Evaluation of Corn Gluten Meal as a Protein Source in Tilapia Diets

Y. Victor Wu,*,† Ronald R. Rosati,‡ David J. Sessa,† and Paul B. Brown§

Biopolymer Research Unit, National Center for Agricultural Utilization Research, Agricultural Research Service, U.S. Department of Agriculture, Peoria, Illinois 61604, Department of Agriculture, 5020 Illinois State University, Normal, Illinois 61790-5020, and Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907-1159

Corn gluten meal was incorporated into tilapia diets containing 32 and 36% protein from corn and soybean with and without fish meal and soy lecithin, respectively. A 75-day feeding study indicated that the five diets containing corn gluten meal yielded higher weight gain, higher protein efficiency ratio, and better or equal feed conversion ratio values of tilapia than a commercial fish feed containing 36% protein and fish meal. Tilapia fed 32% protein diets had the same weight gain as 36% protein diets. No advantage was realized when fish meal (6%) was incorporated into the diet. Likewise, diets containing soy lecithin (1%) did not result in enhanced weight gain relative to diets devoid of lecithin.

Keywords: *Corn gluten meal; tilapia; nutrition; fish feed*

INTRODUCTION

Wet milling of corn separates the kernel into starch, oil, corn gluten meal, and corn gluten feed. Most of the starch produced from corn is converted into ethanol or high fructose corn syrup. An increasing amount of corn gluten meal (60% plus protein fraction) is produced as the demands for fuel ethanol and high fructose corn syrup increase. Traditionally, corn gluten meal has been used for animal feed. It is desirable to find new uses for corn gluten meal.

The undesirable flavor of corn gluten meal limits its use in food products. Phillips (1977) obtained a bland, protein-enriched product by extracting crude corn gluten with a solvent containing 70–100% ethyl acetate, 0–15% of an aliphatic alcohol containing one to four carbon atoms, and 0–30% water by weight. Neumann et al. (1984) decolorized corn gluten meal similar to that described by Phillips (1977) by extraction with a 2:1 (solvent/meal) ratio of ethyl acetate.

Corn gluten meal has been studied by Anderson et al. (1992) and Fowler and Banks (1972) in salmon diet, by Cowey and Cho (1992), Reinitz (1980), Ketola (1979), Moyano et al. (1992), Pongmaneerat and Watanabe (1992), and Alexis et al. (1985) in trout diet, by Alliot et al. (1979) for sea bass, by Brown et al. (1985) and Hilge (1984) for catfish, by Alava and Lim (1988), Seneriches and Chiu (1988), and Chiu et al. (1986) for milkfish, and by Pongmaneerat and Watanabe (1991) for carp. Lorico-Querijero and Chiu (1989) found the true digestibility of corn gluten meal was 97% for tilapia.

Tilapia (*Oreochromis niloticus*) is a warmwater fish with mild flavor; it is resistant to disease, very hardy, and tolerant to low levels of dissolved oxygen and to overcrowding conditions and has high yield potential. The cost of feed is an important part (around 50%) of the total production cost in aquaculture. Commercial fish feeds contain fish meal, which is relatively expensive and frequently imported and, therefore, may not be available. This study investigates the incorporation of corn gluten meal in tilapia diets, containing 32 and 36% protein from corn and soybean with and without fish meal and soy lecithin.

* Author to whom correspondence should be addressed [fax (309) 681-6689].

† U.S. Department of Agriculture.

‡ Illinois State University.

§ Purdue University.

MATERIALS AND METHODS

Corn gluten meal was supplied by Pekin Energy Co. (Pekin, IL), and the meal was ground in an Alpine Model 160Z pin mill (Augsburg, Germany) at 14 000 rpm. Soy flour (bakers' Nutri Soy) was purchased from Archer Daniels Midland Corp. (Decatur, IL). Menhaden fish meal and menhaden fish oil were supplied by Zapata Haynie Corp. (Hammond, LA). Catfish trace mineral premix was obtained from Triple F Products (Des Moines, IA), and soy oil came from Archer Daniels Midland. Vitamin premix for warmwater fish was formulated by Hoffmann-La Roche (Paramus, NJ). L-Ascorbyl-2-polyphosphate was used in the vitamin mix for increased stability of vitamin C activity. Ground corn was obtained from a local commercial source. The compositions of the tilapia diets are listed in Tables 1 and 2.

The ingredients for tilapia diets were mixed and fed into an InstaPro Model 600 Jr. extruder (Des Moines, IA). The extruded pellets were air-dried overnight at room temperature to reduce the moisture content of the pellets to around 7–9%. The control diet was a Silver cup catfish finisher feed with 36% protein and contained soybean meal, fish meal, wheat middlings, blood meal, feather meal, fish oil, and vitamin and mineral mix from Nelson & Sons Inc. (Murray, UT).

Tilapia having initial average weight of 30 g were used in the feeding experiment. Groups of 20 fish each were fed in 33 × 46 × 38 cm cages in triplicate for each diet and in two triplicates for control diet. A solid plastic tray formed the bottom of the cage to prevent feed loss through the bottom into the tank. The top of each cage was covered to prevent fish from leaving the cage. The cages were suspended into the culture water of an 18 500 L recirculating system.

Water quality, such as temperature, dissolved oxygen, and pH, were measured daily; total ammonia and nitrite were monitored four times a week; and nitrate, alkalinity, hardness, phosphate, carbon dioxide (CO_2), and salinity were measured weekly. The average (± standard error) water quality parameters were as follows: temperature, 26.4 ± 0.1 °C; dissolved oxygen, 10.4 ± 0.3 mg/L; pH, 7.7 ± 0.1; total ammonia, 0.98 ± 0.07 mg/L; nitrite, 0.33 ± 0.03 mg/L; nitrate, 74.5 ± 20.7 mg/L; alkalinity, 214 ± 32 mg/L as calcium carbonate; hardness, 277 ± 5 mg/L as calcium carbonate; phosphate, 17.0 ± 3.5 mg/L; carbon dioxide, 9.4 ± 2.2 mg/L; and salinity, 0.027 ± 0.047%.

0021-8561/95/1443-1585$09.00/0

Table 1. Percent Composition (As-Is Weight Basis) of Tilapia Diets

ingredient	diet 321	321L	324	361	361L
ground corn	42	42	44	35	35
corn gluten meal	16	16	16	18	18
soy flour	35	35	27	40	40
fish meal	0	0	6	0	0
soy oil	2	1	2	2	1
fish oil	2	2	2	2	2
soy lecithin	0	1	0	0	1
vitamin mix[a]	0.5	0.5	0.5	0.5	0.5
mineral mix[a]	2.5	2.5	2.5	2.5	2.5

[a] The vitamin and mineral premix supplied per kilogram diet: vitamin A, 9900 international units (IU); vitamin D, 2200 IU; vitamin E, 82.5 IU; vitamin B_{12}, 0.014 mg; riboflavin (B_2), 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 (K_3), 9 mg; thiamin (B_1), 16.2 mg; 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.

Table 2. Proximate Composition and Trypsin Inhibitor Activity of Tilapia Diets and Control[a]

diet	moisture, %	protein, % N × 6.25	fat, %	ash, %	crude fiber, %	trypsin inhibitor, mg/g
321	8.8	32.1	5.3	5.0	3.4	3.0
321L	10.0	31.7	4.9	5.1	3.4	3.3
324	11.1	32.0	5.7	5.5	2.8	2.7
361	9.2	35.2	5.0	5.2	3.9	3.5
361L	9.2	35.3	4.9	5.2	5.3	3.0
control	7.7	38.6	6.4	8.3	4.3	0.7

[a] All figures on as-is basis.

The fish were fed twice daily. The amount of feed offered per day was 3.8% of the body weight at the beginning of the experiment and gradually decreased to 3.1% of the body weight at the end of the experiment. The fish in each cage were weighed as a group biweekly, and the feed weight was adjusted after each fish weighing. The increase in fish weight was estimated between weighings, and the feed weight was increased daily. The total feeding period was 75 days. Weight gain (WG) was calculated as (final weight − initial weight)/initial weight and expressed as percent increase for 75 days. Feed conversion ratio (FCR) was calculated from dry feed offered/wet weight gain. Protein efficiency ratio (PER) was weight gain/protein fed.

Nitrogen, fat, ash, crude fiber, moisture contents, and trypsin inhibitor activity were determined by AACC Approved Methods 46-13, 30-26, 08-03, 32-10, 44-19, and 71−10, respectively (AACC, 1983). Nitrogen was determined by micro-Kjeldahl, and protein was estimated by using the conversion factor N × 6.25. Fat was obtained from petroleum ether extraction, ash was from the weight remaining after the sample was heated 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 with 6 N HCl for 4 h at 145 °C (Gehrke et al., 1987). Cystine and methionine were oxidized with performic acid before hydrolysis (Moore, 1963). Amino acids were determined by cation exchange chromatography using a Beckman 6300 amino acid analyzer (Beckman Instruments, Inc., San Ramon, CA). Tryptophan was measured by colorimetric 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. Means were compared by *t*-tests of pairs of least-square means (SAS Institute Inc., 1987).

The tilapia diets (Table 1) were formulated to contain 32 and 36% proteins that meet the amino acid requirement of tilapia (Lovell, 1991). Vitamin and mineral mixes were added on the basis of recommendations for warmwater fish. Diets 321 and 321L differed only in soy oil and soy lecithin contents. Diets 321 and 324 are similar except diet 324 contained fish meal. Diets 361 and 361L likewise differed only in soy oil and soy lecithin contents. The control diet (Table 2) had the highest protein content (38.6%). All diets had low trypsin inhibitor activities and should cause no complications in tilapia feeding. The amino acid compositions of the five experimental and control diets are listed in Table 3, and all six diets met the amino acid requirements of tilapia (Lovell, 1991).

Table 3. Amino Acid Composition (Percent of Protein) of Tilapia Diets and Control

amino acid	diet 321	321L	324	361	361L	control
aspartic acid	9.35	10.9	8.44	9.38	9.41	9.25
threonine	3.40	3.97	3.34	3.64	3.63	4.07
serine	3.96	4.57	4.06	4.55	4.39	4.77
glutamic acid	18.3	20.9	18.0	19.2	19.3	15.5
proline	8.35	11.0	6.84	7.13	7.31	5.83
glycine	3.49	3.94	3.81	3.64	3.68	5.36
alanine	5.58	6.12	6.19	6.19	6.23	5.83
cystine	1.93	2.15	1.75	1.90	1.93	1.71
valine	4.42	4.70	4.69	4.74	4.82	5.75
methionine	1.74	2.15	1.94	1.79	1.73	1.66
isoleucine	4.33	4.20	4.09	4.40	4.48	3.37
leucine	11.3	12.1	10.9	11.3	11.4	8.65
tyrosine	4.39	4.95	3.78	3.84	4.08	3.03
phenylalanine	5.98	6.75	5.09	5.54	5.61	5.16
histidine	2.65	2.97	2.31	2.50	2.55	3.16
lysine	4.58	5.11	4.19	4.55	4.59	6.53
arginine	5.42	6.18	5.00	5.71	5.69	5.75
tryptophan	1.21	1.17	1.03	1.14	1.16	1.27

Table 4. Weight Gains, Feed Conversion Ratio, Protein Efficiency Ratio, and Protein/Energy of Tilapia Diets[a]

diet	WG[b]	FCR[c]	PER[d]	P/E[e]
321	306A	1.86C	1.53A	85.9
321L	297A	1.90BC	1.50A	86.5
324	321A	1.85C	1.51A	87.2
361	291A	2.08AB	1.25B	95.3
361L	296A	2.00ABC	1.29B	97.2
control	244B	2.14A	1.12C	104.3

[a] Means of three replicate cages for diets 321, 321L, 324, 361, and 361L. Means of six replicate cages for control. Mortality was 3.3% for diet 321, zero for the remaining diets and control. Numbers followed by different letters are significantly different ($P < 0.05$). [b] Weight gain = the percentage increase at the end of 75 days. [c] Feed conversion ratio = dry feed offered/wet weight gain. [d] Protein efficiency ratio = weight gain/protein fed. [e] Protein/energy expressed as mg of protein/kcal.

RESULTS AND DISCUSSION

Table 4 shows weight gain of tilapia. Figure 1 gives the weight of fish at each weighing period plotted against the number of days fed. All experimental diets showed significantly ($P < 0.05$) higher weight gain than the control in Table 4. Weight gains for 321 vs 321L as well as 361 vs 361L were not significantly different ($P > 0.05$) and indicated soy lecithin had no advantage over soy oil. Weights gains for 321 vs 324 were not significantly different ($P > 0.05$) and showed that 6% fish meal in diet 324 had no advantage over diet 321 without fish meal. The difference in weight gain between diets 321 and 361 was not significant ($P > 0.05$) and indicated that 36% protein diet had no advantage over 32% protein diet. Table 4 also shows that diets 321, 321L, and 324 had better FCR ($P < 0.05$) than control (less feed needed per unit of weight gain). No significant difference in FCR was observed between diets 321 and 321L ($P > 0.05$) or between diets 361 and 361L ($P > 0.05$), indicating that soy lecithin had no advantage over

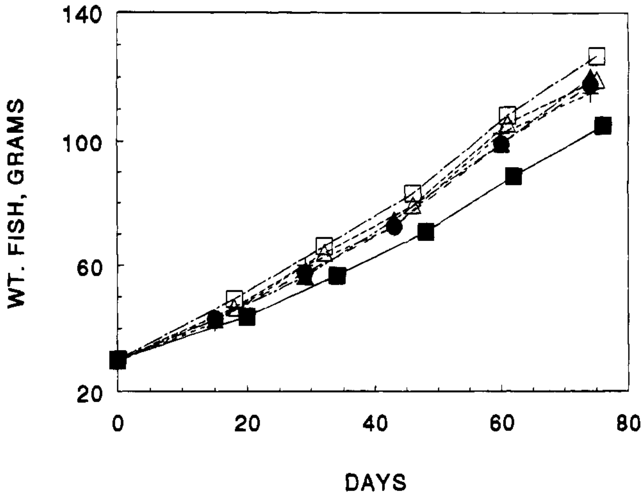

Figure 1. Growth of tilapia for 75 days when fed diet 361 (+), 361L (△), 321 (▲), 321L (●), 324 (□), or control (■).

Table 5. Correlation Coefficients of Protein/Energy Ratio, Protein, Fat, and Nitrogen-Free Extract (NFE) Contents of Diets with Weight Gain, Feed Conversion Ratio, and Protein Efficiency Ratio

	WG[a]	FCR[a]	PER[a]	energy calculated from
P/E1	−0.679***	0.761***	−0.934***	Wang et al. (1985)
P/E2	−0.666***	0.765***	−0.937***	Wilson (1977)
P/E3	−0.678***	0.761***	−0.935***	Jauncey and Ross (1982)
protein	−0.695***	0.765***	−0.932***	
fat	−0.550**	0.423	−0.544*	
NFE[b]	0.680***	−0.712***	0.889***	

[a] *$P < 0.05$. **$P < 0.01$. ***$P < 0.001$. [b] NFE = 100 − protein − fat − fiber − ash − moisture, all in percent.

soy oil. Fish meal in diet 324 had no advantage in FCR over diet 321 without fish meal ($P > 0.05$). Diet 321 with 32% protein had better FCR than diet 361 with 36% protein ($P < 0.05$). For comparison, Hargreaves et al. (1991) reported FCR of 1.65−1.9 for Florida red tilapia of initial 30 g weight in cages. Clark et al. (1990) found FCR of 1.57−2.26 for Florida red tilapia of initial 9.1−12.7 g weight in cages in seawater.

Table 4 indicates all experimental diets gave better (higher) PER than the control. No significant difference in PER was observed between diets 321 and 321L ($P > 0.05$) or between diets 361 and 361L ($P > 0.05$), indicating that soy lecithin had no advantage over soy oil. Fish meal in diet 324 had no advantage over diet 321 without fish meal ($P > 0.05$) in PER. Diet 321 with 32% protein had better PER than diet 361 with 36% protein ($P < 0.05$).

Table 4 also shows the protein/energy ratios of the experimental and control diets. The dietary digestible energies for tilapia based on 4.5, 4.0, and 9.0 kcal/g for protein, carbohydrate, and lipid, respectively, was found to be almost the same as those determined by the direct method (Wang et al., 1985). The values of P/E increases as the protein content of diets increases. All of the experimental diets and the control diets had essentially the same energy of 3.63−3.74 kcal/g based on the values of Wang et al. (1985); crude fiber is not counted as carbohydrate since cellulose is not digested by tilapia (Jauncey and Ross, 1982).

Table 5 gives the correlation coefficients of the protein/energy ratio vs weight gain, feed conversion ratio, and protein efficiency ratio. Weight gain and protein efficiency ratio are both negatively correlated with the protein/energy ratio ($P < 0.001$), but the feed conversion ratio is positively correlated with the protein/energy ratio ($P < 0.001$). When dietary energy for fish was calculated from protein = 5.5, lipid = 9.1, and carbohydrate = 4.1 kcal/g (Jauncey and Ross, 1982) or when dietary energy for catfish (another warmwater fish) with protein = 3.5, fat = 8.1, and nitrogen-free extract = 2.5 kcal/g, practically the same correlation coefficients were obtained, although the values of the protein/energy ratios were somewhat different compared with those of Wang et al. (1985).

Table 5 also shows the correlation coefficients of protein, fat, and nitrogen-free extract contents of diets vs weight gain, feed conversion ratio, and protein efficiency ratio. The protein content of the diet was negatively correlated with weight gain and protein efficiency ratio (both $P < 0.001$) but positively correlated with feed conversion ratio ($P < 0.001$). The fat content of the diet was negatively correlated with weight gain ($P < 0.01$) and with protein efficiency ratio ($P < 0.05$). Nitrogen-free extract of diet was positively correlated with weight gain and protein efficiency ratio (both $P < 0.001$) but negatively correlated with feed conversion ratio ($P < 0.001$).

One possible reason that tilapia fed diets containing corn gluten meal had higher weight gain and protein efficiency ratio as well as better feed conversion ratio than did tilapia fed commercial diet without corn gluten meal is that true digestibility of corn gluten meal was 97% for tilapia (Lorico-Querijero and Chiu, 1989), compared with apparent protein digestibility of 84% for soybean meal for channel catfish (Cruz, 1975) and average digestibility of 60% for "digestible" carbohydrate (cellulose not digested) for fish (Jauncey and Ross, 1982). Winfree and Stickney (1981) found the optimum dietary protein to energy ratio for rapid and efficient gain of juvenile *Tilapia aurea* fell with increasing size of fish and that apparent feed conversion (grams of feed offered/grams of fish weight gain) was superior for diets having lower protein to energy ratios. Since all of our experimental diets with corn gluten meal had lower protein to energy ratios than the control, these lower ratios may account for the better feed conversion (and weight gain as well as protein efficiency ratio) of tilapia fed diets containing corn gluten meal compared with control.

CONCLUSION

Corn gluten meal can be well utilized in a fish meal-free balanced amino acid diet for tilapia. Weight gains for tilapia were higher for experimental diets containing corn gluten meal than for a commercial control diet without corn gluten meal. Soy lecithin had no advantage over soy oil, and 32% protein diets gave the same weight gains as 36% protein diets for tilapia.

ACKNOWLEDGMENT

We thank P. Foley and B. D. Deadmond for technical assistance.

LITERATURE CITED

AACC. *Approved Methods of the AACC*, 8th ed.; American Association of Cereal Chemists: St. Paul, MN, 1983.

Alava, V. R.; Lim, C. Artificial Diets for Milkfish, *Chanos chanos* (Forsskal), Fry Reared in Sea Water. *Aquaculture* **1988**, *71*, 339−346.

Alexis, M. N.; Papaparaskeva-Papoutsloglou, E.; Theochari, V. Formulation of Practical Diets for Rainbow Trout (*Salmo* *gairdneri*) Made by Partial or Complete Substitution of Fish Meal by Poultry Byproducts and Certain Plant Byproducts. *Aquaculture* **1985**, *50*, 61–73.

Alliot, E.; Pastoureaud, A.; Pelaez Hudlet, J.; Metailler, R. The Use of Plant Proteins and Alkane Yeast Proteins for Feeding Juvenile Sea Bass (*Dicentrarchus labrax*). In *Finfish Nutrition and Fishfeed Technology*; Halver, J. E., Tiews, K., Eds.; Report V2; Heenemann Verlagsgesellschaft: Berlin, 1979; pp 229-238.

Anderson, J. S.; Lall, S. P.; Anderson, D. M.; Chandrasoma, J. Apparent and True Availability of Amino Acids from Common Feed Ingredients for Atlantic Salmon (*Salmo salar*) Reared in Sea Water. *Aquaculture* **1992**, *108*, 111–124.

Brown, P. B.; Strange, R. J.; Robbins, K. R. Protein Digestibility Coefficients for Yearling Channel Catfish Fed High Protein Feedstuffs. *Prog. Fish Cult.* **1985**, *47*, 94–97.

Chiu, Y. N.; Camacho, A. S.; Sastrillo, M. A. S. Effect of Amino Acid Supplementation and Vitamin Level on the Growth and Survival of Milkfish (*Chanos chanos*) Fry. In *Proc. First Asian Fisheries Forum*; Maclean, J. L., Dizon, L. B., Hosillos, L. V., Eds.; Asian Fisheries Society: Manila, Philippines, 1986; pp 543–546.

Clark, J. H.; Watanabe, W. O.; Ernst, D. H.; Wicklund, R. I.; Olla, B. L. Effect of Feeding Rate on Growth and Feed Conversion of Florida Red Tilapia Reared in Floating Marine Cages. *J. World Aquacult. Soc.* **1990**, *21*, 16–24.

Cowey, C. B.; Cho, C. Y. Failure of Dietary Putrescine to Enhance the Growth of Rainbow Trout (*Oncorhynchus mykiss*). *Can. J. Fish. Aquat. Sci.* **1992**, *49*, 2469–2473.

Cruz, E. M. Determination of Nutrient Digestibility in Various Classes of Natural and Purified Feed Materials for Channel Catfish. Ph.D. Dissertation, Auburn University, Auburn, AL, 1975.

Fowler, L. G.; Banks, J. L. Alteration Tests of the Abernathy Salmon Diet, 1971. Technical paper 64; U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, July 1972.

Gehrke, C. W.; Rexroad, P. R.; Schisla, R. M.; Absheer, J. S.; Zumwalt, R. W. Quantitative Analysis of Cystine, Methionine, Lysine and Nine Other Amino Acids by a Single Oxidation–4 Hour Hydrolysis Method. *J. Assoc. Off. Anal. Chem.* **1987**, *70*, 171–174.

Hargreaves, J. A.; Rakocy, J. E.; Bailey, D. S. Effects of Diffused Aeration and Stocking Density on Growth, Feed Conversion, and Production of Florida Red Tilapia in Cages. *J. World Aquacult. Soc.* **1991**, *22*, 24–29.

Hilge, V. Development of Formulated Feeds for Warm Water Fish in German Aquacultures. *Veroeff. Inst. Kuesten Binnenfisch. Hamburg* **1984**, *No. 86*, 66 pp.

Holz, F. Automatic Determination of Tryptophan in Proteins and Protein-Containing Plant Products with Dimethylaminocinnamaldehyde. *Landwirt. Forsch., Sonderh.* **1972**, *27*, 96–109.

Jauncey, K.; Ross, B. *A Guide to Tilapia Feeds and Feeding*; Institute of Aquaculture, University of Stirling: Stirling, Great Britain, 1982; 43 pp.

Ketola, H. G. Influence of Dietary Lysine on "Fin Rot", Survival, and Growth of Fry of Rainbow Trout. *Fish Health News* **1979**, *8* (2), 6.

Lorico-Querijero, B. V.; Chiu, Y. N. Protein Digestibility Studies in *Oreochromis niloticus* Using Chromic Oxide Indicator. *Asian Fish. Sci.* **1989**, *2*, 177–191.

Lovell, R. T. *Aquaculture Feed Process*; Nutrition Workshop, Singapore; Akiyama, D. M., Tan, R. K. H., Eds.; American Soybean Association: St. Louis, MO, 1991; pp 173–187.

Moore, S. On the Determination of Cystine as Cysteic Acid. *J. Biol. Chem.* **1963**, *238*, 235–237.

Moyano, F.-J.; Cardenete, G.; Dela Higuera, M. Nutritive Value of Diets Containing a High Percentage of Vegetable Proteins for Trout, *Oncorhynchus mykiss*. *Aquat. Living Resour.* **1992**, *5*, 23–29.

Neumann, P. E.; Jasberg, B. K.; Wall, J. S. Uniquely Textured Products Obtained by Coextrusion of Corn Gluten Meal and Soy Flour. *Cereal Chem.* **1984**, *61*, 439–445.

Phillips, R. D. Process for Producing Bland, Protein Enriched Products from Grain Gluten. U.S. Pat. 4,024,120, May 17, 1977.

Pongmaneerat, J.; Watanabe, T. Nutritive Value of Protein of Feed Ingredients for Carp *Cyprinus carpio*. *Bull. Jpn. Soc. Sci. Fish.* **1991**, *57*, 503–510.

Pongmaneerat, J.; Watanabe, T. Utilization of Soybean Meal as Protein Source in Diets for Rainbow Trout. *Bull. Jpn. Soc. Sci. Fish.* **1992**, *58*, 1983.

Reinitz, G. Growth and Survival of Lake Trout Fed Experimental Starter Diets. *Prog. Fish Cult.* **1980**, *42*, 100–102.

SAS Institute Inc. *SAS/STAT Guide for Personal Computers*, version 6 ed.; Parker, J. C., Ed.; SAS Institute: Cary, NC, 1987; 1028 pp; Chapter 20, The GLM Procedure; Chapter 28, The REG Procedure.

Seneriches, M. L. M.; Chiu, Y. N. Effect of Fishmeal on the Growth, Survival and Feed Efficiency of Milkfish (*Chanos chanos*) Fry. *Aquaculture* **1988**, *71*, 61–69.

Spies, J. R.; Chambers, D. C. Chemical Determination of Tryptophan in Proteins. *Anal. Chem.* **1949**, *21*, 1249–1266.

Wang, K-W.; Takeuchi, T.; Watanabe, T. Optimum Protein and Digestible Energy Levels in Diets for *Tilapia niloticus*. *Bull. Jpn. Soc. Sci. Fish.* **1985**, *51*, 141–156.

Wilson, R. P. Energy Relationships in Catfish Diets. In *Nutrition and Feeding of Channel Catfish*; Stickney, R. R., Lovell, R. T., Eds.; Southern Cooperative Series Bulletin 218; Alabama Agricultural Experiment Station, Auburn University: Auburn, AL, 1977; 21 pp.

Winfree, R. A.; Stickney, R. R. Effects of Dietary Protein and Energy on Growth, Feed Conversion Efficiency and Body Composition of *Tilapia aurea*. *J. Nutr.* **1981**, *111*, 1001–1012.

Received for review October 12, 1994. Revised manuscript received March 7, 1995. Accepted March 23, 1995.[⊗] The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned. All programs and services of the U.S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, age, marital status, or handicap.

JF940570G

[⊗] Abstract published in *Advance ACS Abstracts*, May 1, 1995.