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GROWTH PERFORMANCE, FATTY ACID PROFILE, AND LIPID COMPOSITION OF NILE TILAPIA (Oreochromis niloticus) FED DIETS WITH GRADED LEVELS OF GROUNDNUT MEAL

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Abstract

This study evaluated the impact of substituting fish meal with groundnut meal on the growth performance, fatty acid composition, and lipid profile of Oreochromis niloticus fingerlings. A total of 180 fish were randomly assigned to six dietary treatments (0%, 20%, 40%, 60%, 80%, and 100% groundnut meal), each replicated thrice over 84 days. The highest mean weight gain (8.00±1.68g) was observed at 100% replacement, while the lowest (4.19±0.89g) occurred at 40% inclusion. Protein intake was highest in the 20% group (9.67±0.08g) and lowest in the 100% group (5.85±0.05g). Sixteen fatty acids were detected, notably high levels of palmitic acid, stearic acid, oleic acid, and arachidonic acid. Saturation indices peaked at 20–40% groundnut inclusion. The control and 20% treatments recorded the highest triglycerides, whereas cholesterol was highest at 100% inclusion. Overall, diets containing 20% groundnut meal appear optimal for tilapia growth while offering a promising alternative to fish meal.

Keywords: Fatty acids, Lipid profile, Fish meal, Growth performance, Tilapia

Introduction

Aquaculture plays a major role in boosting global fish production and in meeting the rising demand for fishery products. Aquaculture production bridges the gap between the demand and supply of fish which is beginning to decline due to the overexploitation of our fisheries resources, (Khan et al, 2013). In recent years, aquaculture production has improved steadily and is the fastest growing food production sector in many areas of the world (Prabu et al, 2019). The availability of high-quality feed input determines the effectiveness, growth and development of aquaculture, this also constitutes the major production cost in commercial fish farming, (Duodu et al, 2018). In Nigeria, aquaculture has been recognized as an alternative means of increasing the domestic production of fish. Aquaculture is becoming widely practiced in Nigeria as a result of the developmental progress in most parts of the country.

Fishmeal and oil used to feed farmed fish, chicken and pigs are gotten from up to 36%

of the world's total fisheries catch each year (Ogello et al, 2014). The consumption of fish meal is steadily increasing and has become the most expensive protein source in aquaculture feeds. Aquaculture is likely to grow over the next 20 years and the increasing demand for fish meal and fish oil could place a higher fishing pressure on the already declining stocks of wild fish (Aladetohun and Sogbesan, 2013). Global fishmeal production has been stabilized to be within the range of 6 million tons to 7 million tons annually and its availability is limited. Fish meal is not only important in the diet of fish as a good source of protein, essential amino acids and adequate dietary lipid but is also a very important source of nutrient to man. Hence, coupled with the increase in fish consumption by humans, is also the increase in the use of fish materials for fish feed production, leading to a decline in its availability and also increase in the price of fish meal, (Ogello et al, 2014).

Plant protein sources have certain similarities with fish meal in terms of protein content and digestibility of protein and amino acid, (Ogello et al, 2014). Many of these plant feed resources which could be used in the production of fish feed are still poorly utilized, underdeveloped or some have not even been exploited, (Duodu et al, 2018). Groundnut is a leguminous plant that is readily available in the sub-Saharan Africa and is a valuable source of crude protein, vitamins B, E and K. According to FAO, 2000, it is the richest plant source of thiamine (B1) and is also rich in niacin, which is low in cereals. Groundnut cake with crude protein content of 40-45% is a good supplement. It promotes growth and is palatable to fish. Studies have shown that groundnut cake protein is deficient in lysine and methionine and also has a limited amount of tryptophan and threonine but amino acid quality improves in artificial diets when reinforced with lysine, methionine and tryptophan, (Davies and Ezenwa, 2010). The main aim of this study is to determine the growth performance, the fatty acid and lipid profile of Oreochromis niloticus (Nile Tilapia) by substituting fish meal with groundnut meal in their diet.

MATERIALS AND METHODS

Experimental Design

Eighteen (18) rectangular plastic tanks ($52.5 \times 33.5 \times 21$ cm^3) with a water-holding capacity of approximately 30 L were used for this study over a period of 12 weeks. Each tank was maintained under controlled aeration. Fish were acclimatized for 7 days under optimal water quality conditions: temperature ($\sim$28 °C), pH (7.5), and dissolved oxygen (DO $>$ 5 mg/L). After acclimatization, the fish were sorted by size and reweighed using a digital scale. A total of 180 fingerlings were randomly selected, weighed, and distributed into the 18 tanks representing six treatments (including the control), each replicated three times, at a stocking rate of 10 fish per tank with an average initial weight of 6.90 g per fish.

Experimental Diet

Six experimental diets were formulated, consisting of graded replacement of fish meal (FM) with groundnut cake (GNC) at 0%, 20%, 40%, 60%, 80%, and 100% inclusion levels, and designated as T1, T2, T3, T4, T5, and CO (control), respectively. Each treatment was assigned to triplicate tanks. The feed ingredients used included fish meal (FM), soybean (SB), groundnut cake (GNC), maize (M), rice bran (RB), lysine (L), methionine (M), and a vitamin–mineral premix (P). The formulated diets were pelletized, dried, and stored in well-labeled airtight plastic containers until the commencement of the feeding trial.

Growth Performance Parameters

The initial weight of the fish in each tank was taken at the beginning of the experiment and weighed weekly using a weighing scale (Salter 1073BKDR). The mean value was calculated. Growth performance and nutrient utilization of the experimental fish were determined using the following equations:

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Final Weight Gain (FWG):

$$FWG = Finalweight - Initialweight$$

Mean Weight Gain (MWG):

$$MWG = \frac{Averageweightgain}{Numberofdaysofexperiment}$$

Daily Growth Rate (DGR):

$$DGR = \frac{Weightgain}{Numberofdaysofexperiment}$$

Percentage Weight Gain (PWG):

$$PWG = \frac{F.weight - I.weight}{I.weight} \times 100$$

Feed Conversion Ratio (FCR):

$$FCR = \frac{Feedintake}{Weightgain}$$

Gross Food Conversion Efficiency (GFCE):

$$GFCE = \frac{1}{FCR}$$

Protein Intake (PI):

$$PI = Weightoffeed \times \%Proteinfed$$

Specific Growth Rate (SGR):

$$SGR = \frac{\ln(F.weight) - \ln(I.weight)}{No.ofdaysofexperiment} \times 100$$

Protein Efficiency Ratio (PER):

$$PER = \frac{Meanweightgain}{Proteinintake}$$

Fatty Acid Analysis

The fatty acid analysis was carried out as described by Osibona et al, 2009. Fatty acid methyl esters (FAMEs) were analyzed using gas chromatography (GC-FID; Agilent 6890) equipped with a DB-23 capillary column. The fats were converted to free fatty acids by saponification. The fatty acids were converted to their methyl esters and into heptane.

Lipid Analysis

The lipids were extracted from the internal organ (liver) of the fish. The lipid analysis was carried out at the Biotechnology department of the Nigerian Institute of Medical Research (NIMR), Lagos.

Statistical Analysis

The data obtained for growth performance parameters during the experiment were subjected to analysis of variance (ANOVA). Significant means between treatments were ranked using Duncan's multiple range tests. Comparison among the different treatments were carried out at the level of significance (P<0.05) among treatments and determined using the computer statistical package for social scientists (SPSS-25) windows.

RESULTS

Growth and Nutrient Utilization in the Fingerlings of Oreochromis niloticus Fed Diet Containing Graded Levels of Groundnut Meal. Table 2 shows a representation of the growth parameters and nutrient utilization of Oreochromis niloticus fed with diets containing varying levels of GNC. There was no significant difference (P¿0.05) in the control weight and final weight of all the experimental fish. The highest mean weight gain (8.00±1.68g) was recorded in fish fed with T5 (100%) diet while the lowest weight gain (4.19±0.89g) was recorded in fish fed with T2 (40%) diet.

Table 1: Nutrient composition of experimental diets

Ingredients	**CO**	**T1 (20%)**	**T2 (40%)**	**T3 (60%)**	**T4 (80%)**	**T5 (100%)**
FM	31.00	24.60	18.60	12.40	6.40	–
SB	21.00	21.00	21.00	21.00	21.00	21.00
RB	26.00	26.00	26.00	26.00	26.00	26.00
M	20.00	20.00	20.00	20.00	20.00	20.00
GNC	–	6.40	12.40	18.60	24.60	31.00
Premix	1.00	1.00	1.00	1.00	1.00	1.00
Lysine	0.50	0.50	0.50	0.50	0.50	0.50
Methionine	0.50	0.50	0.50	0.50	0.50	0.50
Total	100	100	100	100	100	100
Crude Protein (%)	32.86	31.20	28.55	25.90	23.24	20.59

Fatty Acid Analysis

The fatty acid composition as a percentage of eluted methyl esters of the five different treatments is summarized in Table 3. Among the fatty acid composition of all the treatments, those occurring in the highest proportions were myristic, palmitic, palmitoleic, stearic, oleic, linoleic, lignoceric, arachidonic, heptadecanoic, behenic.

Lipid Profile

The lipid profile which includes cholesterol, triglyceride, high density lipoprotein and low-density lipoprotein are presented in Table 4. The highest level of cholesterol was found in the 100% inclusion (T5-6.25mmol/ml). The lowest level of cholesterol was found in the 60% inclusion (T3-1.45mmol/ml). The CO (3.13mmol/ml) and T1 (2.83mmol/ml) had the highest mean of triglycerides and T2 had the lowest amount (2.02mmol/ml).

DISCUSSION

Fish feeds made from oil seeds are important sources of protein in fish diet but are considered to be low in protein content and nutritional quality compared to fishmeal. Although, some oilseeds are exceptions; legumes like groundnuts and soybeans are considered to be good substitutes for animal proteins. Data presented in table 2 depicts that fish fed with 100% inclusion (T5) was significantly higher than the control diet, it also had the highest growth performance although the 100% inclusion had the lowest crude protein (20.59) as shown in table 1. This is suggested to be due to high cholesterol level contained in the treatment as shown in table 4. It could be deduced that tilapia fed T5 diet, relied mostly on the dietary lipid as energy sources which is in agreement with Duodu et al, (2018).

From Table 3, ten different fatty acids were found to be in high occurrence among other fatty acids; myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), heptadecanoic acid (C17:0), behenic acid (C22:0), palmitoleic acid (C16:1), oleic acid (C18:1), lignoceric acid (C24:0), linoleic acid (C18:2) and arachidonic acid (C20:4). Generally, the fatty acid composition of the analysed fish is in agreement with the data available on the fatty acid composition of similar fish species as reported in the work of Osibona et al, 2009. Of the saturated fatty acids, myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0) were found to occur in high proportions in all inclusions.

The lignoceric acid (C24:0) amongst all saturated fatty acids occurred in the highest proportion in all inclusions. This is contrary to the report of Abelti, (2017) which stated that the most abundant saturated fatty acids in animal and plant tissues are straight-chain compounds with 14, 16 and 18 carbon atoms. The inclusion of groundnut in the diet could be responsible for the presence of lignoceric acid in the fatty acid composition.

The monounsaturated fatty acids (MUFA) found in all inclusions are palmitoleic acid (C16:1) and oleic acid (C18:1).

Table 2: Growth and nutrient utilization in the fingerlings of *Oreochromis niloticus* fed diet containing graded levels of groundnut meal

Parameters	CO	T1 (20%)	T2 (40%)	T3 (60%)	T4 (80%)	T5 (100%)
INW (g)	8.44±0.07^{a}	8.43±0.04^{a}	8.55±0.00^{a}	8.48±0.08^{a}	8.50±0.03^{a}	8.56±0.01^{a}
FNW (g)	14.18±1.21^{a}	13.86±1.52^{a}	12.74±0.89^{a}	14.82±0.95^{a}	12.81±0.45^{a}	16.56±1.67^{a}
MWG (g)	5.75±1.17^{a}	5.43±1.56^{a}	4.19±0.89^{a}	6.34±1.00^{a}	4.31±0.42^{a}	8.00±1.68^{a}
DGR	0.07±0.01^{a}	0.07±0.02^{a}	0.05±0.02^{a}	0.08±0.01^{a}	0.05±0.01^{a}	0.10±0.02^{a}
PWG (%)	67.94±13.60^{a}	64.58±18.78^{a}	48.99±10.36^{a}	74.82±12.02^{a}	50.64±4.82^{a}	93.50±19.69^{a}
FI (g/day)	29.14±0.32^{a}	30.98±0.26^{b}	29.78±0.24^{a}	31.94±0.49^{c}	30.40±0.41^{b}	28.42±0.25^{a}
FCR	5.57±1.26^{a}	6.75±1.89^{a}	8.05±2.23^{a}	5.38±1.09^{a}	7.21±0.80^{a}	4.01±1.10^{a}
GFCE	19.69±3.90^{ab}	17.50±5.01^{ab}	14.11±3.06^{a}	19.94±3.37^{ab}	14.19±1.48^{a}	28.26±6.09^{b}
PI	9.57±0.10^{d}	9.67±0.08^{d}	8.50±0.07^{c}	8.27±0.13^{c}	7.06±0.10^{b}	5.85±0.05^{a}
SGR (%/day)	0.61±0.10^{a}	0.58±0.13^{a}	0.47±0.09^{a}	0.66±0.09^{a}	0.49±0.04^{a}	0.77±0.13^{a}
PER	0.60±0.12^{a}	0.56±0.16^{a}	0.49±0.11^{a}	0.77±0.13^{a}	0.61±0.06^{a}	1.37±0.30^{b}

Note: All values are mean of triplicate feeding groups. Values in the same row with different superscripts are significantly different (p¡0.05). INW – initial weight, FNW – final weight, MWG – mean weight gain, DGR – daily growth rate, PWG – percentage weight gain, FI – feed intake, FCR – feed conversion ratio, GFCE – gross food conversion efficiency, PI – protein intake, SGR – specific growth rate, PER – protein efficiency ratio. CHOL – Cholesterol, TRIG – Triglycerides, HDL – High density lipoprotein, LDL – Low density lipoprotein.

Oleic acid occurred in the highest proportion of the two MUFAs present; this finding correlates with the report of Chepkirui et al. (2021). From table 3, the 40% and 20% inclusions contained the highest amount of oleic acid respectively.

Polyunsaturated fatty acids (PUFAs) are classified into two main groups depending on the position of double bond from the methyl end group of the fatty acids- omega-3 and omega-6, (Chepkirui et al, 2021). The polyunsaturated fatty acids (PUFAs) dominant in the findings from table 2 are linoleic acid (C18:2) and arachidonic acid (C20:4). Linoleic acid (C18:2) is an important omega-6 fatty acid not synthesized in human body and hence must be supplemented in the diet, (Jabeen and Chaudhry, 2011). Arachidonic acid can only be synthesized from linoleic acid. Arachidonic acid (C20:4), is an omega-6 fatty acid essential for human nutrition. It is a precursor for the production of prostaglandin and thromboxane biosynthesis. Arachidonic acid can interfere with the clotting of blood process and attach to endothelial cells during wound healing, Osibona et al. (2009).

Groundnut meal used in this experiment also contains significant levels of dietary lipids. Lipids are important for the growth and development of fish. They play important physiological roles in providing energy, essential fatty acids and fat-soluble nutrients. Fish have the ability to accumulate lipids in their body (Osibona et al, 2009). Cholesterol and triglycerides are not water soluble and for this reason, lipids must be transported in association with proteins (lipoproteins). Lipoproteins are considered to be complex particles whose formation and function can be facilitated by cholesterols and triglycerides (Feingold, 2021).

In this study, results for Low Density Lipoprotein and High-Density Lipoprotein were obtained and recorded in Table 4 above. Results from Table 4 shows that T5 had the highest amount of HDL which is 4.357mmol/ml. This is suggested to be because of the high dietary lipid in the 100% inclusion level. T2 had the highest amount of LDL which is 1.548 mmol/ml. The ratio of HDL to LDL is important because high levels of HDL and low levels of LDL are very essential to reduce the chances of coronary heart diseases (Guijarro et al, 2003). Generally, the results obtained for all treat-

Table 3: Fatty acid composition of the samples (% of eluted methyl esters)

Fatty acids (%)	CO	T1	T2	T3	T4	T5
Lauric	1.301	1.401	1.661	1.221	1.040	0.601
Stearic	1.847	1.990	2.359	1.734	1.478	0.853
Palmitic	1.666	1.794	2.127	1.563	1.332	0.768
Arachidonic	1.978	2.130	2.525	1.856	1.582	0.913
Oleic	1.835	1.976	2.343	1.722	1.468	0.847
Heptadecanoic	1.757	1.891	2.243	1.648	1.405	0.811
Linoleic	1.822	1.962	2.325	1.709	1.457	0.841
Lignoceric	2.394	2.578	3.057	2.247	1.998	1.105
Myristic	1.483	1.597	1.894	1.392	1.186	0.684
Behenic	2.212	2.382	2.825	2.076	1.770	1.021
Butyric	0.572	0.616	0.731	0.537	0.458	0.264
Valeric	0.664	0.715	0.847	0.623	0.531	0.306
Palmitoleic	1.653	1.778	2.110	1.551	1.322	0.763
Caprylic	0.941	1.013	1.201	0.883	0.753	0.434
Propionic	0.755	0.813	0.964	0.708	0.604	0.348
Acetic acid	1.399	1.507	1.787	1.313	1.119	0.646

Table 4: Lipid profile of the samples

Sample	CHOL (mmol/L)	TRIG (mmol/L)	HDL (mmol/L)	LDL (mmol/L)
CO	1.75	3.13	0.169	0.955
T1 (20%)	1.91	2.83	0.197	1.324
T2 (40%)	2.38	2.02	0.428	1.548
T3 (60%)	1.45	2.19	0.307	0.705
T4 (80%)	2.41	2.63	1.297	0.891
T5 (100%)	6.25	2.64	4.357	1.365

ments were considered to be within acceptable ranges.
Most of the fat calories are stored in triglycerides; they are the main source of fatty acids (Sutharshiny and Sivashanthini, 2011). Fatty acids are transported as triglycerides to avoid toxicity (Feingold, 2021). In table 4, T1 (20% inclusion) contained 2.83mmol/ml of triglyceride amongst other inclusions and this closer in value to Co with 3.13mmol/ml.

CONCLUSION

Findings from the results above indicate that the diet with 20% inclusion, T1 diet (20% GNC) maintained growth performance and enhanced fatty acid quality, validating GNC as a viable partial substitute for fishmeal. T1 had the best fatty acid profile and the lipid profile had no significant difference with that of the control diet.
The growth performance and utilization of feed were not compromised by the inclusion of GNC. This suggests that GNC serve as a replacement or substitute for up to 20% fish meal protein in Oreochromis niloticus diets. In other to further improve the prospects of using oil seeds like groundnut in fish diets, it is important to research safe ways of processing these ingredients to enhance their nutritional value and reduce anti-nutritional factors to reasonable values. Further research should focus on anti-nutritional factors like aflatoxins and tannins in groundnut, and how processing (e.g. fermentation, heat treatment) could enhance digestibility.

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