The Progressive Fish-Culturist 55:95–100, 1993

Growth, Body Composition, and Organoleptic Evaluation of Channel Catfish Fed Diets Containing Different Percentages of Distillers' Grains with Solubles

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Abstract.—Juvenile channel catfish (*Ictalurus punctatus*) were stocked in twelve 1.25-m^3 floating cages at densities of 320 fish/m^3 and fed to satiety twice daily for 110 d with one of four diets. Each diet contained a certain percentage (0, 10, 20, or 30%) of distillers' grains with solubles (DGS), which partially replaced soybean meal and corn. Individual weights of fish, survival, food conversion (FC, weight of feed given/weight gain by fish), and body composition (percentage moisture, protein, fat, and ash) of waste (head, skin, and viscera) and dressed carcasses were not significantly different ($P > 0.05$) among treatments. Fish fed a diet containing 10% DGS (mean individual total length, 26.7 cm) were significantly shorter ($P < 0.05$) than fish fed a diet containing 30% DGS (27.6 cm), but they were not significantly different in length ($P > 0.05$) from fish fed diets with 0 and 20% DGS. Average individual weight was 219 g, survival was 92.1%, and FC was 1.6. Percentage fat (dry-matter basis) in the carcasses of cage-reared channel catfish averaged 38%. Organoleptic evaluation of fillets indicated that the fat complex flavor was of significantly higher intensity ($P < 0.05$) in cage-reared fish than in pond-raised fish. However, organoleptic evaluation indicated that DGS impart no adverse taste to channel catfish. These data indicate that DGS can be used in a least-cost diet formulation for channel catfish at rates of up to 30%. This option allows feed producers flexibility in diet formulations for commercial catfish diets.

Least-cost diet formulations offer economic advantages in the preparation of a nutritionally complete diet by allowing change in diet formulations when ingredient prices fluctuate. Evaluation of alternative protein sources remains a high priority for fish nutritionists. Distillers' grains with solubles (DGS) are primary fermentation residues from yeast fermentation of cereal grains and are a good protein source (29% crude protein) without the antinutritional factors present in soybean meal (Wilson and Poe 1985; Shiau et al. 1987) or cottonseed meal (gossypol) (Jauncey and Ross 1982; Robinson 1991). It has been reported that DGS is an acceptable ingredient in diets for channel catfish (*Ictalurus punctatus;* Tidwell et al. 1990; Webster et al. 1991b). However, before individual feedstuffs can be recommended for inclusion, growth performance (Robinette 1984) and organoleptic quality (Johnsen and Kelly 1990) of channel catfish fed diets containing DGS under production conditions (i.e., pond or cage culture) should be evaluated.

Organoleptic evaluation is the first step in quality control during the processing of farm-raised catfish (Johnsen and Kelly 1990). Detection of off-flavors may make the fish unsuitable for market. Because flavor quality is essential to the marketability of channel catfish, some attention should be focused on factors that might affect flavor quality. One such factor is diet. Before a diet ingredient can be recommended in a least-cost formulation, effects of the ingredient on the flavor of the fish should be evaluated (Johnsen and Dupree 1991).

The purpose of this study was to evaluate growth, body composition, and organoleptic quality of cage-reared channel catfish fed diets containing different percentages of DGS.

Methods

Experimental Design and Animals

Channel catfish juveniles (average individual weight ± SE, 33.0 ± 1.5 g) were stocked on 29 May 1991 into twelve 1.25-m^3 floating cages moored over the deepest area (4 m) of a 1.0-hectare pond (average depth, 2.0 m) located at the Agricultural Research Farm, Kentucky State University, Frankfort. Four hundred juveniles were hand-counted and randomly stocked into each cage. Fish were fed for 110 d on one of four ex-

TABLE 1.—Composition of experimental diets with different percentages of distillers' grains with solubles (DGS) fed to juvenile channel catfish.

Component	Diet 1	Diet 2	Diet 3	Diet 4
Ingredients (% of total)				
Corn	37.525	32.525	28.525	23.525
Soybean meal (44%)	51.75	46.75	40.75	35.75
Menhaden fish meal	8.00	8.00	8.00	8.00
DGS	0.00	10.00	20.00	30.00
Ascorbic acid	0.025	0.025	0.025	0.025
Dicalcium phosphate	1.00	1.00	1.00	1.00
Vitamin mix[a]	0.10	0.10	0.10	0.10
Mineral mix[b]	0.10	0.10	0.10	0.10
Cod liver oil	1.50	1.50	1.50	1.50
Proximate analysis				
Moisture (%)	10.21	10.24	9.83	9.35
Protein (%)[c]	31.89	31.41	32.15	32.24
Lipid (%)[c]	5.00	5.70	6.36	7.06
DE[d]	2.44	2.46	2.49	2.53
P/E (mg protein/ kcal DE)	131	128	129	127

[a] Vitamin mix provided the following (mg/kg of diet, unless otherwise stated): biotin, 0.20; chloride, 1,793; folic acid, 2.7; niacin, 113.2; pantothenic acid, 45.5; B_6, 16.7; riboflavin, 16.5; thiamin, 13.9; B_{12}, 20.8; E, 76.8; K, 4.5; A, 4,401 IU/kg; D_3, 2,200 IU/kg; ascorbic acid, 580.

[b] Mineral mix provided the following: potassium, 1.20%; chloride, 0.08%; magnesium, 0.20%; sodium, 0.06%; sulfur, 0.31%; copper, 19.4 mg/kg of diet; iron, 380.1 mg/kg; manganese, 126.8 mg/kg; selenium, 0.36 mg/kg; zinc, 245.3 mg/kg; iodine, 0.002%; aluminum, 1 mg/kg.

[c] Dry-matter basis.

[d] DE = digestible energy; values were calculated from published values for the diet ingredients (NRC 1981, 1983).

truded diets formulated to be isonitrogenous (32% dietary protein) and isocaloric (2.4 kcal of digestible energy per gram of diet) and containing different percentages (0, 10, 20, and 30%) of DGS (Table 1). Diets were extruded by a commercial feed mill (Integral Fish Foods, Inc., Grand Junction, Colorado) for use in this study. Fish were fed twice daily (0800 and 1530 hours) to satiation. After 30 min, uneaten pellets were removed with a hand net and their weight was subtracted (after conversion to a dry-matter basis) from the amount fed. There were three replications per treatment.

Diets were analyzed for crude protein, fat, and moisture. Crude protein was determined by the macro-Kjeldahl method, crude fat was determined by the acid hydrolysis method, and moisture was determined by drying samples to constant weight (AOAC 1990). Digestible energy (DE) values were calculated from the diet ingredients (for DGS: NRC 1981; for other ingredients: NRC 1983). Diets were stored in plastic-lined bags in a cool (15°C), dry place for the duration of the study.

Each cage had a wooden frame with a removable lid and was constructed of 10-mm polyethylene mesh. A panel of polyethylene net (0.2-mm mesh, 8 cm high) was installed around the top of the inside of each cage to prevent loss of floating diet. Density of fish in these cages was 320 fish/m^3. Cages were anchored to a floating dock, and the distance between cages was 2 m.

Temperature and dissolved oxygen (DO) were monitored twice daily (0800 and 1630 hours) outside the cages, at a depth of 0.75 m, with a YSI model 57 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio). If DO was graphically predicted to decline below 4.0 mg/L, aeration was provided with a paddlewheel connected to a tractor power take-off. Weekly measurements of pH were recorded with an electronic pH meter (Accumet 900, Fisher Scientific). Total ammonia-nitrogen and nitrite were measured with a DREL/5 spectrophotometer (Hach Co., Loveland, Colorado).

Average monthly morning water temperatures (±SE) ranged from 25.3 ± 2.2°C (for September) to 28.1 ± 1.6°C (for July), whereas average monthly afternoon water temperatures ranged from 25.3 ± 2.3°C (for September) to 29.4 ± 1.3°C (for July). Morning DO levels averaged 5.8 ± 1.4, 6.5 ± 2.3, 6.6 ± 0.9, and 6.4 ± 0.8 mg/L for June, July, August, and September, respectively, whereas afternoon values were 6.9 ± 1.5, 7.7 ± 2.8, 7.4 ± 0.9, and 7.1 ± 0.9 mg/L for those respective months. Total ammonia-nitrogen averaged 0.24 ± 0.20 mg/L, nitrite averaged 0.006 ± 0.016 mg/L, and pH averaged 8.8 ± 1.00 during the study and were within accepted values for growth of channel catfish (Boyd 1979).

Before the start of the study, fish were fed a floating, medicated (Romet-30) diet for 7 d. Because of an infection of *Edwardsiella ictaluri* 4 weeks prior to harvest, fish were fed the medicated diet for 7 d. Fish were harvested on 26 September 1991 and were not fed for 24 h before harvest. Total number and weight of fish in each cage were determined at harvest. Fifty fish were randomly sampled from each cage and individually weighed (g) and measured for total length (cm). Ten fish were randomly sampled from each cage for analysis of dressing percentage, abdominal fat, and body weight. Fish were skinned by machine and dressed by removing head and viscera. Abdominal fat was removed, weighed, and reported as a percentage of total weight. Carcasses and waste (head, skin, and viscera) of three fish sampled from each cage were homogenized separately in a blender and analyzed for protein, fat, moisture, and ash. Protein was determined by the Kjeldahl method, fat was determined by ether extraction, ash was determined by a muffle furnace, and moisture was measured by drying in an oven at 95°C to constant weight (AOAC 1990).

Food conversion (FC) and specific growth rate (SGR, %/d) were calculated as follows: FC = total weight of diet fed/total fish weight gain; SGR = $[(\log_e W_t - \log_e W_i)/T] \times 100$, where W_t is the average individual weight of fish at time t, W_i is the average individual weight of fish at time 0, and T is the culture period in days.

Date were analyzed with the SAS analysis-of-variance procedure (SAS Institute 1988) for significant differences among treatment means. Means were analyzed by Duncan's multiple-range test. All percentage and ratio data were transformed to arcsine values before analysis (Zar 1984).

Sample Preparation for Sensory Analysis

Samples for sensory analysis were made from blended individual fish samples according to the methods of Johnsen and Kelly (1990). These individual portions were prepared by combining fillets from all test fish in an individual cage, representing a replicate unit of a diet treatment. The fillets were shredded by a food processor and, after thorough mixing, 10-g samples were placed in Seal-a-Meal® bags (7 × 7 cm). Samples were frozen at −20°C until presentation to the panel of tasters.

Sensory Panel Protocols

The sensory evaluation panel comprised 10 members who have served on the catfish panel for 15–41 months at the U.S. Department of Agriculture, Agriculture Research Center, Southern Regional Research Center, New Orleans, Louisiana. Panelists were trained, according to the methods described in Johnsen and Kelly (1990), to use the spectrum method of sensory evaluation (Meilgaard et al. 1987). All members are continually evaluated for performance and undergo additional training when necessary.

Samples were presented under red light to the panelists for flavor-by-mouth assessment; texture was not assessed. Descriptive analysis profiles were prepared with the lexicon of descriptors presented by Johnsen et al. (1987) and modified by Johnsen and Kelly (1990). Although all descriptors were scored by the panelists, five attributes describing the desirable flavors of catfish were analyzed for this experiment (Table 2).

TABLE 2.—Catfish flavor descriptors used in this experimental analysis.

Descriptor	Description
Chickeny	The aromatic associated with sweet cooked chicken meat
Nutty	The aromatic associated with fresh pecans and other hardshell nuts
Fat complex	The aromatic associated with dairy lipid products, melted vegetable shortening, and cooked chicken skin
Corn	The aromatic associated with cooked corn kernels
Sweet	The taste on the tongue associated with sugars

Intensities were judged on an open-ended scale established in reference to flavor intensities that are assigned to specific characteristics apparent in several commercially available food products (Johnsen and Kelly 1990). Farm-raised catfish flavor intensities are less than 10 on this scale.

The interval between sample presentations was 7 min. Unsalted crackers and distilled, deionized water were used to rinse the mouth between samples. Four experimental samples were evaluated in 2-h-long panel sessions that convened twice per week. Three replicates of each diet were evaluated in three sessions. Sensory evaluations were recorded on a computer system as described by Johnsen and Kelly (1990). Sample identification, individual panelist responses, and panel means and SD were processed and returned to panel members at the conclusion of each session for discussion or coaching. For further analysis, data were transposed to SAS files (SAS Institute 1985) and subjected to specific statistical analyses.

Panel sessions were initiated with members tasting and reviewing the intensity references. First, a commercially obtained pond-raised fish sample was chosen as the "standard" and evaluated. The panel means for individual attributes were calculated and discussed. Consensus values were then agreed upon. This exercise served to assist individuals to establish their daily calibration (O'Mahony et al. 1988). The experimental samples were then presented in a random order previously determined for the experiment.

Results

Growth and Survival

Individual weights of channel catfish fed diets containing 0, 10, 20, and 30% DGS were not significantly different ($P > 0.05$) and averaged 219.1 g overall (Table 3). Channel catfish fed the 30% DGS diet were significantly longer (total length,

TABLE 3.—Effect of increasing dietary percentage of distillers' grains with solubles (DGS) on growth of juvenile channel catfish reared in cages. Values are means ± SEs of three replications. Within rows, means followed by different letters were significantly different ($P < 0.05$). In rows without letters, no significant differences were found among treatments. FC = food conversion; SGR = specific growth rate.

Variable	Diet (%DGS)			
	0%	10%	20%	30%
Final individual weight (g)	217.6 ± 8.2	207.8 ± 5.9	224.4 ± 6.5	226.4 ± 6.4
Final individual total length (cm)	27.0 ± 0.3 zy	26.7 ± 0.2 y	27.2 ± 0.3 zy	27.6 ± 0.4 z
Total weight per cage (kg)	76.6 ± 5.8	80.5 ± 2.0	86.2 ± 2.3	82.2 ± 1.8
Net weight gain per cage (kg)	62.0 ± 5.8	66.1 ± 1.8	72.1 ± 2.2	68.4 ± 1.4
Survival (%)	92.13 ± 2.68	93.27 ± 0.73	93.20 ± 2.17	89.60 ± 1.12
FC	1.65 ± 0.09	1.58 ± 0.01	1.52 ± 0.01	1.61 ± 0.02
SGR	1.54 ± 0.03 zy	1.46 ± 0.04 y	1.54 ± 0.03 zy	1.56 ± 0.02 z
Dressing percentage	53.41 ± 0.45	52.21 ± 0.57	54.02 ± 0.61	54.42 ± 1.53

27.6 cm) than fish fed the diet containing 10% DGS (26.7 cm long; $P < 0.05$), but not significantly longer than fish fed diets containing 0% DGS (27.0 cm long) and 20% DGS (27.2 cm long; $P > 0.05$). No significant differences ($P > 0.05$) in total weight per cage, net weight gain per cage, survival, and FC were found among treatments; averages for these respective factors were 81.4 kg, 67.2 kg, 92.1%, and 1.6. The SGR calculated for channel catfish fed the 30% DGS diet (1.56%/d) was significantly higher ($P < 0.05$) than that obtained for fish fed the 10% DGS diet (1.46%/d), but was not significantly different ($P > 0.05$) from SGRs of fish fed the 0 and 20% DGS diets (1.54%/d in both cases).

Body Composition

No significant differences ($P > 0.05$) in percentage moisture, protein, fat, and ash of waste (head, skin, and viscera) and dressed carcass were found among treatments (Table 4). Percentage protein, fat, and ash of waste averaged 39.9, 42.3, and 15.8% on a dry-weight basis, respectively (14.1, 15.0, and 5.6% on a wet-weight basis), and carcass protein, fat, and ash averaged 57.3, 38.2, and 6.0% on a dry-weight basis, respectively (16.7, 11.1, and 1.7% on a wet-weight basis).

Organoleptic Evaluation

Mean intensities of the five desirable sensory attributes of the experimental and standard fish samples did not differ significantly ($P > 0.05$) among fish fed the four experimental diets (Table 5). Fish fed the four experimental diets were not different ($P > 0.05$) from the commercial pond-raised catfish except for the fat complex flavor attribute. Cage-reared channel catfish had significantly higher ($P < 0.05$) intensities for this attribute than did the standard fish (i.e., cage-reared fish tasted fatty compared with the standard).

Discussion

Data presented in this study are in agreement with the findings of Tidwell et al. (1990) and Webster et al. (1991b), that 30–40% DGS can be added in a channel catfish diet without adverse effects

TABLE 4.—Percentage moisture and percentage protein, fat, and ash (dry-weight basis) of waste (head, skin, and viscera) and carcass for juvenile channel catfish fed diets containing various percentages of distillers' grains with solubles (DGS). Values are means ± SEs of three replications. No significant differences were found among treatments ($P > 0.05$ for all within-row comparisons).

Sample and component	Diet (%DGS)			
	0%	10%	20%	30%
Waste				
Moisture (%)	64.99 ± 1.01	64.39 ± 1.61	65.06 ± 0.50	63.85 ± 0.57
Protein (%)	39.61 ± 0.54	41.39 ± 1.59	40.54 ± 0.30	38.12 ± 2.07
Fat (%)	42.79 ± 2.07	40.84 ± 3.08	42.06 ± 1.42	43.32 ± 4.17
Ash (%)	16.24 ± 2.15	15.08 ± 2.06	15.73 ± 2.37	16.21 ± 2.48
Carcass				
Moisture (%)	71.37 ± 0.93	71.71 ± 1.15	70.78 ± 0.18	69.93 ± 0.70
Protein (%)	59.19 ± 0.93	59.86 ± 2.74	55.29 ± 0.80	54.83 ± 1.60
Fat (%)	36.08 ± 1.75	36.66 ± 2.36	40.62 ± 0.57	39.38 ± 1.66
Ash (%)	5.88 ± 0.22	5.61 ± 0.25	5.86 ± 0.25	6.49 ± 1.15

on growth of fish. Weight gains and FC of fish fed diets containing 10, 20, and 30% DGS were not different from those of fish fed a diet with a formulation similar to that of commercial catfish diet. No explanation can be offered for the differences in total length between fish fed a diet with 10% DGS and fish fed 30% DGS. Variation within each treatment was small, and this may have contributed to the statistical differences. Survival of channel catfish reared in cages during this study was high and in agreement with survival in other studies (Kilambi et al. 1977; Newton et al. 1980; Helfrich et al. 1984).

Initial size of stocked fish affects the harvest weight and may be of critical importance when rearing times are brief (Roell et al. 1986). A minimum marketable weight (approximately 350 g liveweight) was not achieved from the initial stocking size of 35 g. Because rearing time cannot be extended, stocking larger channel catfish appears to be necessary. Fish had an aggressive feeding response, and FC values were within the acceptable range for channel catfish reared in cages (Newton and Robison 1981; Webster et al. 1992) and in ponds (Brown and Robinson 1989; Robinson 1991; Webster et al. 1991a).

This study suggests that growth and body composition of channel catfish were not affected when fish were fed diets containing 0, 10, 20, and 30% DGS. No differences in percentage moisture, protein, fat, and ash were found among treatments. Percentage fat of carcass reported in our study was higher than previously reported values (Reis et al. 1989; Tidwell and Robinette 1990; Webster et al. 1991a). The level of DE in a diet affects the amount of food consumed by fish and the ratio of protein to energy (P/E) in the diet will influence conversion efficiency of the diet (Reis et al. 1989). An excessively low ratio may increase fat deposition in fish, whereas when the ratio is too high, protein may be used as an energy source. Page and Andrews (1973) demonstrated that the optimum P/E value for weight gain was 120 mg protein/kcal DE. Reis et al. (1989) reported that the optimum P/E was between 110 and 127 mg protein/kcal DE. Diets in this study had P/E values similar to these. However, the high percentages of fat in the carcasses of channel catfish in this study, even in those fed the control diet, indicated that a diet with a higher P/E value may be required when feeding channel catfish reared in cages.

Trained sensory panels found no differences among fish fed diets containing up to 30% DGS. Substituting DGS for soybean meal and corn had no effect on any individual flavor attribute. Therefore, DGS may serve as an ingredient for least-cost fed formulation without concern of adversely affecting catfish flavor quality or growth of the fish at levels up to 30% of the diet. Use of DGS in channel catfish diets may allow the feed producer more flexibility in formulating a nutritious diet at the lowest possible cost by adding another possible ingredient to the least-cost formulation and decreasing the dependence upon soybean meal.

TABLE 5.—Mean sensory scores for fillets of channel catfish fed diets containing different percentages of distillers' grains with solubles (DGS) and for commercial catfish fillets (standard, STD). Within rows, means followed by different letters were significantly different ($P < 0.05$). In rows without letters, no significant differences were found among treatments.

		Diet (%DGS)			
Descriptor	STD	0%	10%	20%	30%
Chickeny	2.11	2.28	2.13	2.21	2.22
Nutty	1.01	1.03	1.02	1.05	0.96
Fat complex	0.60 z	0.75 y	0.77 y	0.75 y	0.85 y
Corn	0.43	0.51	0.47	0.46	0.44
Sweet	1.01	1.14	1.10	0.74	1.11

Sensory evaluation did indicate that differences in production method may have affected flavor quality more than diet ingredients. Cage-reared fish had higher intensity fat complex flavors than did the pond-reared (standard) catfish. Because of consumer emphasis on reduced fat in foods, this finding suggests the need for further research on diets that limit fat deposition in cage-reared fish.

Acknowledgments

We thank Darrel Baker, Keenan Bishop, Julia Clark, Jackie Lamb, Steven Mims, Tashawa Reeves, Hank Schweickart, Mac Stone, Louis Weber, John Woods, and Daniel Yancey for their technical assistance. We also thank Sandra Hall for typing this manuscript. This study was partially funded by a grant from the Distillers Feed Research Council, Des Moines, Iowa; a U.S. Department of Agriculture (USDA), 1890 Institution Capacity Building Grant; and a USDA, Cooperative State Research Service grant to Kentucky State University under agreement KYX-89-88-03A.

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