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Evaluation of distillers' grains with solubles as a protein source in diets for channel catfish

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ABSTRACT

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A 12-week feeding trial was conducted in aquaria with juvenile (10 g) channel catfish (*Ictalurus punctatus*) to evaluate the use of distillers' grains with solubles (DGS) as a partial replacement for soybean meal in a prepared diet. In three diets, DGS were added at 0, 35, and 70% of the diet. A fourth diet also contained 70% DGS, but was supplemented with 0.4% crystalline L-lysine (70% DGS+LYS). All diets were isonitrogenous (36% crude protein) and isocaloric (2.7 kcal/g of diet). Fish fed the 35% DGS and 70% DGS+LYS diets were significantly larger (total length), had greater weight gains, and higher specific growth rate (SGR) than fish fed a diet with 70% DGS without supplemental lysine ($P<0.05$). No significant differences ($P>0.05$) were found in weight gain, food conversion ratio (FCR), and SGR in fish fed the 35% DGS, 70% DGS+LYS, or the control (0% DGS) diets.

These data suggest that growth in channel catfish juveniles fed a diet with 35% DGS is equivalent to that in fish fed a commercially formulated diet with a high proportion of soybean meal. A diet containing 70% DGS appeared to be lysine-deficient for juvenile channel catfish since the addition of crystalline lysine to the diet significantly improved growth rate.

INTRODUCTION

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). Fish diets have been formulated with small percentages of DGS (Phillips, 1949). Lovell (1980) stated that DGS may contain unidentified growth factors for fish. However, their use has been severely limited because DGS is limiting in lysine for channel catfish (*Ictalurus punctatus*) (NRC, 1983). Sinnhuber (1964) reported that a diet with 3%

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distillers' dried solubles (DDS) was readily accepted by rainbow trout (*Oncorhynchus mykiss*). Hughes (1987) found that DGS could be used in diets for lake trout (*Salvelinus namaycush*) at a level of 8.0%. Robinette (1984) stated that 7.5% DGS could be included in a channel catfish diet containing 36% protein. A diet containing 15% distillers' dried solubles has been found to be adequate in catfish diets (Hastings, 1967).

Reports on utilization of diets with crystalline amino acid supplementation are contradictory among researchers and fish species (Rumsey and Ketola, 1975; Hardy, 1982; Murai et al., 1982; Murai et al., 1986). Rumsey and Ketola (1975) reported that addition of crystalline amino acids to soybean meal improved growth in juvenile rainbow trout. Dabrowska and Wojno (1977) showed that rainbow trout fed diets with L-cystine, L-lysine, and L-tryptophan had growth rates similar to fish fed a control diet. Murai et al. (1986) reported that addition of L-methionine to a soybean-meal-based diet improved growth in common carp (*Cyprinus carpio*) juveniles. Juvenile channel catfish may utilize feed-grade lysine as a supplement in peanut-meal diets that are lysine deficient (Robinson et al., 1980). However, Andrews and Page (1974) reported that addition of crystalline methionine and cystine to soybean meal diets did not improve growth in channel catfish. El-Sayed (1990) found that addition of crystalline lysine to tilapia (*Oreochromis niloticus*) diets containing cottonseed meal did not improve growth compared to diets without added lysine.

The purpose of this study was to evaluate DGS as a partial replacement for soybean meal in diets for juvenile channel catfish and to determine if juvenile channel catfish can effectively utilize crystalline lysine to improve growth and feed efficiency when lysine is limiting.

MATERIALS AND METHODS

Experimental diets

Four experimental diets were formulated to contain varying percentages of distillers' grains with solubles (DGS). Diet 1, with 0% DGS, served as control and was similar to a commercially formulated diet composed of soybean meal, corn, fish meal, and vitamin and mineral supplements. Diets 2, 3, and 4 contained 35% DGS, 70% DGS, and 70% DGS supplemented with 0.4% L-lysine (70% DGS+LYS), respectively, partially replacing soybean meal and corn (Table 1). Amino acid compositions of the diets were determined from tabular valves provided for diet ingredients and L-lysine was added at 0.4% in order to bring the calculated lysine content up to the level of the requirement of channel catfish (NRC, 1983). All diets were isonitrogenous (36% crude protein).

In preparing diets, dry ingredients were first ground to a small particle size (approximately 250 μm) in a Wiley mill. Ingredients were thoroughly mixed

TABLE 1

Composition of experimental diets fed to juvenile channel catfish containing varying percentages of distillers' grains with solubles (DGS)

Ingredient	Diet DGS (%)			
	0	35	70	70+LYS
Fish meal (67%)	10.00	10.00	10.00	10.00
Soybean meal (44%)	54.00	34.99	15.99	15.99
DGS	0.00	35.00	70.00	69.60
Ground corn	31.99	16.00	0.00	0.00
Cod liver oil (BHT 0.02%)	2.00	2.00	2.00	2.00
Premix[1]	1.01	1.01	1.01	1.01
Monocalcium phosphate	1.00	1.00	1.00	1.00
L-lysine	0.00	0.00	0.00	0.40

[1]Premix supplied the following vitamins and minerals per kg of diet: retinol palmitate (A), 4532 IU; cholecalciferol (D3), 2266 IU; alpha-tocopherol (E), 75 IU; menadione (K), 11 mg; cyanocobalamine (B12), 0.009 mg; ascorbic acid (C), 778 mg; folic acid, 2.2 mg; riboflavin (B2), 13.2 mg; pantothenic acid, 35.2 mg; niacin, 88 mg; choline chloride, 516 mg; thiamine (B1), 11 mg; pyridoxine (B6), 11 mg; Zn (as $ZnSO_4$), 173 mg; Fe (as $FeSO_4$), 60 mg; Cu (as $CuSO_4$), 7.5 mg; I (as $CaIO_3$), 3.75 mg; Co (as $CoSO_4$), 1.6 mg; Mn (as $MnSO_4$), 180 mg; Al (as $AlK(SO_4)_2$), 1 mg; Se (as Na_2SeO_3), 0.3 mg; K (as KCl), 3474 mg; and Na (as Na_2PO_4), 1932 mg.

and water was added to obtain a 30% moisture level. Diets were passed twice through a mincer with die into 1.6-mm diameter "spaghetti-like" 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 dried pellets 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.) (Sweeney and Rexroad, 1987) and percentage fat was determined by ether extraction (AOAC, 1984). Digestible energy (DE) values were estimated from DE values of the diet ingredients (NRC, 1981; NRC, 1983). Diets were also analyzed for amino acid composition and trypsin inhibitor activity (AOAC, 1984) (Tables 2 and 3).

Dried diets were measured for pellet stability in water. Ten g of pellets of equal length were distributed uniformly on a pre-weighed brass screen (2-mm mesh size) of 100 cm^2 in area with raised sides. Samples were lowered into static water (approximately 10 cm under water surface), removed after 10 min, and dried in an oven (100°C) for 8 h. The residue left on the screen was recorded as dry solids not leached in water. The percentage of dry solids on the screen after 10 min in water to total solids in the pellets was used as a comparative measure of pellet stability in water.

Experimental system and animals

The feeding trial was conducted in 16 37.5-l glass aquaria. Water was recir-

TABLE 2

Proximate and physical composition of experimental diets containing distillers' grains with solubles (DGS)[1]

Component	Diet DGS (%)			
	0	35	70	70+LYS
Dry matter (%)	86.00	87.67	89.00	86.50
Protein (%)[2]	35.76	35.84	35.75	36.51
Lipid (%)[2]	5.80	8.15	11.52	11.16
DE[3]	2.56	2.65	2.84	2.84
P:E ratio[4]	139.69	135.25	125.88	128.56
Trypsin inhibitor[5]	2.00 ± 0	1.50 ± 200	2.65 ± 50	2.85 ± 50
Pellet water stability[6]	86.2 ± 0.9^a	76.3 ± 0.5^b	61.7 ± 2.5^c	63.5 ± 1.1^c

[1]Mean values of three replications.
[2]Moisture-free basis.
[3]DE = digestible energy in kcal/g of diet; based on estimated values of the diet ingredients (NRC, 1981; NRC, 1983).
[4]P:E ratio = protein-to-energy ratio in mg protein/kcal of DE.
[5]Trypsin inhibitor measured in trypsin inhibitor units (TIU)/mg diet.
[6]Pellet water stability = percentage of dry solids retained after 10 min in static water.
[a,b,c]Means with different superscripts were significantly different ($P < 0.05$).

TABLE 3

Amino acid composition of control and experimental diets containing varying percentages of distillers' grains with solubles (DGS) (amino acids expressed as percentage of diet)[1]

Amino acid	Required[2]	Diet DGS (%)			
		0	35	70	70+LYS
Arginine	1.55	2.40	1.90	1.67	1.58
Cystine	–	0.63	0.60	0.64	0.58
Histidine	0.54	0.84	0.73	0.77	0.77
Isoleucine	0.94	1.21	1.03	1.00	1.01
Leucine	1.26	2.68	2.83	3.22	3.10
Lysine	1.84	2.17	1.81	1.38	1.80
Methionine[3]	0.83	0.62	0.66	0.72	0.69
Phenylalanine[4]	1.80	1.51	1.38	1.51	1.46
Threonine	0.72	1.24	1.16	1.29	1.20
Tryptophan	0.18	0.29	0.24	0.24	0.26
Tyrosine	–	1.13	1.02	1.09	1.10
Valine	1.08	1.60	1.55	1.65	1.58

[1]Values are means of two replications.
[2]Amino acid requirement (% of diet) based on a 36%-protein diet (NRC, 1983).
[3]Methionine requirement is met because 60% of cystine can substitute for methionine (Lovell, 1989).
[4]Phenylalanine requirement is met because 50% of tyrosine can substitute for phenylalanine (Lovell, 1989).

culated through biological and mechanical filters. The recirculating system was a 1200-l vertical screen filter system utilizing high-density polyester screens to remove particulate material and provide substrate for *Nitrosomonas* and *Nitrobacter* bacteria (Red Ewald, Inc., Karnes City, Texas). Continuous aeration was provided by a blower and air stones. Water exchange rate was approximately 10% of total volume per week. Chloride levels were maintained at approximately 1000 mg/l (by addition of food-grade NaCl) to minimize potential adverse effects of nitrite to fish health (Perrone and Meade, 1977). Each aquarium was supplied with water at a rate of 1.6 l/min and cleaned weekly. Black plastic covered the back and sides of all aquaria to minimize disturbances resulting when personnel were present in the laboratory (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). Total ammonia and nitrite were measured daily using a DREL/5 spectrophotometer (Hach Company, Loveland, CO, USA). Total alkalinity, hardness, and chlorides were monitored once each week using the DREL/5; pH was monitored weekly using an electronic pH meter (Omega Engineering, Stamford, CT, USA). Through the duration of the study average ($\pm$s.e.) water quality parameters were: water temperature, 25.9 ± 0.1 °C; dissolved oxygen, 7.36 ± 0.12 mg/l; total ammonia, 0.69 ± 0.06 mg/l; nitrite, 0.36 ± 0.19 mg/l; total alkalinity, 43.77 ± 7.21 mg/l; hardness, 201.5 ± 18.0 mg/l; chlorides, 1051 ± 130 mg/l; pH, 7.09 ± 0.23.

Juvenile channel catfish (mean individual weight 10 g) were obtained from the Kentucky Department of Fish and Wildlife Resources and acclimated in aquaria for 1 week while being fed a commercial pelleted diet (Purina Trout Chow, 38% crude protein). Fish were randomly stocked into all aquaria at a density of ten fish/aquarium, with four replications per treatment. Fish from each aquarium were weighed at the beginning of the experiment and then weekly until the conclusion of the feeding trial. Total length of each fish was measured at the beginning of the experiment and every 3 weeks thereafter. All fish were fed twice daily (08.00 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. After homogenization a sample was weighed and dried in a drying oven (95 °C for 24 h) for moisture determination.

Statistical analysis

Growth performance and feed conversion were measured in terms of final individual fish weight (g), total length (mm), percentage weight gain, percentage survival, specific growth rate (SGR, %/day), food conversion ratio

(FCR), and protein efficiency ratio (PER). Growth response parameters were calculated as follows:

Specific growth rate (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;

Food conversion ratio (FCR) = total dry feed fed (g)/total wet weight gain (g);

Protein efficiency ratio (PER) = wet weight gain (g)/amount of protein fed (g).

Data were analyzed by analysis of variance (ANOVA) using the SAS ANOVA procedure (Statistical Analysis System, 1988). Duncan's multiple-range test was used to compare differences among individual means. Percentage survival, percentage weight gain, and carcass composition (percentage protein and fat) were transformed to arc sin values prior to analysis (Zar, 1984).

RESULTS

Weight gains of channel catfish receiving diets containing 0% distillers' grains with solubles (DGS) and 35% DGS were significantly higher than those of fish fed a diet containing 70% DGS ($P<0.05$) (Table 4; Fig. 1). Channel catfish fed the 35% DGS diet were significantly larger (total length) than fish fed diets containing 0% DGS and 70% DGS ($P<0.05$), but not significantly

TABLE 4

Effect of increasing percentage of distillers' grains with solubles (DGS) on growth of juvenile channel catfish[1]

	Diet DGS (%)			
	0	35	70	70+LYS
Final wt. (g/fish)	62.00 ± 8.58[ab]	79.29 ± 4.14[a]	44.14 ± 4.91[b]	74.04 ± 7.91[a]
Weight gain (%)	411.12 ± 87.49[a]	440.62 ± 24.67[a]	231.85 ± 36.49[b]	504.20 ± 57.05[a]
Total length (mm)	184.08 ± 7.34[bc]	202.43 ± 1.26[a]	174.13 ± 4.47[c]	198.23 ± 5.94[ab]
Survival (%)	92.50 ± 7.50[a]	90.00 ± 7.07[a]	95.00 ± 2.89[a]	100.00 ± 0.00[a]
Protein gain (g)	26.07 ± 5.40[ab]	31.00 ± 2.11[ab]	16.22 ± 2.95[b]	35.54 ± 7.27[a]
PER[2]	1.10 ± 0.16[ab]	1.17 ± 0.07[a]	0.77 ± 0.11[b]	1.09 ± 0.07[ab]
SGR[3]	2.00 ± 0.14[a]	2.14 ± 0.07[a]	1.47 ± 0.11[b]	2.12 ± 0.11[a]
FCR[4]	2.35 ± 0.36[a]	2.17 ± 0.14[a]	3.97 ± 0.32[b]	2.19 ± 0.15[a]

[1]Values are means ± s.e. for four replications. Means within a column having the same superscript were not significantly different ($P>0.05$).

[2]Protein efficiency ratio = weight gain (g)/protein fed (g).

[3]Specific growth rate (%/day) = 100(log W_t − log W_i)/days.

[4]Food conversion ratio = total dry diet fed (g)/total wet weight gain (g).

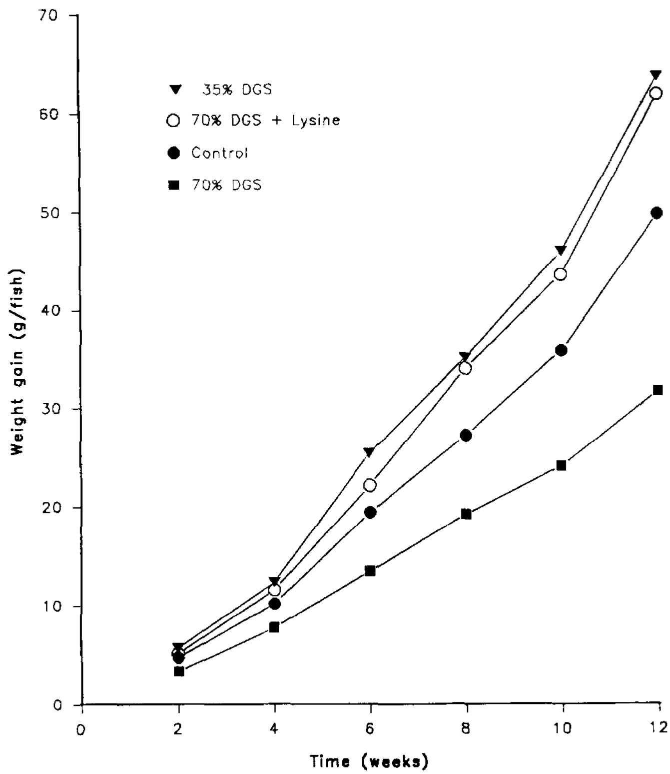

Fig. 1. The effects of different levels of distillers' grains with solubles (DGS) on weight gain of channel catfish. Values are means of four replications.

larger than those fed the 70% DGS+LYS diet. Amino acid supplementation with crystalline L-lysine in a diet containing 70% DGS significantly ($P<0.05$) improved channel catfish growth compared to that of fish fed a diet containing 70% DGS without added lysine.

Survival was 90% or better for each treatment and was not significantly different among the four treatments ($P>0.05$) (Table 4). Protein gain in fish fed the 70% DGS+LYS diet was significantly higher than in fish fed the 70% DGS diet ($P<0.05$). Channel catfish fed the 35% DGS diet had a significantly higher protein efficiency ratio (PER), 1.17, than fish fed the 70% DGS diet, 0.77 ($P<0.05$). Specific growth rate (SGR) value calculated for channel catfish fed the 70% DGS diet was significantly lower than that obtained for fish fed 0% DGS, 35% DGS, and 70% DGS+LYS diets ($P<0.05$). Food conversion ratio (FCR) of fish fed a diet with 70% DGS was significantly higher (4.51) than values for fish fed diets containing 0% DGS, 35% DGS, and 70% DGS+LYS (2.73, 2.41, and 2.54, respectively) ($P<0.05$).

Whole-body proximate composition of fish fed the control diet (0% DGS) showed that they had significantly less body fat (14.58%, dry-weight basis)

TABLE 5

Whole-body protein and lipid percentage (dry-weight basis) of juvenile channel catfish fed diets containing various percentages of distillers' grains with solubles (DGS)[1]

DGS (%)	Crude protein (%)	Crude lipid (%)
Initial composition	62.20 ± 3.71	20.65 ± 2.58
0	56.33 ± 1.80^{a}	14.58 ± 1.40^{b}
35	53.92 ± 2.45^{a}	25.23 ± 3.72^{a}
70	54.91 ± 1.69^{a}	21.21 ± 1.24^{ab}
70+LYS[2]	55.79 ± 6.27^{a}	27.79 ± 2.11^{a}

[1]Values are means ±s.e. for four replications. Means within a column having the same superscript were not significantly different ($P > 0.05$).
[2]Diet 4 was identical to Diet 3 except that 0.4% crystalline L-lysine was added.

than fish fed any of the diets containing DGS ($P < 0.05$) (Table 5). No significant differences in protein and moisture were found among treatments ($P > 0.05$).

All diets were readily consumed; however, a binder should be added to prepared diets incorporating large percentages (>35%) of DGS because of reduced water stability. Diets with 35 and 70% DGS had significantly less ($P < 0.05$) dry solids after 10 min in water (Table 2).

DISCUSSION

The present study indicates that distillers' grains with solubles (DGS) can be added up to 35% in a channel catfish diet without adverse effects on growth of the fish. The growth performance and feed conversion of fish fed a diet containing 35% DGS were not different from those of fish fed a commercially formulated diet containing soybean meal. It is known that antinutritional factors, primarily trypsin inhibitors, affect growth in trout (Smith et al., 1980), carp (Viola et al., 1983), tilapia (Shiau et al., 1987), and channel catfish (Robinson et al., 1981; Wilson and Poe, 1985) when fed diets with a high percentage of soybean meal. However, analysis of the diets used in this study indicated that trypsin inhibitor activity was not present in appreciable quantity (a value of 6.0 TIU/mg diet is considered to be low; pers. commun., Woodson-Tenent Laboratories, 1990).

The present study demonstrated that juvenile channel catfish can effectively utilize crystalline lysine supplementation in diets containing high percentages of DGS. Fish fed a diet with 70% DGS showed a significant reduction in growth compared to those fed a control diet. However, addition of 0.4% crystalline L-lysine to the 70% DGS diet resulted in channel catfish growth similar to that of fish fed a control diet. Percentage weight gain, total length, specific growth rate (SGR), and food conversion ratio (FCR) in fish fed diets containing 0% DGS, 35% DGS, and 70% DGS+LYS were higher than in fish fed a diet with 70% DGS.

Andrews and Page (1974) found no significant improvement in growth of channel catfish fed soybean-meal diets with crystalline methionine and cystine added. Addition of crystalline methionine (Ng and Wee, 1989) and lysine (El-Sayed, 1990) to diets did not improve growth in Nile tilapia (*Oreochromis niloticus*). This may be due to insufficient supplementation of crystalline amino acids to meet the requirements for Nile tilapia (Ng and Wee, 1989). Recent studies have demonstrated that channel catfish can utilize crystalline lysine and methionine supplemented to diets. Robinson (1990) showed that channel catfish fed diets containing cottonseed meal as the primary protein source exhibited lower growth rates than fish fed a control diet (containing soybean meal). However, when the diet was supplemented with lysine, growth was equivalent to that of fish fed the control diet. Murai et al. (1982) reported improved growth in channel catfish when methionine was added to soybean-meal protein. Murai et al. (1986) reported that addition of crystalline methionine improved growth in carp (*Cyprinus carpio*). Rumsey and Ketola (1975) reported that addition of several essential amino acids to soybean-meal diets was necessary before significant improvement in growth by rainbow trout (*Oncorhynchus mykiss*) could be demonstrated.

These contrasting conclusions from earlier amino acid supplementation studies may be due to adding amino acids to diets replete in the particular amino acid investigated (Robinson, 1989). Further, amino acid analogs, such as methionine hydroxy analog (MHA) are not utilized as effectively as the L-form of the amino acid (Robinson et al., 1978). Channel catfish appear to utilize crystalline L-lysine. Results from this study are in agreement with findings reported in Robinson et al. (1980) and Robinson (1990). A third possibility to account for the conflicting results may be the feeding frequency used in the experiment. Fish may not utilize crystalline amino acids when fed once a day because amino acids may be rapidly excreted or converted into other compounds. Thebault (1985) reported that crystalline methionine is converted to methionine sulfoxide in sea bass (*Dicentrarchus labrax*). Murai et al. (1986) stated that common carp fed diets containing crystalline methionine four times a day had growth rates similar to those of carp on a control diet. This study indicates that juvenile channel catfish fed diets supplemented with crystalline L-lysine two times a day had growth rates similar to those of fish fed a control diet.

The protein-to-energy ratio of the diets fed in this experiment (125–140 mg protein/kcal DE) were higher than used in some studies where an optimum value of 88 mg protein/kcal was reported using purified ingredients (Garling and Wilson, 1976). Our values were in agreement with practical diets which range from 120 to 150 mg protein/kcal (Reis et al., 1989). Differences may be due to the methods used to calculate energy values. Garling and Wilson (1976) based energy on physiological fuel values which are higher than digestible energy values.

None of the dietary treatments had any significant effect on percentage of crude protein in whole-body compositions. However, the crude fat levels in fish fed diets containing 0% DGS (control diet) were lower than in fish fed diets containing 35% DGS and 70% DGS plus supplemental lysine. This may be due to the slightly lower digestible energy value (2.56 kcal/g of diet) calculated in the control diet compared to diets with 35% DGS and 70% DGS plus lysine (2.65 and 2.84 kcal/g of diet, respectively). Fish fed the control diet were also smaller (62.0 g) than fish fed diets containing 35% DGS and 70% DGS plus supplemental lysine (79.3 and 74.0 g, respectively), although this difference was not significant.

Food conversion ratios (FCR) in our experiment were higher (2.2–4.0) than in some aquaria studies using channel catfish; however, they were below FCR values found in several studies performed at this laboratory (unpubl. data). Robinson et al. (1985) reported an FCR of 1.50; however, fish were fed 6% of body weight daily, not to satiation. It may also be that a P:E ratio of greater than 125 mg protein/kcal DE is too high. Catabolism of excess dietary protein for fat deposition in fish may have resulted in reduced feed efficiency. Mangalik (1986) found that increasing DE in a 37%-protein diet improved feed efficiency. Perhaps increasing the DE would have improved feed efficiency by reducing the amount of diet consumed while still allowing fish to satisfy daily protein requirements.

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