Effect of Diets Containing Various Levels of Protein and Ethanol Coproducts from Corn on Growth of Tilapia Fry

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Experimental diets containing 32−40% protein and 16−49% corn gluten meal, corn gluten feed, or corn distillers' grains with solubles were fed to tilapia with 0.4 g initial weight for 8 weeks in aquaria. Weight gain, feed conversion ratio, and protein efficiency ratio for experimental and control diets were in the range of 3270−5320%, 1.06−1.38, and 1.87−2.37, respectively. Statistically, the highest weight gain was achieved from control diet and a 40% protein diet with 35% corn distillers' grains with solubles; the best feed conversion ratio was obtained from control diet and two 40% protein diets with 35% corn distillers' grains with solubles or 30% corn gluten feed; the highest protein efficiency ratio was from control diet and two 36% protein diets with 49% corn distillers' grains with solubles or 42% corn gluten feed.

Keywords: *Tilapia; corn gluten meal; corn gluten feed; corn distillers' grains with solubles*

INTRODUCTION

Corn is the major cereal grain used to make ethanol by fermentation in the United States. Protein-containing coproducts of ethanol production from corn are corn distillers' grains with solubles (26% protein) from dry milling plants and corn gluten meal (64% protein) and corn gluten feed (21% protein) from wet milling plants. Traditionally, these ethanol coproducts are used as feed ingredients for cattle, hog, and poultry. An increasing amount of ethanol coproducts are produced as the demand for fuel ethanol increases. It is desirable to find additional use of these coproducts.

Tilapia is a widely cultured warmwater fish (Bardach et al., 1972). The cost of feed can account for 50% of the total production cost of fish. Wu et al. (1994, 1995) reported that diets containing corn gluten meal (18%) or corn distillers' grains with solubles (29%) and 32% or 36% protein resulted in higher weights of tilapia than fish fed a commercial fish feed containing 36% protein and fish meal for tilapia with initial weight of 30 g. Since the protein requirements of fish vary with size or age of fish (National Research Council, 1977; Andrews, 1977; DeLong et al., 1958; Lovell, 1977), this paper investigates the growth responses of tilapia with initial weight of 0.4 g for feeds containing up to 49% ethanol coproducts and 32%, 36%, and 40% protein contents.

MATERIALS AND METHODS

Corn gluten meal and corn gluten feed were supplied by Pekin Energy Company (Pekin, IL); soy flour (baker's Nutri Soy) and soy oil were from Archer Daniels Midland Corp. (Decatur, IL). Corn distillers' grains with solubles was purchased from Jack Daniels Distillery (Lynchburg, TN). Menhaden fish oil came from International Protein Corp. (St. Paul, MN). Vitamin premix for warmwater fish was from Hoffman-LaRoche (Paramus, NJ), and mineral premix came from Triple F Products (Des Moines, IA). The control diet was a Silver Cup catfish feed with minimum of 35% protein but actually contained 36% protein in Table 1 (Nelson & Sons, Inc., Murray, UT). Corn gluten meal, corn gluten feed, and corn distillers' grains with solubles were each ground in an Alpine pin mill at 14 000 rpm. The experimental tilapia diets were made by a Randcastle extruder (Cedar Grove, NJ). The analyzed compositions of the tilapia and control diets are listed in Table 1.

Table 1. Percent and Proximate Compositions (As-Is weight Basis) of Tilapia and Control Diets

	diet							
	32M	36D	36F	36M	40M	40D	40F	control
ingredient								
corn gluten meal	16	0	0	19	22	0	0	
soy flour	34	44	51	39	44	58	63	
corn gluten feed	0	0	42	0	0	0	30	
corn distillers' grains with solubles	0	49	0	0	0	35	0	
corn	43	0	0	35	27	0	0	
soy oil	2	2	2	2	2	2	2	
fish oil	2	2	2	2	2	2	2	
vitamin mix[a]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
mineral mix[b]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
proximate composition								
moisture, %	9.9	8.6	8.1	8.4	7.5	7.3	8.7	9.4
protein, % N × 6.25	32.2	36.8	35.4	36.5	40.2	40.4	39.2	36.4
fat, %	4.7	8.8	4.3	5.0	4.9	7.4	4.3	9.7
ash, %	5.8	7.2	7.9	6.0	6.0	7.2	8.1	7.5
crude fiber	2.9	7.1	5.1	2.3	2.2	5.5	4.3	5.1

[a] The vitamin premix supplied per kilogram diet: vitamin A, 9900 international unit (IU); vitamin D, 2200 IU; vitamin E, 8.25 IU; vitamin B-12, 0.014 mg; riboflavin (B2), 18.2 mg; niacin, 10.7 mg; pantothenic acid, 37 mg; choline, 715 mg; folic acid, 6.1 mg; biotin, 0.17 mg; ascorbic acid, 220 mg; menadione (K3), 9 mg; thiamine (B1), 16.2 mg. [b] The mineral premix supplied per kilogram diet: calcium, 4.3 g; phosphorus, 2.6 g; copper, 5.0 mg; iron, 41 mg; manganese, 120 mg; zinc, 115 mg; iodine, 2.5 mg; cobalt, 1.0 mg; sulfur, 153 mg.

Tilapia (*Oreochromus niloticus*) with an average initial weight of 0.4 g were used in the feeding experiment. Groups of 25 fish each were fed in 38 L aquaria in duplicate for each diet and in four replicates for control. The fish were fed twice

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Table 2. Essential Amino Acid Composition (Percent of Protein) of Tilapia and Control Diets

	diet								
amino acid	32M	36D	36F	36M	40M	40D	40F	control	requirement[a]
arginine	5.6	6.0	6.0	5.7	5.7	6.4	6.7	5.8	3.5
histidine	2.5	2.5	2.5	2.4	2.5	2.5	2.6	3.1	1.3
isoleucine	4.3	4.2	4.0	4.3	4.4	4.3	4.3	3.4	3.1
leucine	11.1	8.6	7.5	10.8	11.1	8.1	7.8	8.2	2.8
lysine	4.4	5.1	5.3	4.6	4.6	5.5	5.8	6.4	4.6
methionine + cystine	3.6	3.2	2.8	3.6	3.7	3.1	3.0	3.6	3.2
phenylalanine + tyrosine	9.4	8.5	7.8	9.4	9.7	8.5	8.3	7.8	5.0
threonine	3.6	3.6	3.5	3.6	3.6	3.7	3.8	4.0	3.6
tryptophan	1.1	1.2	1.2	1.1	1.0	1.2	1.3	1.0	0.7
valine	4.8	4.8	4.5	4.8	4.9	4.8	4.8	5.8	2.3

[a] Santiago (1985).

Table 3. Weight Gain (WG), Feed Conversion Ratio (FCR), and Protein Efficiency Ratio (PER) of Tilapia and Control Diets[a]

diet	initial weight, g	final weight, g	WG	FCR	PER	digestible energy, kcal/g
32M	0.40	14.46	3550(50)c	1.32(0.01)a	2.12(0.02)bc	3.65
36D	0.41	16.96	4050(300)bc	1.13(0.05)b	2.19(0.10)abc	3.71
36F	0.40	16.78	4050(250)bc	1.13(0.09)b	2.30(0.19)ab	3.55
36M	0.45	16.36	3560(910)c	1.34(0.09)a	1.87(0.12)d	3.76
40M	0.45	15.14	3270(460)c	1.24(0.09)ab	1.87(0.13)d	3.82
40D	0.40	20.66	5100(300)ab	1.13(0.02)bc	2.03(0.04)cd	3.77
40F	0.40	17.49	4240(520)bc	1.12(0.00)bc	2.08(0.01)cd	3.57
control	0.41	22.45	5320(550)a	1.05(0.03)c	2.37(0.07)a	3.79

[a] Means of duplicate (standard deviation) for experimental diets, means of four replicates for control. Weight gain expressed as the percentage increase at the end of 56 days. Feed conversion ratio is dry feed/wet weight gain. Protein efficiency ratio is weight gain/protein fed. Numbers followed by different letters are significantly different ($P < 0.05$).

daily. The amount of feed introduced per day was 13% of body weight at the beginning of the experiment and was gradually decreased to 5.6% of body weight at the end of the 8 week experiment. The fish in each aquarium were weighed every 2 weeks, and the feed weight was adjusted after each fish weighing. The increase in fish weight was estimated between weighings, and the feed weight was adjusted daily.

Nitrogen, fat, ash, and moisture contents were determined by the AACC Approved Methods (AACC, 1983). Nitrogen (N) was determined by micro-Kjeldahl, and protein was calculated by N × 6.25. Fat was from 4 h petroleum ether extraction, ash was from the weight remaining after heating the sample to 600 °C for 2 h, and moisture was from the weight loss after oven drying at 135 °C for 2 h. Samples for amino acid analyses were hydrolyzed at 145 °C for 4 h (Gehrke et al., 1987). Methionine and cystine were oxidized with performic acid before hydrolysis (Moore, 1963). Amino acids were determined by cation exchange chromatography in a Beckman 6300 amino acid analyzer (Beckman Instruments, Inc., San Raman, CA). Tryptophan was determined by colorimetric method after enzymatic hydrolysis by pronase (Spies and Chambers, 1949; Holz, 1972).

Water quality, such as temperature, dissolved oxygen, and pH, was measured daily; nitrate, nitrite, ammonia, carbon dioxide, alkalinity, and hardness were determined weekly. The average (±standard deviation) water quality parameters were temperature, 29.8 ± 1.1 °C; dissolved oxygen, 6.9 ± 0.4 mg/L; pH, 7.35 ± 0.22; nitrite, 0.80 ± 0.31 mg/L; nitrate, 92.1 ± 25.0 mg of nitrate−nitrogen/L; ammonia, 1.72 ± 0.50 of mg ammonia−nitrogen/L; carbon dioxide, 8.6 ± 2.5 mg/L; alkalinity, 125.7 ± 47.9 mg/L as calcium carbonate; and hardness, 306.9 ± 24.8 mg/L as calcium carbonate.

Weight gain was (final weight − initial weight)/initial weight and expressed as percentage increase for 56 days. Feed conversion ratio was dry feed offered/wet weight gain. Protein efficiency ratio was weight gain/protein fed. The dietary digestible energy for tilapia was calculated from values of 4.5, 4.0, and 9.0 kcal/g for protein, carbohydrate, and lipid, respectively (Wang et al., 1985).

The data were analyzed by analysis of variance. Means were compared by *t*-tests of pairs of least-squares means (SAS Institute Inc., 1987).

RESULTS AND DISCUSSION

The first two digits of the experimental diets (Table 1) give the approximate protein content on as-is basis, and M, D, and F represent corn gluten meal, corn distillers' grains with solubles, and corn gluten feed, respectively. The diets in Table 1 were formulated to contain 40%, 36%, and 32% proteins that meet the amino acid requirement of tilapia (Santiago, 1985). Vitamin and mineral mixes were added based on recommendations for warmwater fish.

The amino acid compositions of the experimental and control diets (Table 2) met the amino acid requirements of tilapia (Santiago, 1985) except diet 36F (2.8% sulfur amino acids vs 3.2% required), diet 40F (3.0% sulfur amino acids vs 3.2% required), and diet 32M (4.4% lysine vs 4.6% required).

Weight gains of tilapia fed experimental and control diets (Table 3) were good compared with 3300% for sibling of initial weight 0.5 g fed a commercial 36% protein diet for the same 8 week period. The control and diet 40D (40% protein and 35% corn distillers' grains with solubles) had the highest weight gain. The differences in weight gain between diets 40D and 36D (36% protein and 49% corn distillers' grains with solubles), 36F (36% protein and 42% corn gluten feed) or 40F (40% protein and 30% corn gluten feed) were not significant ($P > 0.05$). Weight gain of diet 32M (32% protein and 16% corn gluten meal) was not significantly different from diets 36D, 36F, 36M (36% protein and 19% corn gluten meal), 40M (40% protein and 22% corn gluten meal), and 40F ($P > 0.05$). Thus, the 32% protein diet did as well as all three 36% diets and two of the three 40% protein diets ($P > 0.05$) in terms of weight gain.

Feed conversion ratios of tilapia fed various diets (Table 3) showed diets 40D, 40F, and control were best and not significantly different ($P > 0.05$), but the ratios from diets 36D, 36F, and 40M were not significantly

different from those of diets 40D and 40F ($P > 0.05$). Diets 32M and 36M gave highest feed conversion ratios. The dietary digestible energies for tilapia diets in Table 3 ranged from 3.55 to 3.82 kcal/g; crude fiber is not counted as carbohydrate because cellulose is not digested by tilapia (Jauncey and Ross, 1982). Weight gain, feed conversion ratio, and protein efficiency ratio are not correlated with protein content, digestible energy, or protein/energy ratio (all $P > 0.05$). However, fat content is positively correlated with weight gain and protein efficiency ratio (all $P < 0.02$) and negatively correlated with feed conversion ratio ($P < 0.01$). Nitrogen free extract (100 − protein − fat − fiber − ash − moisture, all in percent) is negatively correlated with weight gain and positively correlated with feed conversion ratio (all $P < 0.001$). In general, the feed conversion ratios were good, and 1.06−1.38 kg of feed was converted to 1 kg of weight gain for tilapia. For comparison, Davis and Stickney (1978) reported a feed conversion ratio of 1.46 for tilapia of 0.39−0.45 g initial weight, fed 36% protein diet for 84 days in 46 L tanks.

Protein efficiency ratios (Table 3) of experimental and control diets ranged from 1.87 to 2.37, and the best diets were 36D, 36F, and control, which were not significantly different ($P > 0.05$). However, the protein efficiency ratios of tilapia fed diets 32M, 40D, and 40F were not significantly different from that of 36D. Our protein efficiency ratio values compared favorably with 0.86−2.09 from Siddiqui et al. (1988) for tilapia with initial weight of 0.84 g fed 98 days with 20−50% protein diets in tanks.

CONCLUSION

Experimental diets containing 32%, 36%, and 40% protein and 16−49% of protein-rich ethanol coproducts resulted in good weight gain, feed conversion ratio, and protein efficiency ratio for tilapia fry. The ethanol coproducts were well utilized by the tilapia.

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