EFFECT OF DIETARY LIPID SOURCE ON THE GROWTH PERFORMANCE AND BODY COMPOSITION OF *Oreochromis niloticus*

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ABSTRACT

The study evaluated the growth performance and body composition of *Oreochromis niloticus* fed isonitrogenous and isocaloric diets containing different types of lipids (corn oil, olive oil, cod liver oil and beef tallow) at 14% level for a period of 65 days. Significant (P< 0.05) differences were observed in the body weight gain, specific growth rate (SGR), condition factor, feed conversion ratio (FCR), protein efficiency ratio (PER), net protein retention (NPR), apparent net energy retention (ANER) and hepatosomatic index (HSI) values. The diet containing a mixture of all the 4 dietary lipids in equal proportions (3.5g of each lipid per 100g of diet) produced the best results (SGR, 1.73%; condition factor, 2.95; FCR, 1.27; PER, 2.06; NPR, 29.30% and ANER, 20.21%) whereas the diet containing beef tallow showed the poorest performance (SGR, 1.50%; condition factor, 2.76; FCR, 1.53; PER, 1.73; NPR, 26.26% and ANER, 18.53%). The growth performance of fish fed on diet containing beef tallow was however, significantly (P< 0.05) better than that of lipid free diet. The diets containing corn oil, olive oil, and cod liver oil did not show any significant difference in the growth performance of fish. The hepatosomatic index (HSI) value increased in fish fed diets containing lipids (maximum 1.55% in case of corn oil) as compared to those fed lipid free diet (1.31%). No significant differences were observed in the feed consumption of fish fed different diets. The type of dietary lipid significantly affected the body composition of fish. The data on the body composition of fish is very much correlated with the growth performance data. The fish fed on diets containing lipids showed higher body fat and crude protein but lower moisture and gross energy contents as compared to those fed lipid free diet. The fish fed on diet containing beef tallow however showed similar body protein and ash contents as those fed lipid free diet. The results of the present study suggest that diet supplemented with a mixture of different types of lipids will produce the best growth response in *Oreochromis niloticus*.

Keywords: *Oreochromis niloticus*, growth performance, body composition.

INTRODUCTION

Dietary lipids play an important role as potential supplier of energy, essential fatty acids and fat soluble vitamins. They also affect the quality of cultured fish because of their influence on the fatty acid composition of body tissues (Nematipour *et al.*, 1992; Thomassen and Rosjo (, 1989; Wagboo *et al.*, 1993; Guillou *et al.*, 1995; Mukhopadhayay and Rout, 1996). The addition of lipids in fish diets contributes to protein sparing by increasing their digestible energy value (Watanabe, 1982; Cho and Kaushik, 1990; De Silva *et al.*, 1991). Polyunsaturated fatty acids (PUFA) are required in fish for membrane permeability and plasticity, enzyme activation, prostaglandin production and different other physiological and metabolic functions (Watanabe, 1982; Greene and Selivonchick, 1987; Sargent *et al.*, 1999). Essential fatty acids deficiency may affect the fish health similar to mammals. It has been suggested that many of the disease problems that occur in warmwater fishes with seasonal changes in water temperatures could be diet related (Steffens, 1989).

The lipid requirement of different fish species varies. Most of the carnivorous fish species appear to digest and utilize dietary lipids more effectively as compared to omnivorous and herbivorous fishes (Shimeno *et al.*, 1979; Furuichi and Yone, 1980; NRC, 1993). Studies conducted with various Tilapia species have shown that they require approximately 1% of n-6 fatty acids in their diets (Kanazawa *et al.*, 1980; Teshima *et al.*, 1982, 1985; Takeuchi *et al.*, 1983). In general n-3 fatty acids are not required by warm water fishes but it is considered that for proper membrane structure at least a small amount of these acids may be needed. *Tilapia aurea* has a requirement for relatively high levels of n-6 fatty acids, though the requirement can be reduced when n-3 fatty acids are present (Stickney and McGeachin, 1983; Stickney and Hardy, 1989). Since vegetable oils such as corn, soybean and cotton seed oils contain high levels of n-6 and also significant amounts of n-3 fatty acids they can be used in Tilapia diets.

Takeuchi *et al.* (1983) reported that 5% supplement of corn oil or olive oil resulted in better growth and feed utilization than the addition of cod liver oil. Beef tallow produced the poorest results. Stickney and McGeachin (1983) reported that the addition of 12% of beef tallow in the diets of *O. aureus* resulted in significantly better growth and feed utilization than in fish fed a fat free diet. Animal fats particularly beef tallow and more especially micronized hardened fatty acids have been reported to be less effective than sunflower seed oil when fed to rainbow trout (Schulz *et al.*, 1984; Hartfiel *et al.*, 1984). The use of a few per cent of beef tallow in conjunction with soybean or corn oil has been reported to be effective in producing rapid growth and good feed conversion efficiency in warm water fishes (Stickney and Hardy, 1989). As compared to coldwater fishes, the knowledge on the quantitative requirements of lipids and essential fatty acids for warm water fishes, particularly for Tilapia is still limited. The present study was, therefore, conducted to study the effect of different types of dietary lipids on the growth performance and body composition of *O. niloticus*.

MATERIALS AND METHODS

Oreochromis niloticus with an average weight of 24.56 ± 0.43g were collected from the fish hatchery of King Abdulaziz City for Science and Technology (KACST) Deerab, Riyadh. The fishes were acclimatized to the experimental conditions for a period of two weeks. During this period they were kept on the same standard diet as fed previously at the hatchery. To determine their initial body composition, 30 randomly selected fish were killed immediately and after recording their body weight and length, were stored at –30°C for the proximate analysis at a later stage (AOAC, 1990). One hundred and eighty fish were then randomly divided into 6 different groups with 3 replicates containing 10 fish in each replicate. The fish were kept in glass tanks (100 x 42.5 x 50.0 cm) containing dechlorinated and well aerated tap water. The tanks were fitted with waste filtration facility. The water of the tanks was changed twice weekly. The temperature of water was maintained at 28 ± 1°C with the help of a thermostatically controlled heating system. Compressed air was used to maintain the oxygen supply. Regular monitoring of water quality parameters was carried out. The values ranged pH (7.1 - 8.0), dissolved oxygen (5.3 - 6.7 $mg.l^{-1}$), ammonia nitrogen (0.12 - 0.20 $mg.l^{-1}$), nitrite nitrogen (0.33 - 0.58 $mg.l^{-1}$) and alkalinity as CaCO3 (235 - 350 $mg.l^{-1}$). These parameters were within the tolerance limits for *Oreochromis niloticus*.

Five isonitrogenous and isocaloric experimental diets B, C, D, E and F containing different types of lipids at 14% level were prepared (Table 1). The diet A contained no supplementary lipid and acted as control. The moist pelleted diets were prepared using a pellet press of 2 mm die. The diets were dried in a hot air driven oven at 60°C and then stored at –18 °C throughout the experimental period. The proximate chemical composition of diets as determined by the methods of AOAC (1990) is given in Table 2. The gross energy content of the diets was calculated on the basis of their protein, fat and carbohydrate (NFE) contents using the equivalents of 23.64, 39.54 and 17.15 $MJ.Kg^{-1}$ respectively (Kleiber, 1975). Each diet was fed ad-libitum to 3 replicates in a completely randomized design. The diets were offered twice daily. The experiment lasted for 65 days. To quantify the exact amount of feed intake any feed refusal was siphoned out immediately, dried and weighed. The experiment was conducted under artificial light with a light and dark cycle of 12:12 hours. At the end of the experimental period all the fish were killed and their body weight and length were recorded. Five fish from each group were dissected to collect their livers. The liver weights were recorded immediately. To determine the whole body composition, the other 5 fishes from each replicate were cut into pieces and minced through a meat mincer. The homogenized samples were immediately frozen at –30°C for further analysis. The proximate chemical composition was determined according to the methods of AOAC (1990). The gross energy content of fish was calculated from their fat and protein content using the equivalents of 39.54 $MJ.Kg^{-1}$ for fat and 23.64 $MJ.Kg^{-1}$ for crude protein (Kleiber, 1975).

Feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), net protein retention (NPR), apparent net energy retention (ANER) and hepatosomatic index (HSI) were calculated as follows:

Feed conversion ratio = Kg dry feed consumed per Kg wet weight gain.

Specific growth rate (as percentage of body weight gain per day) = 100 [ln final wt. (g) - ln initial weight (g)] / time (days).
Protein efficiency ratio = live weight gain (g) / protein consumed (g).
Net protein retention = [increase in carcass protein / protein fed] x 100.
Apparent net energy retention (ANER) = [(final wt. x final GE $KJ.g^{-1}$) - (initial wt. x initial GE $KJ.g^{-1}$) / KJ GE fed] x 100
Hepatosomatic Index = (liver weight / fish weight) x 100

The condition factor (k) was calculated according to the equation k = [W(g)/L(cm)3] x 100, where W is the wet weight of fish in grams and L is the length in centimeters. The data so collected was subjected to statistical analysis using the analysis of variance and the means were compared by Fisher's LSD test according to Snedecor and Cochran (1989).

RESULTS

The data on the growth performance of *Oreochromis niloticus* fed different types of dietary lipids is presented in Table 3. Significant ($P < 0.05$) differences were observed in the body weight gain of fish fed different types of lipids. The maximum weight gain was observed in fish fed diet F containing a mixture of all the 4 dietary lipids (corn oil, olive oil, cod liver oil and beef tallow) in equal proportions. The fish fed on diet E containing beef tallow showed the poorest performance as compared to diets containing other supplementary lipids. The performance of diet E containing beef tallow was however significantly better than that of diet A containing no supplementary lipid. The diets containing corn oil, olive oil and cod liver oil did not show any significant difference in the growth performance of fish. Similar results were observed for the specific growth rate of fish. The fish fed on diet E containing beef tallow showed significantly lower body condition factor as compared to those fed other dietary lipids. No significant difference was observed in the body condition factor of fish fed diet E containing beef tallow and that of diet A without any supplementary lipid. The diets A, B, C, and F containing corn oil, olive oil, cod liver oil and a mixture of all the 4 lipids respectively, did not show any difference in the body condition factor of fish. The relative liver weight of fish in all the groups fed supplementary lipids increased as compared to the fish fed diet without any supplementary lipid. However, no significant differences were observed in the hepatosomatic index (HSI) values of fish fed different types of dietary lipids.

No significant difference was observed in the feed consumption of fish. The diet A without any supplementary lipid showed the highest FCR values followed by the diet E containing beef tallow. The best FCR value was observed on diet F containing a mixture of all 4 dietary lipids. The diets B, C and D containing corn oil, olive oil and cod liver oil did not show any difference in their FCR values. Similarly the best PER value was observed in fish fed diet F containing a mixture of all the 4 dietary lipids. The diets B, C and D did not show any significant difference in their PER values. The fish fed on diet A (without any supplementary lipid) showed the lowest NPR value followed by those fed on diet E (containing beef tallow). No significant difference was observed in the NPR values of fish fed diets B, C, D and F. Similar results were observed for the apparent net energy retention (ANER) values.

Significant ($P < 0.05$) differences were observed in the body composition of fish fed different types of dietary lipids (Table 4). The fish fed on diet A showed the maximum body moisture content followed by the fish fed diet E containing beef tallow. No significant difference was observed in the body moisture content of fish fed diets B, C, D, and F. The fish fed diets A and E showed lower body crude protein content, followed by the fish fed on diet D. The fish fed on diets B, C and F did not show any significant difference in their body crude protein content. The fish fed on diet A (without any supplementary lipid) showed the lowest body fat content followed by the diets containing a mixture of all the 4 dietary lipids and beef tallow respectively. No significant differences were observed in the body fat content of fish fed diets B, C and D containing corn oil, olive oil and cod liver oil. The body ash content of fish fed different types of dietary lipids also differed significantly ($P < 0.05$). The fish fed diet A showed the lowest gross energy (GE) content followed by the fish fed diets F and E. No significant differences were observed in the GE content of fish fed on diets B, C and D.

DISCUSSION

The results of the present study indicated that the type of dietary lipid significantly affected the growth performance of *O. niloticus*. The best growth rate was observed on diet containing a mixture of all the 4 dietary lipids in equal proportions. Similarly the FCR, PER, NPR and ANER values were also the best on diet containing a mixture of all the four dietary lipids. The results are in line with the findings of Takeuchi *et al.* (1983) who reported that Nile Tilapia fingerlings fed diets containing corn oil or soybean oil, attained the best weight gain and feed efficiencies as compared to those given beef tallow or cod liver oil. They observed that the diet containing cod liver oil however showed better performance than beef tallow. Our results indicated that diets containing corn oil, olive oil or cod liver oil did not produce any significant difference in the growth performance of fish. The poor performance of fish on beef tallow diet may be attributed to its lower content of polyunsaturated fatty acids (PUFA). Hassanen and Abd-El-Fadeel (1991) reported lower feed conversion rates in Tilapia nilotica on beef tallow or corn oil diets. Animal fats particularly beef tallow and more especially micronized hardened fatty acids have been reported to be less effective than sunflower seed oil when fed to rainbow trout (Schulz *et al.*, 1984; Hartfiel *et al.* 1984). Santiago and Reyes (1993) observed the highest weight gains in *O. niloticus* (L) brood stock fed cod liver oil. Yingst and Stickney (1979) reported that the channel catfish fry showed the best growth rate when reared on practical diets containing menhaden oil followed by soybean oil and the poorest on beef tallow. Guillou *et al.* (1995) reported that the soya and canola oils can replace fish oils in the diets of brook charr (S. fontinalis).

The performance of fish fed diet containing beef tallow (Diet E) was however significantly better than the control diet A (without any supplementary lipid). This may be due to the lower fat content on the one side and subsequently the lower energy value of the diet on the other side. Because of its (Diet A) very low lipid content (1.66%), the dietary energy level could not be balanced out at par wit other diets. Stickney and McGeachin (1983) reported that the addition of 12% of beef tallow in the diets of *O. aureus* resulted in significantly better growth rate and feed utilization than in fish fed a fat free diet. The poorest performance of fish on the control diet (Diet A) indicated that fish require a certain level of lipid in their diet. In general n-3 fatty acids are not required by warmwater fishes but for proper membrane structure at least a small amount of these acids may be needed (Stickney and McGeachin, 1983; Stickney and Hardy, 1989). Different Tilapia species however require approximately 1% of n-6 fatty acids in their diets (Kanazawa *et al.*, 1980; Teshima *et al.*, 1982, 1985; Takeuchi *et al.*, 1983). Since vegetable oils contain high levels of n-6 and also significant amounts of n-3 fatty acids they can be effectively used in Tilapia diets. Chou and Shiau (1996) reported that the growth performance of juvenile hybrid tilapia (*O. niloticus* x *O. aureus*) was better on diets containing lipids as compared to those fed lipid free diets. Fish can de novo synthesize fatty acids within the n-9 family but requires dietary n-3 and n-6 fatty acids, which can be desaturated and elongated to variable degrees (Kanazawa *et al.*, 1980). The requirement for essential fatty acids (EFA) differ considerably among fish species mainly because of their variable abilities to elongate and desaturate 18-C fatty acids to longer chain fatty acids (Sargent *et al.*, 1999). The HSI values vary as a function of dietary protein, carbohydrates and lipid level (Lee and Putnam, 1973; Garling and Wilson, 1977; Hilton and Atkinson, 1982, Ali and Al-Asgah, 2000). Our results indicated that the HSI values in fish fed different types of dietary lipids were not affected.

Data on the body composition of fish allows to assess the efficiency of transfer of nutrients from feed to fish and also helps in predicting the overall nutritional status. Both the endogenous and exogenous factors operate simultaneously to affect the composition of fish (Burtle, 1990; Haard, 1992; Shearer, 1994). The results of the present study indicated that the type of dietary lipid significantly affected the body composition of the fish. The data on the body composition of fish is very much correlated with the growth performance data. The fish fed diets containing supplementary lipids showed higher body fat and crude protein but lower moisture and gross energy contents as compared to those, fed diet without lipid supplementation. The fish fed diet containing beef tallow however showed similar body protein and ash contents as that of control group (without any supplementary lipid). These results are partially in line with the findings of Runge *et al.* (1988) who reported that carbohydrate rich diets affected the body composition of fish in a similar way as that of a diet containing 12% beef tallow. The n-3 / n-6 fatty acid ratio can also alter the lipid and protein contents in fish muscle (Robaina *et al.*, 1998). Fish stores lipid among several depot organs, including mesenteric membranes, liver and muscles as opposed to a single depot type (adipose tissue) in homeotherms. A substantial portion of dietary lipid is incorporated into the depot fat that mainly goes to visceral fat as compared to the rest of the body (Sheridan, 1994). The results of the present study suggest that the diet supplemented with a mixture of different types of lipids can produce the best growth responses in Tilapia. The vegetable oils are cheaper, available in large quantities and are less subjected to oxidation (Watanabe, 1982; Dosanjh *et al.*, 1984). They permit a growth and feed conversion which is as efficient as the fish oils without significantly affecting the flesh's organoleptic qualities (Guillou *et al.*, 1995). Their use in fish diets should therefore be promoted and explored further.

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Table 1: Composition of the experimental diets (%)

Ingredients/diets	A	B	C	D	E	F
Fish meal	10.00	10.00	10.00	10.00	10.00	10.00
Soybean meal	25.00	25.00	25.00	25.00	25.00	25.00
Casein	15.00	15.00	15.00	15.00	15.00	15.00
Maize	25.00	20.00	20.00	20.00	20.00	20.00
Dextrin	20.00	11.00	11.00	11.00	11.00	11.00
Corn oil	00.00	14.00	00.00	00.00	00.00	03.50
Olive oil	00.00	00.00	14.00	00.00	00.00	03.50
Cod liver oil	00.00	00.00	00.00	14.00	00.00	03.50
Beef tallow	00.00	00.00	00.00	00.00	14.00	03.50
Gelatin	02.00	02.00	02.00	02.00	02.00	02.00
Mineral mixture[1]	02.00	02.00	02.00	02.00	02.00	02.00
Vitamin mixture[2]	01.00	01.00	01.00	01.00	01.00	01.00
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0

1. Per Kg of the premix contains: $CaHPO_4$ 530 g; K_2HPO_4, 80 g; $NaHPO_4$ 90 g; $MgCl_2.6H_2O$ 100 g; KCl 67.5 g; K_2SO_4 80 g; NaCl 30 g; KI 0.05 g; $ZnSO_4.7H_2O$ 2.5 g; SeO_2 0.03 g; $CuSO_4.H_2O$ 0.15 g; $FeSO_4.7H_2O$ 18 g; $(NH_4)_6Mo_7O_{24}.4H_2O$ 0.01 g; $MnSO_4.H_2O$ 0.5 g; NaF 1.2 g; $CoCl_2.6H_2O$ 0.01 g.
2. Per Kg of the premix contains: Vitamin A 400,000 I.U.; D3 200,000 I.U.; E 5000 I.U.; K3 1g; B1 1g; B2 1.5g B6 1g; Pantothenic acid 5g; Niacin 3g; Folic acid 0.5g; B12 2mg; Biotin 100 mg; Vitamin C 20 g (Adapted from Lim, 1989).

Table 2: Proximate chemical composition of the experimental diets (on % dry matter basis)

Parameters/Diets	A	B	C	D	E	F
Dry matter (%)	91.19	93.01	93.01	92.83	93.28	93.01
Crude protein	38.54	37.57	37.98	38.27	37.39	38.15
Crude fibre	2.01	1.79	1.84	1.95	1.71	1.99
Total fat	1.66	16.35	15.14	15.17	15.98	15.41
Ash	7.53	7.25	7.25	7.12	7.23	7.26
Nitrogen free extract (NFE)	50.26	39.03	37.79	37.49	37.69	37.46
Gross energy ($MJ.Kg^{-1}$)	19.38	21.45	21.43	21.46	21.60	21.51

Table 3: Growth performance and body composition of *Oreochromis niloticus* fed different types of dietary lipids

Parameters/Diets	A	B	C	D	E	F	S.E.
Initial weight ($g.fish^{-1}$)	24.17	23.43	25.37	25.31	24.98	24.11	± 0.43^{NS}
Final weight ($g.fish^{-1}$)	59.80^a	69.90^c	71.40^{bc}	72.40^b	66.20^d	74.20^a	± 1.49
Weight gain ($g.fish^{-1}$)	35.63^d	46.47^b	46.03^b	47.09^b	41.22^c	50.09^a	± 1.32
Specific growth rate (SGR)	1.39^d	1.66^b	1.61^b	1.64^b	1.50^c	1.73^a	± 0.17
Condition factor (K)	2.78^b	2.99^a	2.93^a	3.06^a	2.76^b	2.95^a	± 0.19
Dry feed consumed ($g.fish^{-1}$)	62.74	63.18	63.45	62.88	63.01	63.49	± 1.59^{NS}
Feed conversion ratio (FCR)	1.76^a	1.36^c	1.39^c	1.34^c	1.53^b	1.27^d	± 0.13
Protein efficiency ratio (PER)	1.55^d	1.89^b	1.86^b	1.97^{ab}	1.73^c	2.06^a	± 0.15
Net protein retention (NPR) %	24.60^c	29.58^a	28.96^a	28.3^a	26.26^b	29.30^a	± 1.48
Hepatosomatic index (HIS) %	1.31^b	1.55^a	1.51^a	1.53^a	1.50^a	1.48^a	± 0.17
Apparent net energy retention %	15.92^c	19.89^a	19.74^a	19.62^a	18.53^b	20.21^a	± 1.03

NS = Non significant; a, b, c = Different alphabets in the same row means significant at 5%.

Table 4: Data on the body composition of *Oreochromis niloticus* fed different types of dietary lipids (on % wet basis)[1]

Parameters/Diets	A	B	C	D	E	F	S.E.
Moisture (%)	75.41^a	73.49^c	73.25^c	73.59^c	74.48^b	73.7^c	± 0.61
Crude protein	14.79^c	15.61^a	15.54^{ab}	15.36^b	14.83^c	15.70^a	± 0.24
Total fat	4.64^d	5.7^a	5.98^a	5.90^a	5.58^b	5.25^c	± 0.23
Ash	4.37^{ab}	4.22^c	4.26^{bc}	4.39^{ab}	4.46^a	4.20^c	± 0.17
Gross eenrgy ($MJ.Kg^{-1}$)	5.32^c	5.97^a	6.03^a	5.95^a	5.69^b	5.79^b	± 0.14

1 = Composition of fish slaughtered at the beginning of the experiment (moisture 74.85%; crude protein 14.92%; fat 4.78%; ash 4.23% and gross energy 4.86 $MJ.KG^{-1}$). a, b, c, d = different alphabets in the same row means significant at 5%.

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