish were pooled and graded to a uniform size, and 15 fish were collectively weighed and restocked in each aquarium. Initial fish weight was determined and averaged 9.1 ± 0.2 g $fish^{-1}$ (mean ± SD). Fish were fed to apparent satiation (in about 40 min) once daily for 8 weeks. Satiation was achieved by first feeding an amount of diet based on the percentage of fish body weight (less than satiation), followed by feeding several times from a pre-weighed diet container. Diet consumption was monitored and recorded at each feeding. Dead fish, if any, were removed daily from the aquarium and weighed. Aquaria were cleaned weekly.

At the end of the feeding period, feed consumption and weight gain per fish, FER and survival were calculated. Feed efficiency ratio was determined as follows:

$$\begin{aligned}\text{FER} = {} & ([\text{final fish weight, g tank}^{-1}] \\ & - [\text{initial fish weight, g tank}^{-1}] \\ & + [\text{weight of dead fish, g tank}^{-1}])/ \\ & (\text{total feed fed, g tank}^{-1})\end{aligned}$$

Table 1 Ingredient and proximate compositions of experimental diets (expressed percentage on an as-fed basis)

	All-plant control	Fish meal control	30% EDDGS*	30% DDGS†	1% brewer yeast	2% brewer yeast
Ingredient						
Soybean meal (dehulled)	44.60	37.85	26.60	29.75	42.90	42.05
Menhaden fish meal	0.00	5.00	0.00	0.00	0.00	0.00
EDDGS*	0.00	0.00	30.00	0.00	0.00	0.00
DDGS†	0.00	0.00	0.00	30.00	0.00	0.00
Brewers yeast	0.00	0.00	0.00	0.00	1.00	2.00
Corn meal (cooked)	30.71	33.50	22.40	23.00	31.52	31.37
Wheat middlings	10.00	10.00	6.31	5.00	10.00	10.00
Lysine HCl	0.00	0.00	0.40	0.30	0.00	0.00
Dicalcium phosphate	1.50	1.00	1.30	1.25	1.50	1.50
Corn oil	2.49	1.95	2.29	0.00	2.38	2.38
Other ingredients‡	10.70	10.70	10.70	10.70	10.70	10.70
Proximate analysis (%)§						
Dry matter	87.9 ± 0.02	88.67 ± 0.01	88.30 ± 0.02	87.80 ± 0.02	88.37 ± 0.03	87.64 ± 0.06
Crude protein¶	27.7 ± 0.10	27.59 ± 0.11	28.22 ± 0.10	28.25 ± 0.18	27.38 ± 0.09	27.35 ± 0.18
Crude fat¶	4.68 ± 0.02	4.64 ± 0.04	4.50 ± 0.00	5.01 ± 0.01	4.49 ± 0.00	4.49 ± 0.03
Lutein+zeaxanthin¶ (mg kg^{-1})	3.91 ± 0.00	4.16 ± 0.11	3.54 ± 0.10	9.78 ± 0.48	3.90 ± 0.06	4.00 ± 0.06
DE:P ratio (kcal g^{-1} protein) ‖	10.2	10.2	9.2	9.5	10.2	10.2

*Ethanol extracted distillers dried grains with solubles.

†Distillers dried grains with solubles.

‡Includes 7.5% cottonseed meal, 1% menhaden fish oil, 2% carboxymethyl cellulose (pellet binder), 0.05% vitamin premix, 0.05% L-ascorbyl monophosphate and 0.1% trace mineral premix. Vitamin and trace mineral premixes were the same as described by Robinson and Li (2007).

§Values represent mean ± SD ($n = 2$, two batches per diet).

¶Expressed as 900 g kg^{-1} dry matter basis.

‖Estimated digestibility to protein ratio.

After the final fish number and weight were determined, five fish from each aquarium were euthanized by an overdose (500 mg L^{-1}) of tricaine methanesulphonate (MS-222^{TM}, Argent Chemical Laboratories, Redmond, WA, USA), and fillet samples were removed. Digital pictures were taken of one fillet from each fish using an EOS 1D Mark II digital SLR camera (Cannon USA, Lake Success, NY, USA). The yellow intensity values [Commission Internationale de l'Eclairage (CIE) b^* (negative: blueness; positive: yellowness)] were determined from the digital picture of the fillet at three locations along the dorsal line of the fillet using Adobe Photoshop CS3 image editing software (Adobe Systems, San Jose, CA, USA). The fillets were then pooled by aquarium, and stored at − 80 °C for subsequent proximate and pigment analyses.

The fillet samples were homogenized into a paste using a Grindomix GM-200 Knife Mill (Retsch GmbH, Haan, Germany) and part of the sample was lyophilized with a Freezone Freeze Dry System (Labconco, Kansas City, MO, USA) for 16–18 h for protein and fat analyses.

Proximate analyses were performed in duplicate on diet and pooled fillet samples from each aquarium with methods described by AOAC (2000). Crude protein of diet and fillet samples was analysed by the combustion method with the FP-2000 protein determinator (Leco, St Joseph, MI, USA), crude fat by ether extraction with the Soxtec System (Foss North America, Eden Prairie, MN, USA) and moisture by oven drying with a mechanical convection oven (Precision, Winchester, VA, USA). Diet and fillet samples were analysed for lutein and zeaxanthin concentrations using high-performance liquid chromatography (Moros, Darnoko, Cheryan, Perkins & Jerrell 2002).

Data were subjected to one-way analysis of variance (ANOVA) and the Fisher's protected least significant difference procedure (Steel, Torrie & Dickey 1997) with the STATISTICAL ANALYSIS SYSTEM version 9.1 software (SAS Institute 2004). Aquaria were the experimental units and variation among aquaria within a treatment was used as the experimental error in tests of significance. An α level of 0.05 was used.

Results

Hexane extraction method used in the present study removed almost all fat (from 9.49% to 0.06%) in DDGS, but was not effective in removing the yellow

pigments lutein and zeaxanthin (from 30.9 to 26.7 mg kg^{-1}). Ethanol extraction of DDGS removed most of the fat (from 9.49% to 1.89%) and almost all yellow pigments (from 30.9 to 0.6 mg kg^{-1}).

The feeding study showed no significant differences among dietary treatments for feed consumption and survival (Table 2). The overall mortality was 2.5% and the cause was not known. Weight gain of fish fed diets containing 30% DDGS, and 1% and 2% brewers yeast was significantly higher than that of fish fed the all-plant control diet, but not significantly different from that of fish fed the fish meal control diet (5% menhaden meal). Weight gain of fish fed the diet containing 30% EDDGS was significantly lower than that of fish fed the diet containing 30% DDGS, but was intermediate with that of fish fed the all-plant and fish meal control diets. Feed efficiency ratio of fish fed diets containing 30% DDGS and 1% brewers yeast was significantly higher than that of fish fed the all-plant control diet and the diet containing 30% EDDGS, but not significantly different from that of fish fed the fish meal control diet. Feed efficiency ratio of fish fed the diet containing the 2% brewers yeast diet was intermediate, not significantly different from that of fish fed other diets.

Fish fed the fish meal control diet had a significantly higher protein, but had similar levels of fat and moisture compared with fish fed the all-plant control diet (Table 3). Fish fed diets containing 30% EDDGS and 30% DDGS had similar levels of fillet protein, fat and moisture levels. Fillet protein levels of fish fed the EDDGS and DDGS diets were similar to that of fish fed the all-plant control diet, but were lower than that of fish fed the fish meal control diet and brewers yeast diets. Fillet fat levels of fish fed the EDDGS diet were similar to that of fish fed the all-plant control and fish meal control diets, but were lower than that of fish fed the brewers yeast diets. Fillet moisture levels of fish fed the EDDGS diet were higher than that of fish fed the all-plant control, fish meal control and brewers yeast diets. Fillet protein, fat and moisture levels of fish fed the 1% and 2% brewers yeast diets were similar.

Fish fed the diet containing 30% EDDGS had a significantly lower CIE b^* value than fish fed the all-plant control diet and the diet containing 30% DDGS (Table 4). The CIE b^* value of fish fed the all-plant control diet was significantly lower than that of fish fed the 30% DDGS diet. Lutein+zeaxanthin levels in the flesh of fish fed the all-plant control and the diet containing 30% EDDGS were significantly lower than that of fish fed the 30% DDGS diet.

Discussion

Results from the present study support the observation by Li *et al.* (2010) that the use of 30% DDGS in the diet improved weight gain and FER over an all-plant control diet. In addition, the present study demonstrated that the 30% DDGS diet provided the same level of growth and FER as the fish meal control diet. Li *et al.* (2010) suggests that the improvement of weight gain and FER by feeding 30% DDGS is likely caused by the presence of distillers solubles, possibly due to the brewers yeast. In the present study, fish

Table 2 Mean feed consumption, weight gain, feed efficiency ratio and survival of juvenile channel catfish fed various experimental diets for 8 weeks*

Diet description	Feed consumption (g fish^{-1})†	Weight gain (g fish^{-1})‡	Feed efficiency ratio†	Survival (%)
All-plant control	102.1	61.3 c	0.600 b	96.0
Fish meal control	103.3	68.7 ab	0.665 a	98.3
30% EDDGS§	106.6	64.8 bc	0.607 b	98.7
30% DDGS¶	108.7	71.3 a	0.656 a	98.7
1% brewers yeast	104.9	68.2 ab	0.651 a	100.0
2% brewers yeast	110.1	68.7 ab	0.624 ab	93.3
Pooled SEM	2.2	1.9	0.013	1.6

*Means represent average values of five tanks per diet. Means within each column followed by different letters were different ($P \leq 0.05$, the Fisher's protected least significant difference procedure).
†Based on 900 g kg^{-1} dry matter of the diet.
‡Initial weight was 9.1 $\pm$ 0.2 g fish^{-1}.
§Ethanol extracted distillers dried grains with solubles.
¶Distillers dried grains with solubles.

Table 3 Mean fillet protein, fat and moisture concentrations of juvenile channel catfish fed various experimental diets for 8 weeks*

Diet description	Fillet protein (%)†	Fillet fat (%)†	Fillet moisture (%)
All-plant control	16.6 bc	5.88 ab	76.5 b
Fish meal control	17.3 a	5.23 b	76.3 b
30% EDDGS‡	16.3 c	5.08 b	77.7 a
30% DDGS§	16.3 c	5.55 ab	77.1 ab
1% brewers yeast	17.0 ab	6.32 a	75.4 c
2% brewers yeast	17.1 ab	6.33 a	75.4 c
Pooled SEM	0.2	0.31	0.3

*Means represent average values of five tanks with five fish per tank. Means within each column followed by different letters were different ($P \leq 0.05$, the Fisher's protected least significant difference procedure).
†On wet-tissue basis.
‡Ethanol-extracted distillers dried grains with solubles.
§Distillers dried grains with solubles.

Table 4 Mean CIE b^* value and lutein plus zeaxanthin concentrations of juvenile channel catfish fed experimental diets containing distillers dried grains with solubles (DDGS) and ethanol extracted distillers dried grains with soluble (EDDGS) for 8 weeks*

Diet description	CIE b^*	Lutein + zeaxanthin ($\mu g\ g^{-1}$)†
All-plant control	15.1 b	0.83 b
30% EDDGS	13.7 c	0.83 b
30% DDGS	18.2 a	1.03 a
Pooled SEM	0.4	0.01

*Means represent average values of five tanks with five fish per tank. Means within each column followed by different letters were different ($P \leq 0.05$, the Fisher's protected least significant difference procedure).
†On wet-tissue basis.

fed 1% and 2% brewers yeast had similar weight gain and FER as fish fed the 30% DDGS diet. This indirectly confirms that brewers yeast in the DDGS may play a role in the improvement of fish growth performance.

During ethanol production, brewers yeast is typically used to ferment corn to produce ethanol. Distillers dried grains with solubles have been estimated to contain about 3.9% yeast cells (Ingledew 1999). Previous studies with sea bass, *Dicentrarchus labrax* (Oliva-Teles & Goncalves 2001) and hybrid striped bass, *Morone chrysops* × *Morone saxatilis* (Li & Gatlin III 2005), showed that the use of brewers yeast in the diet improved fish growth and FER. Yeast cells contain 5–12% nucleic acids from which nucleotides are derived (Tacon & Jackson 1985). The brewers yeast used in the present study contained 3.0% nucleotides (analysed by Eurofins Scientific, Des Moines, IA, USA). The nucleotides included adenosine-, cytidine-, guanosine-, uridine-5′-monophosphate and a trace amount of inosine-5′-monophosphate. Dietary supplementation of a mixture of nucleotides has been shown to increase the height of villa in the intestine of rat (Uauy, Stringel, Thomas & Quan 1990) and Atlantic salmon, *Salmo salar* (Burrells, Williams, Southgate & Wadsworth 2001). As a result, the mucosal surface area of the intestine is increased and therefore nutrients are more efficiently absorbed and utilized. Li, Gatlin III and Neil (2007) reported that dietary supplementation of a mixture of nucleotides enhanced the growth and FER of red drum, *Sciaenops ocellatus* during the first week of feeding, but the improvement diminished during the following 3 weeks of feeding. Lin, Wang and Shiau (2009) found that the addition of individual and a mixture of nucleotides in the diet improved the growth and FER in grouper, *Epinephelus malabaricus* after 8 weeks of feeding.

Nucleotides such as adenosine-, inosine- and uridine-5′-monophosphate have been shown to stimulate gustatory sensory cells in several fish species (Ishida & Hidaka 1987; Ikeda, Hosokawa, Shimeno & Takeda 1991; Kubitza, Lovshin & Lovell 1997). Li *et al.* (2010) reported that the use of DDGS or distillers solubles in the diet increased feed intake in channel catfish, which they attributed to the possible chemoattractive effects of nucleotides present in the yeast cells. However, no significant differences in feed consumption were observed among fish fed various diets in the present study. The discrepancy between responses of the present study and Li *et al.* (2010) cannot be easily explained, but could be due to the larger variation in feed consumption of fish in various replicated tanks in the present study.

In the present study, fish did not perform well on the all-plant control diet as compared with fish fed diets containing fish meal, DDGS and 1% brewers yeast. Although results from previous studies are inconclusive, more evidence appears to indicate that the inclusion of fish meal in the diet improves the growth and FER of juvenile channel catfish (Mohsen & Lovell 1990; Li, Peterson, Janes & Robinson 2006; Li, Robinson, Peterson & Bates 2008). Fish muscle is rich in nucleotides (Ikeda, Hosokawa, Shimeno & Takeda 1988), which may contribute to the growth-enhancing effect of fish meal on channel catfish.

Several studies have demonstrated that relatively high levels of DDGS can be used in channel catfish

diets without adversely affecting fish performance (Webster *et al.* 1991; Robinson & Li 2008; Lim *et al.* 2009), but there is a concern about high yellow pigment levels in DDGS. Studies have shown that feeding diets containing lutein+zeaxanthin levels higher than 7–10 mg kg^{-1} can deposit enough pigment in catfish flesh to be visible (Lee 1987; Li *et al.* 2009). Fish fed the DDGS diet in the present study only showed slightly yellow colouration by visual examination. Also, the CIE b^* values and lutein+zeaxanthin concentration in fish flesh were at low levels. This is mostly due to the short feeding period and small fish size used in the present study. However, both the CIE b^* value and lutein+zeaxanthin concentration in fish fed EDDGS were significantly lower than in fish fed DDGS. This is anticipated because yellow pigments lutein and zeaxanthin in the EDDGS were effectively removed by ethanol extraction. Analyses of yellow pigments conducted at our laboratory on various batches of DDGS showed that the pigment varied from 22 to 40 mg kg^{-1}. Longer periods of feeding of DDGS containing a high level of the pigment at 30% would result in yellow pigment deposition that may reduce marketability of the catfish product.

Ethanol extraction does not appear to extract the nucleotides from the DDGS. Total nucleotide (the same four main nucleotides found in brewers yeast) concentrations were 0.17% for DDGS and 0.25% for EDDGS. However, fish fed the 30% EDDGS diet had lower weight gain and FER than fish fed the 30% DDGS diet. This response cannot be easily explained with regard to the nucleotide concentrations of the diets.

Significant differences were observed in fillet proximate composition of fish fed various experimental diets. The differences cannot be easily explained. However, these differences were relatively small and fillet protein, fat and moisture levels were within the normal range for this size of fish. Although all diets were formulated to be isonitrogenous and isolipidic, differences in dietary ingredient composition, digestible energy and other nutrients may have affected the nutrient retention of these fish.

With the method used in the present study, ethanol extraction effectively removed most of yellow pigments in DDGS, while hexane did not. Further investigations are needed to optimize extraction conditions using hexane as a solvent to remove oil and pigments because hexane is commonly used as the solvent in extracting oil from oilseeds and other feedstuffs.

In summary, the present study demonstrates that diets containing 1% brewers yeast or 30% DDGS support the same level of growth and FER as a diet containing 5% fish meal for juvenile channel catfish. The diet containing EDDGS resulted in significantly lower growth and FER compared with the diet containing DDGS. However, the weight gain of fish fed the EDDGS diet was intermediate compared with fish fed the all-plant control, fish meal control and 1–2% brewers yeast diets. Ethanol extracted DDGS could potentially be used at high levels as a substitution of soybean meal without causing yellow pigment deposition in catfish flesh, provided that the ethanol extraction process is proven economical. Brewers yeast, used at 1–2% of the diet, appears to improve weight gain and FER over the all-plant control diet used in the present study.

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