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Growth, Feed Conversion, Protein Utilization, and Sensory Evaluation of Nile Tilapia Fed Diets Containing Corn Gluten Meal, Full-Fat Soy, and Synthetic Amino Acids

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ABSTRACT. Experimental diets containing 36% protein, corn gluten meal, full-fat soy meal, and high-lysine corn, as well as a commercial (control) diet were fed to tilapia with 9 g initial weight for 12 weeks in aquaria. Weight gain, feed conversion ratio, and protein efficiency ratio for experimental diets and control diet were not significantly different

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and ranged from 754-918%, 1.67-1.79, and 1.42-1.56, respectively. No advantage was gained when fish meal (4 or 8%) was incorporated into the experimental diets. Tilapia fed diets containing 3-4% fat performed equally well compared with fish fed diets with 7-8% fat. A trained 10-member sensory panel evaluated the flavor characteristics of harvested, cooked tilapia fillets. The intensities of flavor characteristics of cooked fillets from tilapia raised on pellets containing 23 and 34% corn gluten meal were not significantly different from fish fed commercial fish feed without corn gluten meal. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworthpressinc.com <Website: http://www.haworthpressinc.com>]*

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INTRODUCTION

Corn gluten meal (60% plus protein fraction) is a coproduct from wet milling of corn. As the demands for fuel ethanol and high fructose corn syrup increase, more corn gluten meal is produced. It is desirable to find new uses for corn gluten meal in addition to its traditional use in cattle, hog, and poultry feeds.

Although defatted soy meal has been used in both animal and fish feeds, there is little information on full-fat soy meal in fish feed application. Since full-fat soy meal can be made easily by extruding whole soybean, there is increasing interest for farmers to process feeds on site. It is necessary to find out the performance of full-fat soy meal compared with defatted soy meal in feeds before wider use of full-fat soy meal is feasible.

High-lysine corn containing increased level of lysine and tryptophan compared with normal corn was discovered by Mertz et al. (1964). It is estimated that one million tons of high yielding varieties of soft endosperm opaque-2 hybrids (Hi-Lysine Corn) were produced annually in the midwest for on-farm livestock feed (Mertz, 1992). The use of high-lysine corn instead of normal corn can reduce the total level of dietary protein supplement for hog feed. Since fish feed requires a higher percentage of protein with balanced amino acid composition compared with hog feed, it is advantageous to use high-lysine corn instead of normal corn so that dietary protein supplement (from soybean meal or synthetic amino acids) can be reduced.

Most commercial fish feeds contain fish meal as an ingredient. Fish meal is relatively expensive, frequently imported and, therefore, may not be available in the future. Replacement of fish meal with plant protein sources in fish feed has been an objective of many investigations (Webster et al., 1992; Wu et al., 1995). The intensities of flavor characteristics of cooked fillets from tilapia raised on pellets containing 16% of corn gluten meal was not significantly different from fish fed commercial fish feed (Wu et al., 1996). The flavor characteristics of cooked fillets from tilapia fed diets containing much higher than 16% corn gluten meal are not yet available.

The purpose of this study is to investigate the growth response and sensory characteristics of tilapia fed diets containing 21-35% corn gluten meal, high-lysine corn, full-fat soy meal and synthetic amino acids, with and without fish meal.

MATERIALS AND METHODS

Corn gluten meal was supplied by Pekin Energy Company (Pekin, IL). High-lysine corn, SL48, was donated by Crow's Hybrid Corn Company (Milford, IL). Menhaden fish meal was a gift from Zapata Protein (USA) (Hammond, LA). Full-fat soy meal and mineral premix were supplied by Triple F Products (Congerville, IL and Des Moines, IA). Vitamin premix and L-ascorbyl-2-polyphosphate were donated by Hoffman-LaRoche (Paramus, NJ). Tryptosine 10/60 (10% L-tryptophan and 60% L-lysine HCl), L-threonine, and L-lysine HCl were gifts from Archer Daniels Midland Corp. (Decatur, IL). The control diet was Purina 5144 Catfish Cage Chow, a 36% protein pellet containing fish meal purchased from Purina Mills Inc. (St. Louis, MO). The experimental tilapia diets were made by a Leistritz Micro 18GL 30D twin-screw extruder (Somerville, NJ).

Table 1 gives the percentage of ingredients for the three experimental diets. The diets in Table 1 were formulated to contain 36% protein that meet the amino acid requirement of tilapia (Santiago and Lovell, 1988).

Tilapia (*Oreochromis niloticus*) having an initial average weight of 9.0 g were used in the feeding experiments. Groups of 15 fish each were fed in 114 L aquaria in triplicate for each diet. The fish were fed twice daily. The amount of feed offered per day was 8.50% of body weight at start and gradually decreased to 5.70% of body weight after 2 weeks, to 4.38% after 6 weeks, and to 2.20% at the end of 12 weeks.

TABLE 1. Ingredients of 36% protein experimental diets (% as-is weight basis)

	Experimental diet		
Ingredient	36F4[cd]	36F8[cd]	36C[e]
Corn gluten meal	24.52	21.46	34.72
High-lysine corn	30.00	30.00	39.48
Fish meal	4.0	8.0	0
Full fat soy meal	34.76	34.09	18.00
L-ascorbyl-2-polyphosphate	0	0	0.1
Vitamin mix[a]	0.5	0.5	0.5
Mineral mix[a]	2.5	2.5	2.5
Tryptosine[b]	0.96	0.87	1.72
L-lysine-HCl	0.61	0.46	0.74
L-threonine	0.20	0.17	0.29
$KH_2PO_4 + NaH_2PO_4 \cdot H_2O$, 1:1	1.95	1.95	1.95

[a]The vitamin and mineral premix supplied per kilogram diet: vitamin A, 9900 international unit (IU) from vitamin A acetate; vitamin D_3, 2200 IU; vitamin E, 82.5 IU; vitamin B_{12}, 0.014 mg; riboflavin (B_2), 18.2 mg; niacin, 10.7 mg, from niacinamide; d-pantothenic acid, 37 mg, from calcium d-pantothenate; choline, 715 mg, from choline chloride; folic acid, 6.1 mg; d-biotin, 0.17 mg; ascorbic acid, 220 mg, from L-ascorbyl-2-polyphosphate; menadione (K_3), 9 mg, from menadione sodium bisulfite complex; thiamine (B_1), 16.2 mg, from thiamine mononitrate; pyridoxine (B_6), 12 mg, from pyriodoxine hydrochloride; calcium, 4.3 g, from calcium carbonate and dicalcium phosphate; phosphorus, 2.6 g, from dicalcium phosphate; copper, 5.0 mg, from copper sulfate; iron, 41 mg, from ferrous sulfate; manganese, 120 mg, from manganous sulfate; zinc, 115 mg, from zinc sulfate; iodine, 2.5 mg, from ethylenediamine dihydriodide; cobalt, 1.0 mg, from cobaltous carbonate; sulfur, 153 mg.

[b]Tryptosine 10/60 contains 10% L-tryptophan and 60% L-lysine-HCl.

[c]Fish meal.

[d]Percentage of fish meal.

[e]Additional vitamin C.

The fish in each aquarium were weighed as a group 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 changed daily. Weight gain (WG) was calculated as (final weight − initial weight)/initial weight and expressed as percent increase for 84 days. Feed conversion ratio (FCR) was calculated from dry feed offered/wet weight gain. Protein efficiency ratio (PER) was weight gain/protein fed.

After the 12-week feeding study for weight gain, feed conversion ratio and protein efficiency ratio calculations, the same fish were restocked for sensory evaluation study. Diets with 34, 23, and 0% corn gluten meal were fed to tilapia with average initial weights of 110, 135, and 112 g, respectively. This second phase of study lasted another 11 weeks. Half of the fish were chilled in an ice bath, fillet separated from fish and skinned. Fillets were put in plastic bags, frozen at 16°C, and stored at −18°C in double plastic bags before evaluation. The remaining half of the fish were purged 3 days without feed and then fillets were prepared and stored as described above, because purging may affect sensory properties.

A 10-member trained analytical sensory panel evaluated tilapia using descriptive profiling for intensities of individual flavor descriptors, including sweet, nutty, fishy, musty, cereal, and buttery. Samples were rated for individual flavor intensities on a 0-10 point intensity scale with 0 = none and 10 = strong. Frozen fillets were thawed at 4°C and baked for 20 min at 176°C in plastic cooking bags (Reynolds Metal Co., Richmond, VA). Details of preparing the fillets and sensory evaluation were described previously (Wu et al., 1996).

Water temperature, dissolved oxygen, and pH were measured daily; total ammonia-N, nitrate-N, and nitrite-N were measured weekly. The average (± standard deviation) water quality parameters were as follows: temperature, 27.8 ± 1.0°C; dissolved oxygen, 7.7 ± 0.5 mg/L; pH, 7.50 ± 0.2; ammonia-N, 1.14 ± 0.36 mg/L; nitrate-N, 18.1 ± 4.3 mg/L; and nitrite-N, 0.81 ± 0.29 mg/L.

Nitrogen, fat, ash, crude fiber, and moisture contents for diets were determined by the AACC Approved Methods (AACC, 1983). Nitrogen (N) was measured by micro-Kjeldahl, and protein was calculated by N × 6.25. Fat was determined from 4 h petroleum ether extraction. Ash was from the weight remaining after heating the sample for 2 h at 600°C. 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), and methionine and cystine were oxidized with performic acid before hydrolysis (Moore, 1963). Amino acids were determined in a Beckman 6300 amino acid analyzer (Beckman Instruments, Inc., San Ramon, CA) by cation exchange chromatography. Tryptophan was measured by calorimetric method after enzymatic hydrolysis by pronase (Spies and Chambers, 1949; Holz, 1972). The dietary digestible energy for tilapia was calculated by using 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 and means were compared by t-tests of pairs of least-square means (SAS Institute Inc., 1987).

RESULTS AND DISCUSSION

At the beginning of the experiment, the best feeding response (eagerness to consume feed) came from the fish fed P5144 (the commercial control containing fish meal). The two experimental diets containing fish meal (36F4 and 36F8) gave a feeding response close to fish fed P5144 but not quite as aggressive. There was generally poor reaction to diet 36C without fish meal. Towards the latter part of the experiment it appeared that the feeding reaction slowed for P5144 and increased for diet 36C. The two experimental diets containing fish meal remained the same. Overall reactions of fish toward feed consumption seemed very even at the end for all diets.

Proximate composition of experimental and control diets (Table 2) indicated all four diets had 36% protein, but diets 36F4 and 36F8 contained about twice the amount of fat as diets 36C and P5144. However, all the diets contained about the same digestible energy.

The essential amino acid compositions of the experimental and control diets met the amino acid requirements of tilapia (Santiago and Lovell, 1988) except diet 36C was borderline low in arginine (Table 3).

Initial and final weights as well as weight gain (WG), feed conver-

TABLE 2. Proximate composition of experimental and control diets

Diet	Moisture, %	Protein, % N × 6.25	Fat, %	Ash, %	Crude fiber, %	Digestible energy, kcal/g
36 F4[a]	8.9	36.2	7.4	7.0	2.6	3.81
36 F8[b]	8.1	35.5	8.0	7.8	2.6	3.84
36 C[c]	8.4	35.9	3.7	6.1	2.2	3.70
P5144[d]	6.1	36.2	3.3	8.6	2.9	3.64

[a]36% Protein content diet having 4% fish meal.
[b]36% Protein content diet having 8% fish meal.
[c]36% Protein content diet with additional vitamin C.
[d]Commercial control containing fish meal.

sion ratio, and protein efficiency ratio of fish fed experimental and control diets for 84 days are listed in Table 4. Although WG was lowest for diet 36C without fish meal and intermediate for diet 36F4 with 4% fish meal and highest for diet 36F8 with 8% fish meal, the difference was not significant ($P > 0.05$). Also, all three experimental diets had the same WG as the control P5144 diet ($P > 0.05$).

TABLE 3. Essential amino acid composition (% of protein) of tilapia diets

	Diet				
	36 C	36 F4	36 F8	P5144	Requirement[a]
Arginine	3.9	4.8	5.0	6.7	4.2
Histidine	2.3	2.4	2.5	2.6	1.7
Isoleucine	3.9	3.9	4.2	4.0	3.1
Leucine	13.1	11.3	11.1	7.7	3.4
Lysine	7.1	6.6	6.7	6.1	5.1
Methionine + cystine	3.7	3.5	3.7	3.4	3.2
Phenylalanine + tyrosine	9.5	9.4	9.2	7.9	5.5
Threonine	4.0	3.9	3.9	3.9	3.8
Tryptophan	1.4	1.2	1.3	1.2	1.0
Valine	4.5	4.4	4.8	4.6	2.8

[a]Santiago and Lovell, 1988.

TABLE 4. Weight gain (WG), feed conversion ratio (FCR), and protein efficiency ratio (PER) of tilapia fed experimental and control diets

Diet[a]	Initial weight, g	Final weight, g	WG[b]	FCR[c]	PER[d]	P/E[e]
36 C	9.1	77.6	754(74)A	1.79(0.11)A	1.43(0.09)A	95.0
36 F4	8.9	82.3	828(97)A	1.77(0.09)A	1.42(0.07)A	92.5
36 F8	9.2	93.4	918(82)A	1.67(0.09)A	1.56(0.08)A	97.1
P5144	8.8	89.8	917(170)A	1.77(0.25)A	1.49(0.20)A	99.4

[a]Means (standard deviations) of three replicates for each diet.
[b]Weight gain = the percentage increase at the end of 84 days. Numbers followed by different letters in a column are significantly different ($P < 0.05$).
[c]Feed conversion ratio = dry feed offered/wet weight gain.
[d]Protein efficiency ratio = weight gain/protein fed.
[e]Protein/energy expressed as mg protein/kcal.

Feed conversion ratios of tilapia fed experimental and control diets (Table 4) indicated the best FCR (1.67) was obtained from diet 36F8. However, all four diets had the same FCR values statistically ($P > 0.05$). Siddiqui et al. (1991) reported FCR values of 1.7-2.3 for tilapia with an initial weight of 19 g fed 34% protein diet for 98 days in outdoor concrete tanks. Stickney and McGeachin (1984) fed a 32% protein diet to tilapia with initial weight of 4.4 g for 84 days in aquaria and obtained FCR values of 1.9-2.8. Our FCR values of 1.67-1.79 compared favorably with those from Siddiqui et al. (1991) and Stickney and McGeachin (1984).

The best PER value (1.56) for tilapia fed experimental and control diets (Table 4) was from diet 36F8. However, there is no significant difference between any of the four diets ($P > 0.05$) for PER. For comparison, Siddiqui et al. (1988) reported PER values of 0.72-2.15 for tilapia with initial weight of 40 g fed 20-50% protein diets for 98 days in outdoor concrete tanks. Our PER values of 1.42-1.56 are in the middle range of PER values reported by Siddiqui et al. (1988).

Protein/energy ratios for diets 36F4, 36F8, 36C and P5144 were 95, 93, 97, and 99, respectively (Table 4) and were quite close to one another.

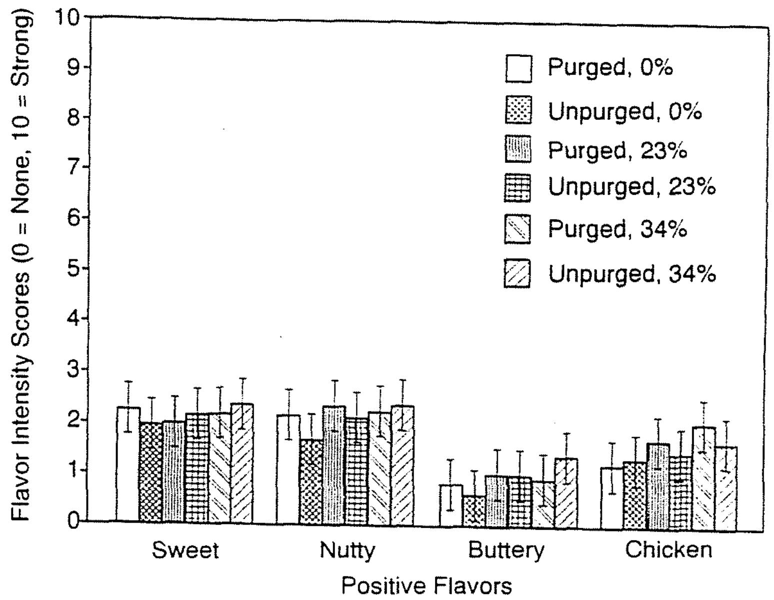
Figure 1 shows the flavor intensity scores of sweet, nutty, butter, and chicken for purged and unpurged tilapia fed diets with 0, 23, and 34% corn gluten meal. No significant difference ($P > 0.05$) was found between purged and unpurged tilapia at all levels of corn gluten meal for each flavor intensity score.

Figure 2 gives the flavor intensity scores of fishy, cardboard, cereal, grassy, musty, and other for purged and unpurged tilapia fed diets with 0, 23, and 34% corn gluten meal. Again no significant difference was found ($P > 0.05$) between purged and unpurged tilapia at all levels of corn gluten meal for each flavor intensity score except purged fish fed 0% corn gluten meal had higher fishy intensity score than unpurged fish fed 34% corn gluten meal ($P < 0.05$).

Results of both figures indicated that diets containing corn gluten meal (up to 34%) fed to tilapia did not cause any flavor problem. Also, purging tilapia did not improve the flavor intensity scores for the diets studied.

Park et al. (1997) found that concentrations of xanthophyll in catfish tissue were linearly related to the corn gluten meal level in the diet, and that the visual scores for flesh pigmentation correlated well with the pigment concentrations in the tissues. There was no visual

FIGURE 1. Positive flavor intensity scores for purged and unpurged tilapia fed diets with 0, 23, and 34% corn gluten meal. Error bar is shown for each measurement.

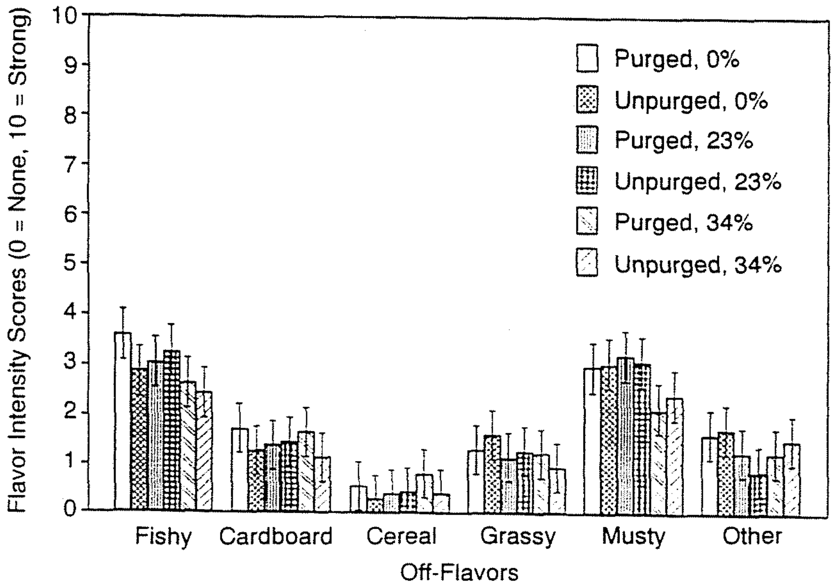


difference in color of fish or fillet for tilapia fed diets containing 0, 23, and 34% corn gluten meal.

CONCLUSION

Experimental diets containing 36% protein, 21-35% corn gluten meal, 18-35% full-fat soy meal, 30-39% high-lysine corn and supplemented with lysine, threonine, and tryptophan resulted in equally good weight gain, feed conversion ratio, and protein efficiency ratio for young tilapia compared with a 36% protein commercial fish feed containing fish meal. There is no advantage for fish meal in tilapia diet, because tilapia fed diets containing fish meal did not perform better than fish fed diet devoid of fish meal. Also, tilapia fed diets containing 3-4% fat performed equally well compared with fish fed diets with 7-8% fat. Full-fat soy meal, corn gluten meal, and synthetic amino acids were well utilized by the tilapia.

FIGURE 2. Off-flavor intensity scores for purged and unpurged tilapia fed diets with 0, 23, and 34% corn gluten meal. Error bar is shown for each measurement.



Corn gluten meal (at least up to 34%) can be included in tilapia diets without causing any flavor problem compared with diets without corn gluten meal.

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