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THE EFFECTS OF VARYING DIETARY LIPID LEVELS ON GROWTH PERFORMANCE AND BODY COMPOSITION OF NILE TILAPIA

(*Oreochr omis niloticus,* Linnaeus).

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ABSTRACT

A study on growth and body composition of Nile tilapia (*Oreochromis niloticus* L.) indicates that mean weight, Mean Weight Gain (MWG), Specific Growth Rate (SGR) and Feed Conversion Ratio (FCR) are not affected significantly (p>0.05) by varying dietary lipid levels. However, fat content levels appear to increase significantly in the viscera of fish fed on higher levels (6% lipid diet) at 8.03±2.03% of total body weight (p<0.05). This may be an indication that diets with high lipid levels may contribute to elevated fat deposits in viscera and may contribute to obesity in fish. There were no significant differences among diets in fat contents of the fillets. Dietary lipid levels had no effect on moisture content of both fillets and viscera (p>0.05). Survival of fish fed on 3% lipid diet was significantly high (p<0.05) compared to the other two diets; suggesting some adverse effects may be associated with dietary lipid levels.

Keywords: *Oreochromis niloticus,* lipids, growth performance, feed utilization, energy efficiency, dietary, fat content, moisture content.

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INTRODUCTION

Digestive and metabolic systems of tilapias have adapted to utilize proteins and lipids for energy. There is no actual requirement for dietary carbohydrates as tilapias are capable of synthesizing carbohydrates from both dietary protein and dietary lipid sources. Carbohydrates are hence, not essential because tilapias grow satisfactorily and show no pathologies when fed carbohydrate-free diets. Carbohydrates supply less energy in tilapia diet (4.1 kjoules) as compared to lipids (9.1 kjoules) and proteins (5.6 kjoules). Typical carbohydrate sources include corn, wheat, rice and a number of agricultural by- products. Carbohydrates are included in feeds as protein sparing energy sources, bulking agents and as binders (Jauncey and Ross, 1982).

The protein requirements for maximum growth are a function of protein quality and fish size; with diets for fry having the highest protein levels and consequently costs (Jauncey and Ross, 1982). The level of dietary protein producing maximum growth of fish depends on the energy content of the diet, the physiological state of the animal, the protein quality, the level of food intake and age of fish. This level decreases with increase in fish age. Adult tilapias need less protein except for brood fish, which require elevated protein and fat levels to increase reproductive efficiency (Lovell, 1989; Popma And Masser, 1999).

Protein is the most expensive source of energy and thus utilization of protein should be maximized by supplying alternative adequate amounts of dietary energy sources at lower costs (Fitzsimmons, 1997; Jauncey and Ross, 1982). Protein requirements for tilapia are high because not only are they needed for growth, but also for energy because they metabolize proteins as sources of energy rather than deposit it as growth. This leads to higher production costs as fish take a longer time to reach market size. There is need therefore, to provide other alternative sources of energy. Lipids have higher energy content (9.1 kjoules) than carbohydrates (4.1 kjoules) and are therefore a better source (Jauncey and Ross, 1982).

Dietary lipids play an important role in tilapia nutrition as a source of energy and essential fatty acids (EFA) to maintain biological structure and normal function of cell membranes (Du *et. al.,* 2005). They act as precursors to prostaglandins, control membrane fluidity and provide a major energy source (Greenberg and Harrell 1998). Fish have a lower dietary energy requirement because they do not have to maintain a constant body temperature; they exert less energy to maintain position and move in water. A dietary deficiency of energy can reduce growth rate because energy needs for maintenance and voluntary activity must be satisfied first before energy is available for growth. Proteins would therefore be used for energy when diet is deficient of the latter. Dietary lipids have a protein sparing effect which results in protein; which may otherwise be used to provide energy, being replaced. However, a diet containing excessive energy can restrict feed consumption and prevent the intake of the necessary proteins and other nutrients (Lovell, 1989).

Dietary lipids contain essential fatty acids (EFA) composed n-6 family and n-3 family. Freshwater fish such as *O. niloticus* requires n-6 series polyunsaturated acids whereas most marine species require n-3 highly unsaturated fatty acids (Cowey *et. al.*, 1976; Greenberg and Harrell, 1998). The optimum dietary levels of n-6 fatty acids have been estimated to be 0.5% for *O. niloticus.* Hence, supplementation of tilapia diets with vegetable oils (soybean oil and corn oil), which are rich in 18:2, n-6 fatty acids has given a greater performance than those containing fish oils high in 20:5 n-3 fatty acids. (Lim, 1989). Within certain limits, increasing dietary lipid levels improve diet utilization (Du *et. al.*, 2005).

The problem with energy provision is that if supplied in excessive amounts lead to deposition of carcass fats and undesirable changes in carcass composition. Therefore, the farmers' dilemma is to design practical feeds that are a compromise between a protein level that produces good growth with little conversion to energy and an energy level that gives high rates of protein synthesis. The purpose of the study therefore, was to determine a suitable lipid level that will result to optimal growth with desirable body composition in *O. niloticus*.

METHODS

Study Area

A preliminary study was conducted for 21 days in March 2007 at Chepkoilel University College which is situated north of Eldoret Municipality on the Eldoret-Ziwa road. It is situated 9km from Eldoret town at Fisheries and Aquatic Sciences Department's Hatchery. The campus is within Rift Valley Province, Uasin Gishu District.

Diet preparation

Three treatment diets each were formulated using fishmeal, wheat bran, soybean oil and premix as described by Abdelghany (2000). The vitamin and mineral premixes were blended separately for 30 minutes. The dry ingredients of each diet were thoroughly mixed in an electric blender for about 20 minutes. The oil and water were then gradually added to the dry mixtures, which were mixed for another 5 minutes. Each diet was cooled to room temperature. The diets were stored in plastic bags at -10^{o}C until needed. Each of the treatment diets contained 34% crude protein. The different treatments had varying levels of lipids at 0 % (control diet), 3%, and 6%. The source of the lipid was soy bean oil. There were two replicates for each of the three diets.

Fish

A total of 270 *O. niloticus* fry each weighing 2.0 ± 0.1g were obtained from Department of Fisheries and Aquatic Sciences' Fish Farm, Chepkoilel Campus. They were maintained in the Fisheries and Aquatic Sciences Department's hatchery in glass aquaria measuring 30cm x 30cm x 45cm. The aquaria were first disinfected with formalin and left to dry after thorough rinsing with clean water for one day. They were then filled with 25L-dechlorinated tap water. The aquaria were randomly stocked at a density of 30 fry per aquarium. After stocking the fry were acclimated for seven days.

Feeding

After acclimatization, fry were fed *ad libitum* with a fishmeal diet with varying lipid levels. Fry were fed at a rate of 3% body weight three times a day (0800hrs, 1300hrs and 0500hrs) by hand feeding. The feeding rate was adjusted weekly based on the body weight.

Water quality monitoring

Water quality was maintained by cleaning aquaria. Each aquarium was aerated and water changed three-quarter way with dechlorinated tap water for each aquarium on a daily basis. Temperature, pH, dissolved oxygen and Total Ammonia Nitrogen (TAN) were monitored daily.

Sampling and growth performance determination

The initial weight of the fry was determined after the 7 days of acclimatization. A total of 48 fry were removed using a scoop net and weighed individually for each diet every 7 days. The following growth indices were either measured or derived according to Sanchez *et al.* (1997):

Body weight (Bw) = Weight of the fish (grams)

Mean weight (Mw) = SBw/N, where SBw = total of the body weights of all fish measured, N = number of fish measured.

Specific growth rate (SGR, %/day) = [(ln MwT – ln Mwt)/ (T-t)] x 100,

$$\frac{\ln MwT - \ln Mwt}{T - t} \; X\,100$$

where T-t = number of days over which growth was evaluated.

Mean weight gain (MWG) = Mean final weight- Mean initial weight/mean initial weight

Food conversion ratio FCR= Dry feed intake (g/fish)/wet weight gain (g/fish)

Proximate analysis of diets and Fish

All the diets were analyzed by standard methods according to AOAC (1980). Nitrogen contents were measured by the macro-kjedahl method and used to estimated crude protein by multiplying by 6.25. Fish fillets and viscera were processed in a food grinder and freeze dried for subsequent chemical analyses. Fat (in the form of lipids) contents were established by the ether extract method. Moisture contents of viscera and fillets of fish were estimated by heating samples in a forced air oven at 110^{o}C for 5 hours and computing the weight loss.

Survival

The number of dead fish in each aquarium were counted and recorded on a weekly basis. At the completion of the experiment, survival was determined as a percentage of the final number of fry and the initial number of stocked fry.

Data Analysis

The data was subjected to one-way analysis of variance (ANOVA) using Statistical Package Computer Software (SPSS), 1988 Version, Chicago, Illinois, U.S.A.) Duncan's multiple range test to compare differences among means for all treatments at P=0.05 (Duncan, 1955).

RESULTS

Water quality parameters

Water quality was monitored and was relatively stable throughout the study period with temperature ranging from 8.3-8.5^{o}C. Dissolved oxygen and pH ranged from 4.47-4.55 mg/l and 8.3-8.5 respectively. Total ammonia nitrogen (Tan) was between 0.20 and 0.21mg/l.

Proximate Analysis of diets and fish

Proximate analysis of diets showed that there were differences in expected values in lipids and proteins. This may be attributed to the fact that the diets were formulated from practical feeds whose nutritional requirements not manipulated as is the case with semi-purified or purified feeds (Table 1).

Table 1: Proximate Analysis of the treatment diets fed to fry of *O. niloticus* in static water systems in glass aquaria. Mean values of ±SD of the three diets. Treatments were 0% (control), 3% and 6% dietary lipid levels.

Diet (% lipid level)	**Moisture**	**Protein**	**Lipid**	**Ash**	**Total Carbohydrate**
0	1.85±1.06	34.89±0.01	0.12±0.05	24.9±0.07	0.65±0.30
3	7.14±2.10	34.09±0.01	3.18±0.22	33.38±0.89	1.35±0.13
6	3.24±2.70	33.69±0.19	3.18±0.22	22.38±0.61	1.2±0.10

The fat content in the viscera of fish fed on the 6% lipid diet was significantly higher at 8.03±2.03% of total body weight compared to the control (0%) and 3% lipid diets ($p<0.05$); an indication that elevated fat deposits may be as a result of high lipid levels in diets. There were no significant differences among diets in fat contents of the fillets. (Table 2).

Table 2: Fat content (% of total body weight) in viscera and fillet of *O. niloticus* fry fed with diets of varying dietary lipids levels. Values are Means (± SD) of two replicate samples. * indicates diets with significantly higher fat content levels ($p<0.05$).

Treatment	**Viscera**	**Fillet**
34-0	4.18±1.18	2.74±1.71
34-3	5.65±2.70	2.68±0.07
34-6	8.03±2.03*	2.81±0.11

The moisture content of both the viscera and fillet for the treatments were not significantly different among treatments ($p>0.05$). However, the 6% lipid level diet resulted in the highest moisture content in the viscera (79.92±0.46%) (Table 3). The moisture content of fillets was highest (77.18±0.64%) in fish fed 3% lipid diet.

Table 3: Moisture Content (% total of body weight) in viscera and fillet of *O. niloticus* fry fed with diets of varying dietary lipids levels. Values are Means (± SD) of two replicate samples.

Treatment	Viscera	Fillet
34-0	78.81±0.47	72.00±0.89
34-3	77.94±0.54	77.18±0.64
34-6	79.92±0.46	76.09±0.91

Growth

The mean weight gain (MWG), specific growth rate (SGR) and food conversion ratio (FCR) were not significantly different (p>0.05) among the three diets. However, fish fed 3% dietary lipids generally had higher growth performance in terms of mean weight gain (MWG) (Table 4), mean weight (Figure 1), food conversion ratio (FCR) (Figure 2) and specific growth rate (SGR) (Figure 3).

Table 4: Mean weight gain (±SD) of *O. niloticus* fry fed on diets with different lipid levels.

Lipid levels in Diet (%)	Initial Weight	Final Weight	Mean Weight	Mean Weight Gain (g)
0	57.26 ±0.38	65.33±0.32	2.00±0.09	0.05±0.01
3	57.13± 0.62	68.76±0.12	2.05±0.13	0.06±0.02
6	57.57± 0.32	60.80±0.41	1.95±0.06	0.02±0.01

Figure 1: Mean weight of O. *niloticus* fry fed on different dietary lipid levels at 0, 3 and 6%. Values are means of two replicates.

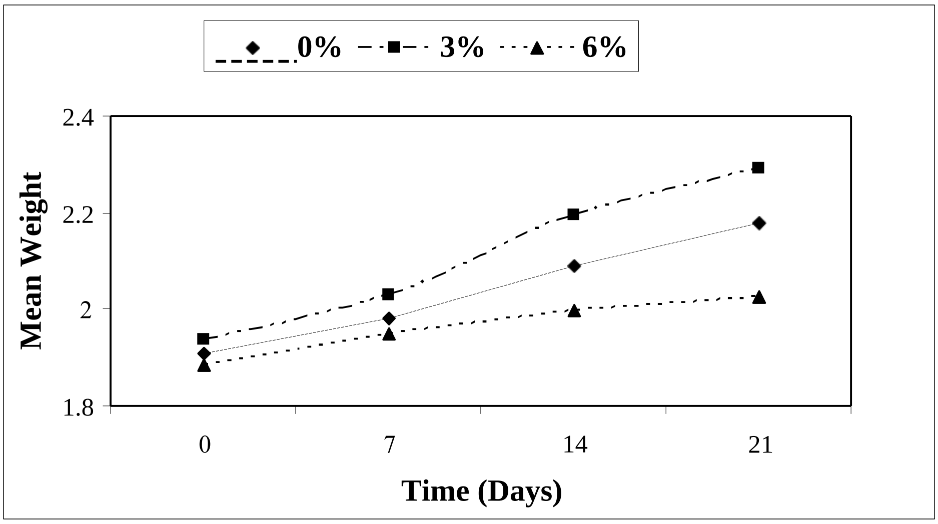


Figure 2: Food Conversion Ratio of *O. niloticus* fry fed varying levels of dietary lipids at 0, 3 and 6%. Values are means of two replicates.

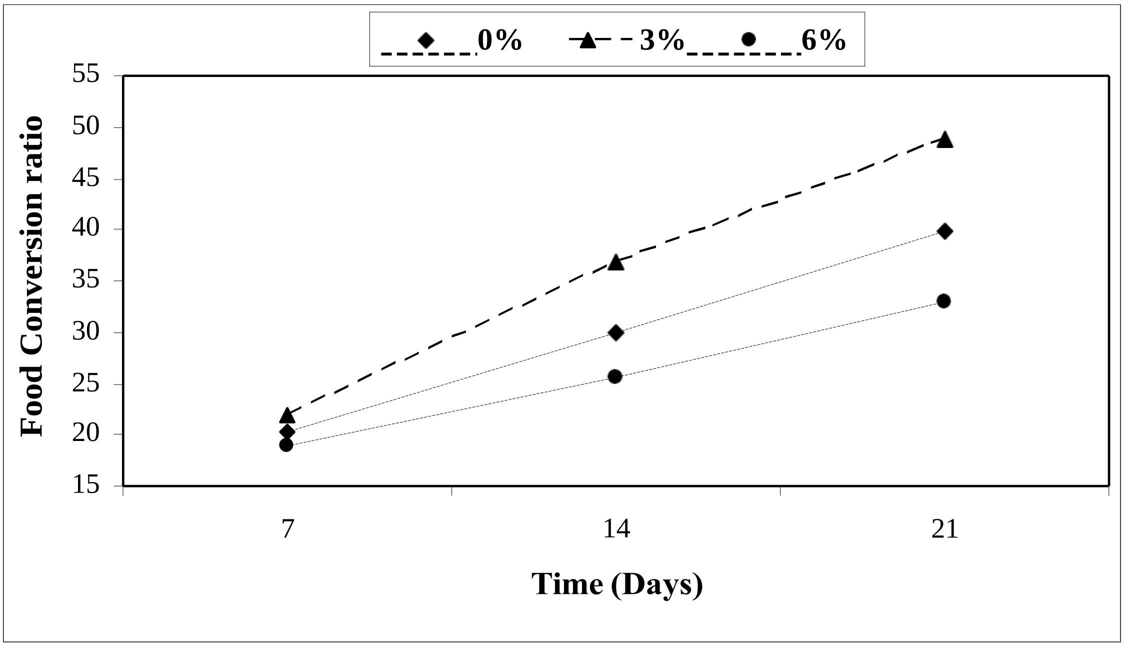
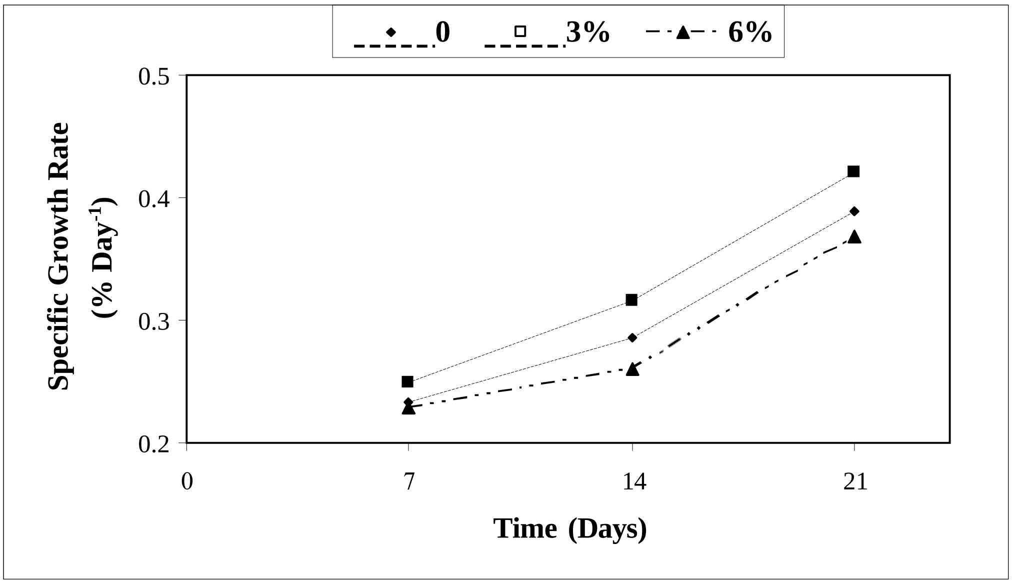


Figure 3: Specific Growth Rate of *O. niloticus* fry fed varying levels of dietary lipids at 0, 3 and 6%. Values are means of two replicates.



This fish were observed to feed ad-libitum and few food remains were seen at the bottom of the aquaria compared to fish fed the control and 6% lipids where high amounts of food remains were observed at the bottom of the aquaria. The 6% lipid diet produced the least growth (mean weight: 1.95±0.06g).

Survival

Mortalities were observed to be highest during the first week. Survival was relatively high during the study period especially for fish fed diets 34-0 and 34-3. Survival was significantly higher ($p<0.05$) in fish fed 3% lipid diet (98.50±1.0%) than in the control and 6% lipid diet (Figure 4).

DISCUSSION AND CONCLUSION

Dismal weight gain in fish fed 6% lipid level is attributed to the fact that fish with high fat content tend to be lighter in weight than lean fish. Fish fed the control diet (0%lipid level) was deficient of energy, therefore energy needs for maintenance and voluntary activity was supplied by proteins before energy for growth was satisfied. Proteins are utilized for energy when the fish diet is deficient of energy (Lovell, 1989). Dietary lipids bring a protein sparing effect, thus replacing protein to provide energy and to reduce organic matter and nitrogen losses.

An increase in dietary lipid content from 4-12% is expected to result to weight gain in tilapia (Teshima and Kanazawa, 1986). The results of this study indicate that although the 3% lipid diet generally had higher growth performance, increasing the lipid level did not produce any significant changes in growth in terms of mean weight gain (MWG), specific growth rate (SGR) and food conversion ratio (FCR). The same observation was made by Nwanna and Bolarinwa (2000), Viola and Arieli (1983) and Hanley (1991) that dietary lipid supplementation does not produce a gain in food utilization and growth in terms of Mean

Weight Gain (MWG), Specific Growth Rate (SGR), and Food conversion Ratio (FCR) of tilapia. In contrast Fitzsimmons, (1997) suggests that improved growth in fingerlings of hybrid tilapia (*O. niloticus* × blue tilapia) can be realized by an increase in dietary lipid levels between 2.5% and 10%. In general, lipid levels above 15% are of no economic benefit as they appear to affect growth (Wang et. al. 2005) produce little or no it appears that all these studies are. Protein efficiency in fish diets is influenced by the ration between dietary lipid and carbohydrate levels; therefore a balance between the two nutrients is necessary as it also affects growth and Food Conversion Ratio (FCR) (Gumus anad Ikiz, 2009).

Fat content in the viscera of fish fed on the 6% lipid diet was significantly higher than the control and 3% lipid diets; an indication that fat content in the viscera increased with higher lipid levels in the diet. These findings are consistent with those of Viola and Arieli (1983) and Hanley (1991) on the effects of varying lipid levels on body fat content in tilapia. These differ from studies by Fitzsimmons et al. (1997) who reported that increases in levels of dietary lipids did not result in increased fat in the viscera. Although there were no significant differences among different diets in fat contents of the fillets, fish fed on the 3% lipid diet had a lower fat content in the fillets that the control and 6% diets. This provides a preference basis for health conscious consumers. The moisture content of both the viscera and fillet for the treatments were not significantly different in all treatments. However, the 6% lipid level diet resulted in the highest moisture content in the viscera.

Survival was significantly higher ($p<0.05$) in fish fed 3% lipid diet than in the control and 6% lipid diet. This may be attributed to several factors; including failure to readily accept feeds due to to unpalatability (Fagberno and Davies, 2000). In this study, it was evident by the amount of food debris observed at the bottom of the aquaria holding fish fed on 6% lipid diet. As the most important characteristic of feedstuffs is the bioavailability of nutrients (Jauncey, 1993); it seems that higher lipid levels in the diet may have contributed to physiological starvation due to unpalatability of the diet; consequently resulting to lower survival. High lipid levels in diets results in increased carcass lipid levels (Ebrahimi and Ouraji, 2011) and may result in low product quality. Dietary lipid levels higher than 15% produce little practical benefit due to higher fat acceration (Wang et al. 2005; Ebrahimi and Ouraji, 2011).

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