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Effect of Dietary Sources and Levels of Lipids on Growth Performance and Feed Utilization of Fry Nile Tilapia, *Oreochromis niloticus* (L.) (Teleostei: Perciformes)

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Abstract: The effect of dietary oil sources and levels on growth, feed utilization, and body chemical composition of fry Nile tilapia (*Oreochromis niloticus*) (Teleostei: perciformes) was studied through two experiments. In the first experiment, Nile tilapia (2±1 g/fish) were assigned to three treatments, with three replicates each. The test diets (CP 30%) contained cod liver oil, corn oil or mixed oil of corn and cod liver oils (1:1 v/v) at 4% level. Fish were fed test diets at the rate of 3% of live body weight three times daily for 90 days. The results revealed that the diet contained mixed oil resulted in the highest fish growth. No significant changes in feed intake, FCR, PER or PPV were observed due to different oil sources in diet. The highest water and protein contents were found in the body of fish fed mixed oil diet and no changes were observed in total lipids and ash contents in fish fed different diets. The second experiment was carried out to test the optimum oil level in fish diet. Fish were fed diets containing dietary oil level of 0 (control), 2, 4, 6 or 8%. The results revealed that the optimum fish growth was found at dietary level of 4%. Also, the optimum feed intake, FCR, PER or PPV were realized by the diet with mixed oil at 4%. The crude protein content in the body of fish significantly ($p<0.05$) decreased at 6-8% oil level. No significant changes in total lipid and ash content were observed, but ash content in fish fed control diet was the highest. It could be concluded from the present study that it is possible to substitute 50% of the fish oil in diets for Nile tilapia fry with corn oil, without affecting the growth performance and feed utilization and the optimal dietary lipid level for Nile tilapia fry is 4%.

Key words: Dietary lipid, *Oreochromis niloticus*, growth, feed intake, proximate chemical composition

Introduction

Dietary lipids play an important role as the source of energy and essential fatty acids for the growth and development of fishes. It can also spare dietary protein from use as energy and limit ammonia production (Cho and Kaushik, 1990). On the other hand, high dietary lipid content might decrease feed consumption and reduce growth (Watanabe, 1982). Moreover, high dietary lipid can also lead to an increase in lipid deposition in fish body and affect quality and nutritional value of fish meat. Therefore, the optimal dietary lipid level must be carefully evaluated and determined.

It is generally accepted that omnivorous fishes have greater capacity to utilize carbohydrate than carnivorous fishes (Wilson and Halver, 1986; Nematipour *et al.*, 1992; Shiau and Lan, 1996). Omnivorous fish, such as tilapia, common carp and channel catfish, are able to effectively utilize both carbohydrate and lipid and usually require 50-60 g kg^{-1} lipid in diets (Luquet, 1991; Satoh, 19991 and Wilson, 1991). Studies on the energy requirement of fish have demonstrated a relationship between feeding habits and the capacity for lipid utilization in fish (Mai *et al.*, 1995).

Good quality fats improve growth, feed conversion and protein utilization, thus reducing nitrogen excretion in farmed fish (Steffens, 1993). In general, the main lipid source employed in fish feeds is fish oil due to its high content in n3 HUFA (polyunsaturated fatty acids of the n3 series with 20 or more carbons), which are considered as essential fatty acids for fish species (Izquierdo, 1996; Ahamad, 2004). There is a steady increase in demand for fish oil as a result of global expansion in aquaculture.

Vegetable oils are (with the exception of some such as coconut and palm oils) rich in fatty acids with 18 carbons, and many of them are also rich in linoleic or linolenic acids, essential for freshwater fish species. Therefore, many vegetable oils are a good energy source in diets for freshwater species such as African catfish *Heterobranchus longifilis* (Legendre *et al.*, 1995) or common carp *Cyprinus carpio* (Fontagne *et al.*, 1999) with maximum replacement rates being up to 40% of the dietary lipids. In other species such as red drum (*Sciaenops ocellatus*) substitution levels of up to 70-80% have been reported with soybean oil (Tucker *et al.*, 1997) or linseed oi (Lochmann and Gatlin, 1993) without growth reduction. Also, in Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhyncus mykiss*) at least 50 and 80%, respectively, of the fish oil can be replaced by different vegetable oils without compromising growth, survival or feed utilization (Rosenlund *et al.*, 2000; Caballero *et al.*, 2002; Grisdale-Helland *et al.*, 2002).

Nile tilapia (*Oreochromis niloticus*) has been popularly cultured all over the world. Generally, Nile tilapia is considered an omnivorous fish and feeds mainly on microorganisms, phytoplankton, zooplankton and detritus in natural habitat (Abdel-Tawwab, 2000; Abdel-Tawwab and EI-Marakby, 2004). The objective of the present study was to investigate the effect of dietary oil sources and levels on the growth performance and the feed utilization by Nile tilapia.

Materials and Methods

Experimental Design

Healthy fish of Nile tilapia, *Oreochromis niloticus* (L.) weighing 2-3 g were obtained from Abbassa fish hatchery, General Authority for Fish Resources Development, Abbassa, Abo-Hammad, Sharkia. Fish were acclimated in indoor tanks for 2 weeks where they were fed a commercial diet containing 30% CP. Weight of 200 g of fish was frozen at -20°C for chemical analyses. The fish of mixed sex of each size were distributed randomly in glass aquaria (75×60×50 cm) containing 100 L aerated water at the rate of 15 fish/aquarium. Each aquarium was supplied with compressed air via air-stones from air pumps (Boss 9500, Germany). Well aerated water supply was provided from a storage fiberglass tank. The temperature ranged between 27-28°C. Siphoning a portion of water from each aquarium was done every day for removing sediments and an equal volume of water replaced it.

Fish Diets and Feeding Regime

In the first experiment, a basal diet was formulated, which was used to formulate three identical diets in all the nutrient contents differing only in lipid source at 4% level (Table 1). The test diets were prepared as semi moist dough. Three aquaria were randomly assigned for each treatment. Fish were fed frequently to satiation daily for 90 days and the amount of feed consumed for each aquarium was recorded. Fish in each aquarium were weighed biweekly.

Table 1: Ingredients and nutrients composition of test diets with different oil sources

	Oil source		
Ingredients (%)	Cod liver oil	1:1 Mixed oil	Corn oil
Fish meal	14.00	14.00	14.00
Soybean meal	36.50	36.50	36.50
Wheat bran	16.50	16.50	16.50
Ground corn	19.50	19.50	19.50
Cod liver oil	4.00	2.00	0.00
Corn oil	0.00	2.00	4.00
Vitamins and minerals mixture*	3.00	3.00	3.00
Ascorbic acid	0.05	0.05	0.05
Calcium phosphate	1.00	1.00	1.00
Carboxymethylcellulose	1.00	1.00	1.00
Starch	4.45	4.45	4.45
Total	100.00	100.00	100.00
Chemical composition (%)			
Dry matter	91.21	91.41	91.35
Crude protein	29.98	30.29	30.30
Ether extract	7.62	7.49	7.53
Crude fiber	5.20	6.28	5.81
Ash	6.61	7.01	6.53
NFE **	50.59	48.93	49.83
GE (kcal/kg feed) ***	4703.10	4684.60	4706.49
E:P ratio	156.87	154.66	155.33

* Vitamin and minerals premix: each 2.5 kg contain vitamin A 12 MI U; D_3 2 MI U, E 10 g; K 2 g; B_1 1 g; B_2 4 g; B_6 1.5 g; B_{12} 10 mg; Pantothenic acid 10 g; Nicotinic acid 20 g; Folic acid 1 g; Biotin 50 mg; Choline chloride 500 mg; Copper 10 g; Iodine 1g; Iron 30 g; Manganese 55 g; Zinc 55 g and Selenium 0.1g

** NFE (Nitrogen Free Extract) = 100-(protein + lipid + ash + fiber)

*** GE (Gross Energy): Calculated after NRC (1993) as 5.64, 9.44 and 4.11 Kcal g^{-1} for protein, lipid and NFE, respectively

Table 2: Ingredient and nutrients composition of test with different oil levels

	Oil levels				
Ingredients (%)	0 (control)	2	4	6	8
Fish meal	14.00	14.00	14.00	14.00	14.00
Soybean meal	36.50	36.50	36.50	36.50	36.50
Wheat bran	16.50	16.50	16.50	16.50	16.50
Ground corn	19.50	19.50	19.50	19.50	19.50
Cod liver oil	0.00	1.00	2.00	3.00	4.00
Corn oil	0.00	1.00	2.00	3.00	4.00
Vitamin and mineral mixture*	3.00	3.00	3.00	3.00	3.00
Ascorbic acid	0.05	0.05	0.05	0.05	0.05
Calcium phosphate	1.00	1.00	1.00	1.00	1.00
Carboxymethylcellulose	1.00	1.00	1.00	1.00	1.00
Starch	8.45	6.45	4.45	2.45	0.45
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition (%)					
Dry matter	90.51	90.77	91.41	91.89	91.95
Crude protein	30.57	29.91	30.29	30.45	30.10
Ether extract	3.51	5.44	7.49	9.88	11.79
Crude fiber	5.51	5.50	6.28	5.72	6.01
Ash	6.88	6.59	7.01	7.21	6.71
NFE **	53.53	52.56	48.93	46.74	45.39
GE (kcal/kg feed) ***	4482.00	4586.70	4684.60	4806.20	4923.10
E:P ratio	146.61	153.35	154.66	157.84	163.56

* Vitamin and minerals premix: each 2.5 kg contain vitamin A 12 MI U; D_3 2 MI U, E 10 g; K 2 g; B_1 1g; B_2 4 g; B_6 1.5 g; B_{12} 10 mg; Pantothenic acid 10 g; Nicotinic acid 20 g; Folic acid 1g; Biotin 50 mg; Choline chloride 500 mg; Copper 10 g; Iodine 1 g; Iron 30 g; Manganese 55 g; Zinc 55 g and selenium 0.1 g

** NFE (Nitrogen Free Extract) = 100-(protein + lipid + ash + fiber)

*** GE (Gross Energy): Calculated after NRC (1993) as 5.64, 9.44 and 4.11 Kcal g^{-1} for protein, lipid and NFE, respectively

The lipid source that showed best performance (a mixture of 1:1 cod liver oil: corn oil) in the first experiment was selected for studying the effect of lipid level in diet on. In the second experiment, the same basal diet used in the first experiment was taken and five diets were formulated with lipid levels of 0 (control), 2, 4, 6 and 8% (Table 2). Preparation of diets, the method of feeding the fish, water management in fish tanks and the duration of feeding trial were the same as in the first experiment.

Growth Parameters

Growth performance of fish and feed utilization were calculated using the following equations:

$$\text{Specific Growth Rate (SGR)} = 100\,(\ln W_2 - \ln W_1)/T^1$$

Where, W_1 and W_2 are the initial and final weight, respectively and T is the number of days in the feeding period.

Feed Conversion Ratio (FCR) = feed intake/weight gain
Protein Efficiency Ratio (PER) = weight gain/protein intake
Protein Productive Value (PPV; %) = 100 × (Protein gain/Protein intake)

Chemical Analysis

The contents of dry matter, crude protein, crude lipid, ash and gross energy were determined for the diets and the fish were analyzed following standard AOAC (1984) methods using Tecator equipment. Gross energy was calculated according to NRC (1993).

Statistical Analysis

All data were subjected to one-way ANOVA to test the significance of the effect of experimental diets. In case where significant differences occurred at 5% level ($p<0.05$), the means were compared using Duncan's Multiple Range Test. All the statistical analyses are done using SPSS software version 10 (SPSS, Richmond, USA) as described by Dytham (1999).

Results

The highest weight gain and SGR are realized by the diet with mixed oil source ($p<0.05$), while individual diets with corn oil and cod liver oil resulted in approximately the same growth performance ($p>0.05$). No fish mortality was observed in any of the treatments tested. Feed intake (FI) increased with mixed oil source better than the other oil sources ($p<0.05$). However, FCR, PER and PPV values did not show significant differences ($p>0.05$) among the treatments. No significant changes (Table 3) in water content, crude protein, total lipids and ash content in the fish were observed after feeding with different diets.

The growth of fish was enhanced at 4% oil level ($p<0.05$), but decreased again at 8%. FCR significantly decreased with increased dietary lipid levels ($p<0.05$) except at 0% (control) and 8% levels (1.891 and 1.827, respectively, while the FCR values at lipid levels of 4 and 6% being 1.602 and 1.692, respectively). There are no significant differences in PER values due to dietary lipid levels ($p>0.05$) except that of control diet, which resulted in the least value (1.867). Also, there are no significant differences in PPV values due to dietary lipid levels ($p>0.05$) except that of the diet with 6% oil, which resulted in the least PPV value of 40.01 (Table 4).

Table 3: Growth performance and body composition of Nile tilapia fed diets containing different oil sources

	Oil sources		
Items	Cod liver oil	1:1 (v:v) mixed oil	Corn oil
Initial weight (g/fish)	2.22	2.15	2.21
Final weight (g/fish)	8.42±0.25^{b}	9.31±0.22^{a}	8.21±0.16^{b}
Weight gain (g/fish)	6.20±0.26^{b}	7.16±0.28^{a}	6.00±0.17^{b}
SGR (%)	1.48±0.037^{b}	1.62±0.059^{a}	1.46±0.027^{b}
Survival (%)	100±0.0	100±0.0	100±0.0
Feed intake (g/fish)	10.47±0.09^{b}	11.65±0.16^{a}	10.28±0.37^{b}
FCR	1.69±0.058	1.63±0.841	1.71±0.091
PER	2.16±0.07	2.22±0.12	2.11±0.11
PPV (%)	43.05±1.17	44.06±1.89	43.64±2.06
Body composition of fish post feeding trial			
Moisture	71.9±0.26	71.9±0.26	71.2±0.37
Crude protein	64.2±0.14^{b}	65.1±0.03^{a}	64.3±0.05^{b}
Total lipids	19.9±0.023	19.9±0.069	19.6±0.203
Ash	15.12±0.41	15.33±0.21	15.21±0.28

The same letter in the same row is not significantly different at $p<0.05$

Table 4: Growth performance and body composition of Nile tilapia fed diets containing different levels of mixed oil

	Oil levels				
	0 (control)	2	4	6	8
Initial weight (g/fish)	2.19	2.24	2.15	2.19	2.24
Final weight (g/fish)	6.6±0.23^{c}	7.7±0.05^{b}	9.31±0.22^{a}	9.07±0.16^{a}	7.96±0.03^{b}
Weight gain (g/fish)	4.41±0.21^{c}	5.46±0.03^{b}	7.16±0.28^{a}	6.88±0.19^{a}	5.72±0.01^{b}
SGR (%)	1.233±0.031^{c}	1.367±0.088^{b}	1.622±0.059^{a}	1.577±.040^{a}	1.400±0.015^{b}
Survival (%)	98.7±2.3	100	100	100	100
Feed intake (g/fish)	8.34±0.18^{d}	9.52±0.13^{c}	11.47±0.17^{a}	11.64±0.25^{a}	10.45±0.04^{b}
FCR	1.891±0.09^{a}	1.74±0.02^{a-c}	1.602±0.08^{c}	1.692±0.05^{bc}	1.827±0.01a^{b}
PER	1.867±0.097^{b}	2.113±0.017^{a}	2.223±0.122^{a}	2.140±0.060^{a}	1.990±0.012^{ab}
PPV (%)	41.03±1.84^{ab}	44.98±0.27^{a}	44.06±1.89^{ab}	40.01±1.06^{b}	40.74±0.28^{ab}
Body composition of fish post feeding					
Moisture	70.85±0.37^{c}	71.28±0.14^{bc}	71.92±0.06^{b}	72.96±0.25^{a}	71.37±0.32^{bc}
Crude protein	64.8±0.15^{a}	65.3±0.31^{a}	65.1±0.03^{a}	63.8±0.21^{b}	63.8±0.26b
Total lipids	18.6±0.24^{c}	19.3±0.22^{b}	19.9±0.07^{ab}	21.3±0.27^{a}	21.1±0.23^{a}
Ash	16.5±0.35^{a}	15.4±0.16^{b}	15.3±0.21^{b}	15.2±0.17^{b}	15.0±0.34^{b}

The same letter(s) in the same row is not significantly different at $p<0.05$

It is noticed that with the increase in dietary lipid level, moisture content increased and reached maximum value (Table 4) at dietary level of 4% (72.96%; $p<0.05$). The crude protein (63.8%) decreased in fish fed with lipid levels of 6 and 8%, whereas at low lipid levels of 0 to 4%, crude protein did not significantly changed ($p>0.05$). Total lipid increased with the increase in dietary lipid ($p<0.05$), while the 6 and 8% lipid level group showed the highest value (21.3 and 21.1%, respectively). There are no significant differences in final body ash content among fish fed diets with different lipid levels ($p>0.05$), but the highest ash content (16.5%)was observed in fish fed the control diet.

Discussion

In the present study, the partial replacement of fish oil with corn oil enhanced the growth and feed intake by Nile tilapia, however FCR was also optimized. Similar results are reported by Izquierdo *et al.* (2003) who studied the effect of partial replacement of fish oil in compound diets for gilthead seabream and seabass, by several vegetable oil sources, on growth, dietary fatty acid utilization and flesh quality. They suggested that it is possible to replace up to 60% of the fish oil by soyabean oil, rapeseed oil and linseed oil or a mixture of them for seabream and seabass, without compromising fish growth and feed utilization. The results of the present study are markedly different from those found by Alexis (1997), EI-Kerdawy and Salama (1997), Yildiz and Sener (1997) where, substitutions of 50% the fish oil by vegetable oils reduced growth of the same species. Watanabe (1982) reported that inclusion of vegetable oils in fish diets modifies the body fatty acid profiles, and this effect is more evident in marine fish species with a limited ability to convert 18-C fatty acids into longer polyunsaturated fatty acids.

The partial replacement of fish oil with corn oil enhanced the protein content of fish body, but not affected the lipid content. In this regard, Izquierdo *et al.* (2003) found that dietary lipid sources did not affect lipid deposition in either liver or muscle of seabass or seabream, however, utilization of dietary lipids differed between these two tissues and was also different for the different fatty acids. They also reported that inclusion of vegetable oils in diets for seabream and seabass led to a diet dependent reduction in liver levels of Eicosapentaenoic Acid (EPA), Docosahexaenoic Acid (DHA) and Arachidonic Acid (ARA), whereas, DHA was preferentially retained in the muscle relative to the other fatty acids. This fact seems to be related to the higher beta-oxidation of EPA than of DHA, particularly in mitochondria (Madsen *et al.*, 1998).

The second experiment in the present study revealed that increase in dietary lipid level from 0 to 8%, increased specific growth rate of Nile tilapia. This is in agreement with reports that increasing dietary lipid level could improve the growth of fish (Watanabe, 1982; Bromley, 1980). Some studies had reported that high dietary lipid level might reduce fish growth (Garling and Wilson, 1977; Ellis and Reigh, 1991 and Pei *et al.*, 2004). These reports suggest that the growth reduction at high lipid levels could be due to the reduced ability to digest and absorb high lipid, reduce in feed intake and/or fatty acid imbalance in feed (NRC, 1983).

The present study however, showed that the increase in dietary lipid level was associated with the increase in feeding rate. It appears that fish could adjust feed intake to satisfy energy requirements (Kaushik and M′edale, 1994). When fish fed diet containing too high energy, decreased feed intake and growth depression was also reported by El-Sayed and Garling (1988) and Ellis and Reigh (1991). Improved feed conversion ratio and protein efficiency ratio with increasing dietary lipid level in Nile Tilapia in the present study are in agreement with other studies (Pei *et al.*, 2004; Einen and Roem, 1997; Weatherup *et al.*, 1997). It has been reported that protein utilization can also be improved by increasing dietary energy level in many fishes (Cho and Kaushik, 1990; Beamish and Medland, 1986). For Nile tilapia in this study, when dietary lipid level increased from 0 to 8%, PRE increased suggesting that increased dietary lipid level could spare dietary protein (Pei *et al.*, 2004; Arzel *et al.*, 1994; Chou and Shiau, 1996).

The increase in dietary lipid levels is usually associated with an increase in whole-body lipid content, while crude protein decreased. Positive correlation between dietary lipid levels and body total lipids was observed in many species (Pei *et al.*, 2004; Chou and Shiau, 1994; Hillestad and Johnsen, 1994; Shearer, 1994). Williams and Robinson (Williams and Robinson, 1988) reported that there was an apparent decrease in body protein content when fish were fed diets with high lipid levels. Dietary lipid seems to affect ash content slightly. Many studies have been conducted in rainbow trout and Atlantic salmon (Helland *et al.*, 1991) common carp and red seabream (NRC., 1983) white sturgeon and hybrid tilapia (Lin *et al.*, 1997). However, in comparative studies, there exist many differences such as diet formulation and composition, feeding rate and strategy, fish size and age, water quality and culture system (Lin *et al.*, 1997).

In conclusion, the present study has shown that it is possible to substitute 50% of the fish oil in diets for Nile tilapia with corn oil, without negative effects on fish performance and feed utilization. The optimal dietary lipid level for Nile tilapia fry is 4%.

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