

GROWTH PERFORMANCE OF (*Oreochromis niloticus*) FED DIETARY SUBSTITUTION OF VARIOUS LEVELS OF FISH MEAL WITH SOYBEAN MEAL

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ABSTRACT

This study was carried out to investigate the growth and economic performance of Nile tilapia (*Oreochromis niloticus*) fed dietary substitution of various levels of fish meal with soybean meal. Fifteen plastic tanks measuring 5x5x4ft (3000L volume) were used for the study for 12 weeks. Juveniles of *O. niloticus* with mean weights of 3.40 ± 0.06 g were stocked in five treatments (T₁, T₂, T₃, T₄, and T₅). Each treatment was replicated three times. The first treatment (T₁) was fed diet with 38.46% fishmeal inclusion, the second treatment (T₂), 26.15% fishmeal and 21.69% soybean meal inclusion, the third treatment (T₃) 19.23% fishmeal and 29.23% soybean meal inclusion, the fourth treatment (T₄) 7.69% fishmeal and 38.69% soybean meal inclusion, and the fifth treatment (T₅) was fed diet with 46.15% soybean meal inclusion. The result on growth performance parameters showed that there were no significant differences in the growth of fish amongst treatments ($P > 0.05$). However, the result showed that the fish fed T₄ did better in terms of weight gain, relative weight gain, absolute growth rate, and feed conversion ratio. Economically, treatment 4 was more profitable than the other treatments with a net profit value and cost incidence of ₦4925 and ₦72 respectively. This study revealed that T₄ had the best result for Nile tilapia without negative effects on growth and economic returns.

Keywords: Fish meal, soybean meal, inclusion, growth performance, economic performance, *Oreochromis niloticus*.

INTRODUCTION

Fish farming has become a worldwide practice over the years. Aquaculture is a form of agriculture that involves the culture of aquatic organisms (aquatic plants and animals) in an enclosed environment under controlled conditions. In recent times, increase in fish production in the world outpace population growth, largely due to important advances in aquaculture production (Garlock *et al.*, 2020).

Tilapia is one of the important cultured fish species, among farmed tilapia, the Nile tilapia (*Oreochromis niloticus*) is the most cultured freshwater species and contributes about 71% of the world total tilapia production (Yakubu *et al.*, 2013). Characteristics of *Oreochromis niloticus* that makes it culturable includes its ability to tolerate to varied environmental conditions, fast growth rate, consumers acceptability because of its firm and tasty flesh.

Fish requires adequate food supply/diets in the right proportions and with proper nutritional contents needed for growth, energy, reproduction, movement, and other activities (Tunde *et al.*, 2016; Umaru *et al.*, 2016). Fish feeds are very important in fish farming and constitute about 70-95% (85% on average) of total operational costs/input which to a large extent determines the viability and

profitability of fish farming enterprise (El-Sayed, 2014).

The sources of animal protein feed ingredients, particularly fish meal, which has been employed for many years, have been found to be the most input in fish feeds (Ogello *et al.*, 2014). The high cost of feed materials especially fishmeal which has become too expensive and difficult to access by fish farmers. This has necessitated aquaculture research or search for alternatives to fishmeal, a very important animal protein ingredient (Zhang *et al.*, 2021).

Consequently, plant protein feedstuffs or ingredients with high protein content are notably used in making diets for most species of fish. It meets the high protein requirement and provides an added advantage in formulations because of its relative content of essential amino acids. The common plant protein sources are legumes and oil-bearing seeds.

This study evaluated the effect of substituting fish meal with a plant-based protein source (soybean meal) in terms of feed utilization, growth, and economic performance of Nile Tilapia (*Oreochromis niloticus*).

MATERIALS AND METHODS

Study Area

The study was carried out at the experimental fish farm of Department of Aquaculture and Fisheries Management, Faculty of Agriculture, University of Benin, Benin City, located at latitude 6°20.022'N and longitude 5°36.009'E, Ovia North-East LGA of Edo State, for a period of 12 weeks. It has a distinct rainy season and dry season with relative humidity of about 80%. The farm is located behind the forestry and wildlife arboretum.

Source of feed ingredients and Preparation of the Experimental Diets

The feed ingredients which included fish meal, soybean meal, bone meal, maize, palm oil, vitamin premix, were obtained Ekiosa market Benin City and animal feed stores in Benin City. Five test diets

with varying levels of soybean meal and fish meal were prepared. Each diet/treatment contained 30% crude protein (CP) and were each replicated three times. The feed was pelletized using a pelletizing machine. The ingredients were crushed into fine powder, except for the soybean meal, palm oil, and vitamin premix. The ingredients were mixed with different inclusion levels of fish meal and soybean meal to form supplement mixture, moistened, and pelleted using a pelleting machine. The resulting 2mm pellets size were bagged and kept in a cool dry place after drying.

Feed formulation

The experimental diet containing 30% CP was formulated using Pearson square method. The proportions of feed ingredients in the formulated diet are displayed in Table 1.

Table 1: Gross composition of feed ingredients in the formulated diet

Parameters	Inclusion levels (%)				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Fish meal	38.46	26.15	19.23	7.69	0
Soybean meal	0	21.69	29.23	38.69	46.15
Maize	55.84	55.84	55.84	55.84	55.84
Palm oil	3	3	3	3	3
Bone meal	1	1	1	1	1
Vitamin premix	0.5	0.5	0.5	0.5	0.5
Lysine	0.5	0.5	0.5	0.5	0.5
Methionine	0.5	0.5	0.5	0.5	0.5

Key: Diet 1 = 38.46% fishmeal inclusion; Diet 2 = 26.15% and 30.93% fish meal and soybean meal inclusion respectively; Diet 3 = 19.23% and 29.23% fishmeal and soybean meal inclusion respectively; Diet 4 = 7.69% and 38.69% fishmeal and soybean meal inclusion respectively; Diet 5 = 46.15% soybean meal inclusion.

Proximate analysis of diets

Proximate composition of the experimental diets was performed using the guidelines provided by AOAC (1995). The diets were examined for moisture content (MC), crude protein (CP), ether

extract (EE), crude fibre (CF), nitrogen free extracts (NFE), and ash. The proximate compositions of the formulated diets are shown in Table 2.

Table 2: Proximate compositions of formulated diets

Parameters	Inclusion levels %				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
MC	8.1	8.2	8.2	8.1	8.3
CP	30.02	32.43	31.56	28.60	27.18
EE	8.67	8.80	8.15	7.60	7.02
CF	2.32	2.37	2.36	2.21	2.10
NFE	41.29	39.10	40.83	44.16	45.91
Ash	9.60	9.10	8.90	9.33	9.49

Key: MC = Moisture content, CP = Crude protein, EE = Ether extract, CF = Crude fiber, NFE = Nitrogen Free Extracts.

Experimental Design and Layout

Five (5) treatments were included in the Complete Randomised Design (CRD) experiment: T₁ (38.46% FM), T₂ (26.15% FM and 21.69% SBM), T₃ (19.23% FM and 29.23% SBM), T₄ (7.69% FM and 38.69% SBM), and T₅ (46.15% SBM). The treatments were replicated three (3) with 60 Nile tilapia fish per replicate stocked in the individual plastic tanks. Thus, a total of 15 experimental units were used.

Experimental Fish

Nine hundred (900) mixed sex *Oreochromis niloticus* juveniles with initial mean weight of 3.40g were procured from a credible private farm

in Sapele, Delta State. The fish were acclimated and fed commercial feeds before the onset of the experiment. After the period of acclimation, the *O. niloticus* fingerlings were weighed and stocked in plastic tanks (3000L) at a stocking density of 10fishes/m².

Culture Conditions

Semi intensive system of culture was employed, the culture experiment was done for a period of 12 weeks and the fish were fed to satiation two times a day (9.00hr and 17.00hr) until harvest. Partial flushing of water, weighing of feed consumed and taking the weight of the cultured fish biweekly was done in order to evaluate the growth performance.

Growth and Feed Utilization Parameters

The following criteria were used to determine the growth performance data that was gathered:

Weight gain (g) = W₁ – W₀ (El-Sherif and El-Feky, 2009)

$$\text{Initial mean weight (g/fish)} = \frac{\text{Initial weight of fish stocked}}{\text{Number of fish stocked}} \text{ (Okonji et al., 2013).}$$

$$\text{Final mean weight (g/fish)} = \frac{\text{Final weight of fish harvested}}{\text{Number of fish harvested}} \text{ (Okonji et al., 2013).}$$

$$\text{Relative weight gain (\%)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100 \text{ (Ahmed et al., 2017)}$$

$$\text{Biweekly weight gain (g)} = \frac{\text{Total biweekly weight of fish}}{\text{Number of fish harvested}} \text{ (Okonji et al., 2013).}$$

$$\text{Absolute growth rate (g/day)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Number of days of culture}} \text{ (Endebu et al., 2016)}$$

$$\text{Specific growth rate (\%)} = \frac{\text{LnW}_1 - \text{LnW}_0}{t} \times 100 \text{ (Emmanuel et al., 2013)}$$

Feed Intake = Initial weight of feed – Final weight of feed (Sajjadi and Carter, 2004).

$$\text{Feed conversion ratio (g)} = \frac{\text{Feed intake}}{\text{Weight gain}} \text{ (Esume and Aliu, 2022).}$$

$$\text{Survival rate (\%)} = \frac{\text{Number of fish after culture}}{\text{Number of fish stocked}} \times 100 \text{ (Arunlertaree and Moolthongnoi, 2008).}$$

Where:

W₀: mean initial weight (g)

W₁: mean final weight (g)

LnW₁: logarithm of final weight gain

LnW₀: logarithm of initial weight gain

t: Number of days of culture

Economic Analysis

To determine the economic returns and profitability of the five treatments that were evaluated during the studies, economic analysis was done. The analysis was based on general farm prices in

Nigeria for harvested Nile tilapia fish and present local market prices for all other items and inputs expressed in naira at the time of the experiment. Economic performance of the five feeding strategies was estimated in terms of commercial

feed cost, cost of producing local feed, cost of fingerlings, cost of feeding, other cost of inputs (both fixed and variable cost), expenditure cost, and net profit/total revenue generated from harvest.
:

Economic performance was estimated by the following

Net profit value (₦) = Sales – Total cost (Mulyana, 2020).

Gross profit margin (%) = $\frac{\text{Net profit value}}{\text{Net sales}} \times 100$ (Nariswari and Nugraha, 2020).

Economy of weight gain (₦) = $\frac{\text{Cost of feed consumed}}{\text{Weight gain}}$ (Mensah and Attipoe, 2013).

Profit index (₦) = $\frac{\text{Net profit value}}{\text{Cost of feeding}}$ (Oké and Goosen, 2019).

Incidence of cost (₦) = $\frac{\text{Cost of feeding}}{\text{Weight gain}}$ (Ahmad *et al.*, 2019).

Statistical Analysis

Data obtained were analysed via GenStat version 12.1, 2009. The analysed data was tested for significant differences using table of Analysis of Variance (ANOVA) and mean comparison was carried out using Duncan Multiple Range Test (DMRT). All tests were carried out at 5% probability level (P < 0.05).

RESULTS

Bi-weekly weight gain

The results on the mean biweekly weight gain of *O. niloticus* fed substituted levels of fish meal with soybean meal is shown in Table 3. The results

indicated that there was significant difference in the biweekly weight gain for the treatments and time intervals (p < 0.05). T₁ had significantly higher level of weight gain followed by T₂, while T₃, T₄, and T₅ were not significantly different from one another (p > 0.05). Thus, growth rate decreased with decreasing level of fish meal in the diet. Figure 1 displays a graph of the average biweekly weight gain over the course of the trial and the result indicates that there was continuous increase in the bi-weekly weight of *O. niloticus* in all treatments throughout the experimental period (0 to week 12).

Table 3: Mean biweekly weight gain of *O. niloticus* fed dietary substitution of various levels of fish meal with soybean meal

Time (weeks)	Treatments					\bar{X} Time **
	T ₁	T ₂	T ₃	T ₄	T ₅	
Initial (0)	11.67	10.00	8.33	8.33	8.33	9.33 ^a
2	20.00	16.67	13.33	15.00	16.67	16.33 ^b
4	25.00	23.33	23.33	21.67	21.67	23.00 ^c
6	30.93	30.98	30.71	30.33	30.70	30.73 ^d
8	38.64	35.49	34.17	34.83	34.41	35.51 ^e
10	45.84	43.87	41.31	42.79	39.29	42.62 ^f
12	54.17	52.16	49.12	49.12	45.97	50.15 ^g
\bar{X} Treatments*	32.32 ^b	30.36 ^{ab}	28.61 ^a	28.90 ^a	28.15 ^a	

NB: At the 5% probability level, means with distinct alphabetic remarks differ significantly from one another.

* Comparing horizontally only.

** Comparing vertically only.

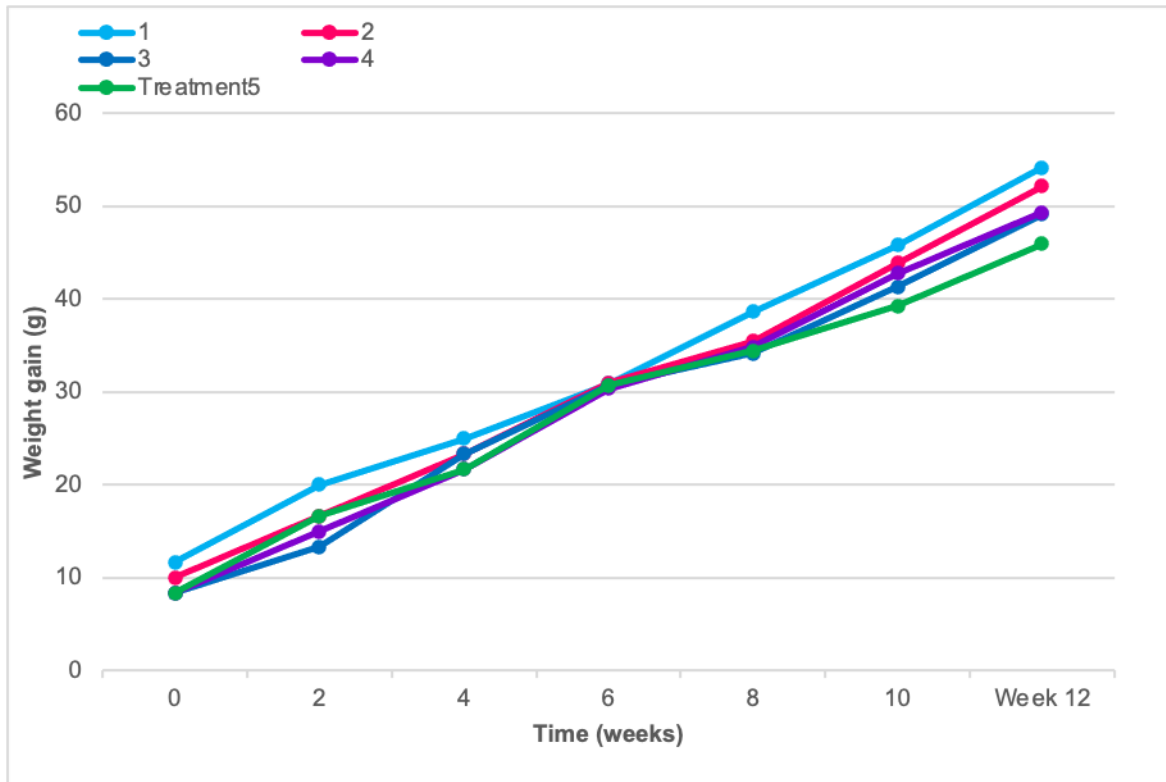


Fig 1: Mean biweekly weight gain of *Oreochromis niloticus* for various treatments over time

Growth performance, Feed Utilization and Economic Parameters

In Table 4, there were no significant differences ($p > 0.05$) in the *O. niloticus* growth performance (final weight gain, total weight gain, relative weight gain, absolute weight gain, and specific growth rate). The feed utilization result indicates

that the feed intake were significantly different ($p < 0.05$), while the feed conversion ratio were not significantly different ($p > 0.05$). The economic performance (Gross profit margin, Net profit, Incidence of cost, and Profit index) of *O. niloticus* in Table 5, showed there were no significant differences ($p > 0.05$).

Table 4: Growth performance parameters of *Oreochromis niloticus* fed dietary substitution of various levels of fish meal with soybean meal

Growth parameters	Treatments				
	T ₁	T ₂	T ₃	T ₄	T ₅
Initial mean weight (g)	3.433 ^a	3.367 ^a	3.367 ^a	3.367 ^a	3.367 ^a
Final mean weight (g)	28.04 ^a	30.06 ^a	28.00 ^a	30.25 ^a	27.07 ^a
Total weight gain (g)	24.60 ^a	26.69 ^a	24.63 ^a	26.88 ^a	23.70 ^a
Biweekly weight gain (g)	32.32 ^b	30.36 ^{ab}	28.61 ^a	28.90 ^a	28.15 ^a
Relative weight gain (%)	715.6 ^a	791.3 ^a	729.1 ^a	799.3 ^a	703.8 ^a
Absolute growth rate (g/day)	0.2733 ^a	0.2967 ^a	0.2733 ^a	0.2967 ^a	0.2633 ^a
Specific growth rate (%)	2.330 ^a	2.427 ^a	2.343 ^a	2.423 ^a	2.307 ^a
Feed intake (g)	977.8 ^d	1000.0 ^e	972.2 ^c	927.8 ^a	955.6 ^b
Feed conversion ratio (g)	0.40 ^a	0.38 ^a	0.40 ^a	0.36 ^a	0.41 ^a
Survival rate (%)	77.22 ^a	65.11 ^a	65.56 ^a	49.45 ^a	71.11 ^a

NB: At the 5% probability level, means with distinct alphabetic remarks differ significantly from one another.

Table 5: Economic performance parameters of *O. niloticus* fed diets with substitution of various levels of fish meal with soybean meal

Economic parameters	Treatments				
	T ₁	T ₂	T ₃	T ₄	T ₅
Economy of weight gain (₦)	41.24 ^a	39.07 ^a	41.58 ^a	38.79 ^a	43.02 ^a
Gross profit margin (%)	26.39 ^a	31.23 ^a	25.70 ^a	30.36 ^a	23.50 ^a
Net profit value (₦)	3818 ^a	4830 ^a	3798 ^a	4925 ^a	3335 ^a
Incidence of cost (₦)	80.64 ^a	76.13 ^a	80.85 ^a	71.97 ^a	82.21 ^a
Profit index (₦)	1.953 ^a	2.913 ^a	1.953 ^a	2.657 ^a	1.747 ^a

NB: At the 5% probability level, means with distinct alphabetic remarks differ significantly from one another.

T₁ (38.46% FM), T₂ (26.15% FM and 21.69% SBM), T₃ (19.23% FM and 29.23% SBM), T₄ (7.69% FM and 38.69% SBM), and T₅ (46.15% SBM).

DISCUSSION

Growth Performance

The bi-weekly weight gain increased with increasing inclusion levels of fish meal and this could be as a result of the presence of key amino acids (methionine) content in fish meal required by fish species for their growth (Wang *et al.*, 2017). A graphical illustration of the mean bi-weekly weight gain illustrates the different levels of mean weight of *O. niloticus* for 12 weeks. The trend indicates continuous increase in bi-weekly weight in all treatments throughout the experimental period (0 to 12 weeks). The variation in weight increase among the different treatments could be due to the inclusion levels of fish meal and soybean meal in the diet.

In terms of total weight gain, relative weight gain, absolute growth rate, and specific growth rate, fish fed diet containing soybean meal with no inclusion level of fish meal – (T₅) 46.15% SBM attained the least weight. This could be attributed to deficiencies in key amino acids especially methionine required by fish for their growth and limiting in soybean, thus reducing the growth rate of fish (Wang *et al.*, 2017). However, this is in line with Lin and Luo, (2011) experiment on *Oreochromis niloticus* × *O. aureus* where fish fed the diet with 100% protein from SBM had lower relative weight gain ratio (RWGR), specific growth rate (SGR) and protein efficiency ratio (PER) than the other groups. A similar experiment conducted by Mahmoud *et al.* (2014) on *Oreochromis niloticus* revealed that growth retardation was observed in diets which soybean meal totally replaced fish meal. Jahan *et al.* (2019) determined that high levels of replacement of FM by SBM leads to lower growth rate in silver barb

(*Barbonymus gonionotus*). Furuya *et al.* (2004) found that fishmeal could be totally replaced with plant protein sources without any adverse effect on the growth of tilapia. Furthermore, Liti *et al.* (2006) found that if diets had a suboptimal protein level of 24%, SBM could completely replace fishmeal without any negative impacts on Nile Tilapia growth. However, this is in contrary to the result obtained from this study as soybean meal could not replace fish meal beyond 30% without adverse effects on the fish growth. This present study observed that (T₂), as well as (T₄) inclusion levels gained more weight than other treatments.

The study recorded high rates of survival, however, treatment 4 recorded the lowest survival rate (49.45%). Evidently, this is associated with the disease incidence during the period of experiment. Thus, mortality could be associated with episodes of disease outbreaks during the culture period, as well as suffering prior to death (Ellis *et al.*, 2012).

Feed utilization

Treatment 4 and Treatment 2 recorded better feed conversion ratio indicating better utilization of fish feed which reflected in the fish growth, hence, minimizing feed wastage (Githukia, *et al.*, 2015). However, the higher feed conversion ratio (FCR) observed in the rest of the treatments could be as a result of the inability of the juveniles to digest and absorb nutrients efficiently (Liti *et al.*, 2006). Low feed efficiency can be caused by low or poor feed intake, low levels of energy and phosphorus, high levels of ANFs like trypsin inhibitor, which affects protein digestibility, and lectins which change the shape of the intestine and reduce absorption of nutrients (Ogello *et al.*, 2014). Thus, from this

study, fish meal replacement affected feed intake and made protein digestibility difficult in the fish. This also agrees with Eriagha and Ekokotu, (2017) who stated that substitution of fish meal with other proteins of plant origin and the addition of certain antibiotics have resulted in the reduction of palatability of fish feed.

Economic Performance

The profitability estimates and production costs were based on farm prices of *Oreochromis niloticus* juveniles, feed, and labor. Fish fed diets containing 38.66% soybean meal recorded the highest weight gain in relation to the cost of feed consumed (₦43.02). The highest gross profit margins (GM) expressed in percentage was recorded in treatment 2 (31.23%). The study revealed a positive Net Profit Values (NPV) among all five treatments with treatment 4 having the highest returns (₦4925) in terms of sales and total cost. The incidence of cost (r) result showed that farmers will spend less (₦71.97) to produce 1 kg of fish which is not up to the amount a kg of tilapia fish is sold (₦800). That is, value above one is profit, below 1 is loss (Okonji *et al.*, 2013), and value equal to 1 is known as the “break-even point”. Thus, the break-even point (BEP) is a situation wherein an enterprise achieves zero profitability of production, meaning the revenues received for goods are equal to the total costs of production (Horváth *et al.*, 2017; Syrůček *et al.*, 2022). Therefore, the Cost Incidence and Net Profit Value of treatment 4 agrees with Suzan, (2020) that an increase or decrease in net profit can be influenced by an increase or decrease in costs of production. The profit index (PI) reveals that fish which fed on diet with 7.73% fish meal and 30.93% soybean meal inclusions had the highest profit value to the production cost (₦2.913). Fish fed diets completely replaced by soybean meal had the lowest profit index (₦1.747).

CONCLUSION

Conclusively, this present study observed that (T2), as well as (T4) inclusion levels gained more weight than other treatments.

It is a clear indication from this study that soybean meal cannot completely replace (substitute) fish meal in diets for Nile tilapia without negative effects on growth and production, as a hundred percent fish meal replacement by soybean meal reduces the growth of fish and reduces feed utilization. It was ascertained that decreasing inclusion levels of fish meal with soybean meal in

the diets led to a decrease in the growth rate of fish. However, T4 had the best result for Nile tilapia without negative effects on growth and economic returns.

Recommendations

Based on the findings during this study, the following recommendations are made:

1. This study has established that soybean meal can partially replace fish meal in the diets of *Oreochromis niloticus*. Therefore, T4 is recommended without adverse effects on the growth performance of fish.
2. Also, soybean meal can be used to substitute up to 30% fish meal in the diets of *O. niloticus* without affecting the cost of production and profitability (revenue) of the farming business

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