Effects of Dietary Lipid Quality on Growth and Food Conversion of Tilapia

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Abstract: Growth and food conversion patterns of *Tilapia aurea* raised in aquaria and fed diets containing 10% lipid from 4 different sources showed that growth and food conversion were significantly better on menhaden oil than on beef tallow. No significant differences were detected in growth of tilapia on catfish oil or soybean oil and either beef tallow or menhaden oil. No mortalities occurred during the course of the 10-week feeding trial. *T. aurea* responded similarly to channel catfish with respect to their ability to utilize menhaden oil as a suitable source of dietary lipid. Tilapia did not grow well on a diet supplemented with beef tallow, whereas channel catfish have been shown to perform equally well on both dietary lipids.

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Fish, in general, appear to have a requirement for dietary linolenic acid family (n-3) dietary fatty acids (Cowey and Sargent 1977, Millikin 1982). Essential fatty acid deficiency signs have been reported for rainbow trout, *Salmo gairdneri,* by Castell et al. (1972*a,* 1972*b,* 1972*c*) when insufficient levels of dietary n-3 fatty acids were present. The requirement for n-3 family fatty acids appears to be near 1.0% for rainbow trout (Yu and Sinnhuber 1975) while common carp (*Cyprinus carpio*) seem to require them at a level of 1.5% of the diet (Csengeri et al. 1979).

Channel catfish (*Ictalurus punctatus*) growth is enhanced when dietary lipids supplied by either fish oil or beef tallow are offered in either semi-purified or practical rations (Stickney and Andrews 1971, 1972, Yingst and Stickney 1979). Oilseed oils such as safflower oil and soybean oil do not lead to optimum growth of channel catfish (Stickney and Andrews 1971, 1972, Yingst and Stickney 1979) except when water temperatures are below the minimum range for best growth of the species (Stickney and Andrews 1971, Gatlin and Stickney 1982).

Kanazawa et al. (1980) provided evidence for the existence of a linoleic acid family (n–6) fatty acid requirement in *Tilapia zillii.* In addition, research with diets supplemented with highly purified individual fatty acid esters has indicated that linoleic acid can support better growth in *T. aurea* than identical diets containing linolenic acid (Stickney and McGeachin 1983).

The present study was initiated to determine the growth responses of *T. aurea* to diets containing various lipids, and represents the first step in determining the qualitative lipid requirements of the species. This research was supported in part by the Texas Agricultural Experiment Station under Project H-3861 and by the United States Agency for International Development under Texas A&M Research Foundation project 4394-3. The authors wish to acknowledge the assistance of Rouse Marketing Associates, Cincinnati, Ohio, in arranging for the beef tallow and fish oils. The soybean oil utilized in the experiment was provided by Riceland Foods, Stuttgart, Arkansas. Constructive criticism of the manuscript by Edwin H. Robinson is gratefully acknowledged.

Methods

The tilapia used in this study were conditioned on a fat free diet (Stickney and McGeachin 1983) at the Aquaculture Research Center of Texas A&M University and the Texas Agricultural Experiment Station from 2 October to 16 November 1982. They were then weighed and stocked in groups of 10 into 40-liter aquaria. The feeding trial with isocaloric (3,600 kcal/kg gross energy), isonitrogenous (32% protein), experimental diets was initiated on 17 November 1982 and continued for 10 weeks until 25 January 1983.

Four diets containing 10% beef tallow, menhaden oil, catfish oil, or soybean oil (Table 1) were manufactured according to the methods outlined by Stickney et al. (1982) and fed to triplicate tanks twice daily, morning and afternoon, at the rate of 8% of body weight daily for the first 42 days and at 5% of body weight daily thereafter. Feed was provided on a dry weight basis. The mean weight of fish in each aquarium was determined at two-week intervals, at which time feeding rates were adjusted. No feed was offered on the days that weight measurements were made.

Each aquarium received well water at the rate of approximately 250 ml/minute through plastic flow regulators. Siphon drains provided constant water level and supplemental aeration was provided by airstones in each of the 12 experimental aquaria. Water temperature averaged 26.6°, 25.7°, and 25.7° C during November 1982, December 1982, and January 1983, respectively, with a range over the 10-week study of 24° to 27° C.

Table 1. Percentage composition of experimental diets fed to *Tilapia aurea.*

Ingredient	Dietary Lipid			
	Beef tallow	Menhaden oil	Catfish oil	Soybean oil
Casein	36.18	36.18	36.18	36.18
Dextrin[a]	20.56	20.71	20.61	20.53
Cellulose[a]	26.16	26.95	26.11	26.53
Lipid	10.00	10.00	10.00	10.00
Vitamins[b]	0.50	0.50	0.50	0.50
Minerals[b]	5.30	5.30	5.30	5.30
Agar (binder)	1.00	1.00	1.00	1.00

[a] Differences in the levels of dextrin and cellulose were necessitated by differences in gross energy within the dietary lipids. Energy levels were determined by bomb calorimetry.
[b] Vitamin and mineral supplements were the same as those described by Stickney et al. (1982).

Upon termination of the experiment, the fish from each aquarium were weighed and ennumerated. The response to dietary lipid was evaluated in terms of final mean fish weight, percentage increase, food conversion ratio (g of dry weight food offered/g of wet weight gain) and survival percentage. Initial mean weight, final mean weight and food conversion ratio data were analysed with the Statistical Analysis System, SAS-79 (Helwig and Council 1979) using the Analysis of Variance procedure and Duncan's New Multiple Range test. Significance was evaluated at the 0.05 level. Differences in fatty acid compositions of the experimental diets were determined by gas chromatography utilizing the methods described by Stickney et al. (1982).

Results and Discussion

Initial mean weights averaged 2.4 g for each experimental group when the fish were transferred from the conditioning diet to the experimental rations (Table 2). After 10 weeks, fish reared on the diet containing 10% menhaden oil were significantly heavier than those which received the beef

Table 2. *Initial and final mean fish weights, mean percentage weight increase,* mean food conversion ratio and percentage survival for *Tilapia aurea* fingerlings fed diets of differing lipid composition.

Dietary lipid (10% of diet)	Initial mean weight (g)	Final mean weight (g)	Mean food conversion ratio	Percent survival
Beef tallow	2.4	13.9B[a]	1.8A	100A
Menhaden oil	2.4	23.3A	1.5B	100A
Catfish oil	2.4	20.3AB	1.6AB	100A
Soybean oil	2.4	19.1AB	1.6AB	100A

[a] Numbers within columns followed by the same letter are not significantly ($P > 0.05$) different.

tallow diet, while no significant differences occurred among fish on the menhaden oil, catfish oil, and soybean oil diets relative to final weight. There were also no significant differences in final weight among the fish which received dietary beef tallow, catfish oil, and soybean oil. The pattern observed in food conversion ratios reflected that obtained from final mean weight data. No mortalities were observed in any of the 4 experimental groups (Table 2).

The fact that *T. aurea* grew as well on soybean oil as they did on menhaden oil provides evidence that tilapia have somewhat different lipid requirements than channel catfish, trout, and certain other groups of fishes. Beef tallow has been found to perform as well as menhaden oil in diets fed to channel catfish (Stickney and Andrews 1971, 1972, Yingst and Stickney 1979), but does not seem to be well utilized by tilapia.

Quantitative recommendations for the dietary lipids utilized in this study cannot be promulgated since only the 10% level was evaluated. Additional studies with a range of lipid levels will be required to demonstrate whether the 10% level selected for study here led to optimum or near-optimum growth and food conversion.

The fatty acid compositions of the four lipids used in this study (Table 3) were distinctly different. The beef tallow was highest in saturated and monounsaturated fatty acids, the menhaden and catfish oils contained the highest levels of linolenic acid family fatty acids of greater than 18 carbon chain length, and the soybean oil contained the highest level of both linoleic and linolenic acids (18:2n-6 and 18:3n-6, respectively).

Stickney and McGeachin (1983) found that high levels of saturated fat in the diet of *T. aurea* have a growth depressant effect. That may help to explain the poor growth of tilapia on the beef tallow diet, which contained over

Table 3. Mean percentages of the dominant fatty acids in each dietary lipid. Each value represents the mean of 3 analyses.

Fatty acid[a]	Beef tallow diet	Menhaden oil diet	Catfish oil diet	Soybean oil diet
14:0	3.3	8.5	2.7	0.3
16:0	21.2	16.8	18.1	11.1
16:1n-7	5.5	12.1	6.6	0.1
18:0	16.4	6.3	4.5	4.2
18:1n-9	39.6	13.2	47.1	24.7
18:2n-6	6.2	2.7	15.6	50.3
18:3n-3	1.1	2.3	1.4	9.0
20:5n-3	—	13.3	0.2	—
22:5n-3	—	2.3	—	—
22:6n-3	—	7.4	0.2	—

[a] The number before the colon indicates the number of carbon atoms, the number immediately after the colon indicates the number of double bonds and the last number indicates the position of the first double bond (in number of carbon units) from the methyl end of the molecule. Thus, 18:0 is stearic acid, 18:1n-9 is oleic acid, 18:2n-6 is linoleic acid, 18:3n-3 is linolenic acid, and so forth.

40% saturated fat (14:0 + 16:0 + 18:0, Table 3). The remaining diets contained less than 30% saturated fat, with most of it being in a form other than stearic acid (18:0).

Tilapia growth does not appear to be reduced by linolenic acid levels of 1% of the diet if linoleic acid and/or oleic acid are also present at a level of no less than 1% of the diet (Stickney and McGeachin 1983). In that study, highly purified fatty acids were fed in semipurified diets. The linolenic acid in the soybean oil utilized in the present experiment accounted for 0.9% of the total diet, while linoleic and oleic acid comprised 5.0 and 2.5%, respectively. Thus, the presence of the high level of linoleic acid, perhaps in conjunction with oleic acid, appeared to prevent the growth depression previously observed in tilapia fed semipurified diets containing certain highly purified fatty acids.

While many fishes appear to have a dietary requirement for n-3 family fatty acids (Cowey and Sargent 1977, Millikin 1982), a similar requirement has not been demonstrated in tilapia. The beef tallow, menhaden oil, and catfish oil diets used in this study all contained less than 0.3% linolenic acid, but only fish reared on the menhaden oil diet grew to a significantly larger size than did those on the beef tallow diet. An important difference between menhaden oil and the other dietary lipids utilized in the study is that the marine fish oil contained relatively high levels of 20 and 22 carbon fatty acids. Those fatty acids may have provided some essential fatty acid activity in tilapia which was not supplied by linolenic acid. It has been demonstrated that the conversion of linolenic acid to higher molecular weight fatty acids in tilapia occurs only at a slow rate (Stickney et al. 1982, Stickney and McGeachin 1983).

Based upon the growth results obtained in this study, it can be concluded that dietary menhaden oil leads to superior performance in *T. aurea* as compared with beef tallow. However, catfish oil, along with soybean oil, and perhaps other oilseed oils, can be used effectively by tilapia. Oilseed oils should be further evaluated as supplemental energy sources in practical tilapia diets.

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