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Cost Benefits and Growth Promoting Ability of Dietary Bambara Nut (*Vigna subterranean*) Powder on the Rearing of Catfish (*Clarias gariepinus*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The efficacy of dietary Bambara nut (*Vigna subterranean)* in the growth performance and cost benefit of *Clarias gariepinus* culture was evaluated. To this end 35% CP diet was formulated using locally available ingredients. Five different diets were prepared from the 35% CP diet, replacing Soybean with Bambara nuts at different percentage as follows: T_1 (0% BN: 100 SB), T_2 (25% BN: 75% SB) T_3 (50% BN: 50% SB), T_4 (75% BN: 25% SB) and T_5 (100% BN: 0% SB), and organoleptic assessment was conducted on the diets to determine texture, aroma and color, while chemical assessment was conducted to determine the nutritional qualities of the diets. One hundred and fifty (150) sub-adult *Clarias gariepinus* were distributed into five (5) groups in triplicates of ten (10) using

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fifteen aquaria, and were fed T_1 – T_5, for eight (8) weeks. Length and weight of fish were evaluated fortnightly to determine: weight gain, percentage weight gain, specific growth rate, performance index and condition factor. And the cost of feed and fish were determined to evaluate the cost benefits of the various diets. At the end of the feeding trials, data were collected and analysed using ANOVA followed by a Turkey multi-companism test with SPSS 170 package software and the following results were obtained: (1) the experimental diets T_1-T_5 had no effects on the physico-chemical properties of the experimental waters (2) the aroma of the experimental diets were less fishy, their texture ranges from fibrous to less fibrous and the colour from dark brown to light brown as the quantity of the Bambara nut in the diets increases (T_1-T_5). (3) The % lipid, % proteins and % fibre decreased as the quantity of Bambara nut increased in the experimental diets (T_1-T_5). (4) All the growth parameters and performance index increased significantly ($P<0.05$) as the quantity of Bambara nuts increased in the various diets (T_1-T_5):- Weight gain (WG): T_1 (54.61±2.11), T_2 (70.96±8.47), T_3 (67.82±0.63), T_4 (70.90±5.90) and T_5 (77.35±3.81), Percentage weight gain (PWG): T_1 (30.76±0.77), T_2 (40.66±1.46), T_3 (35.64±1.64), T_4 (37.46±1.13) and T_5 (44.84±10.30); Condition factor (CF): T_1 (0.55±0.13), T_2 (0.62±1.02), T_3 (0.70±0.41), T_4 (0.64±11.4) and T_5 (0.64±4.30); Specific growth rate (SGR): T_1 (0.34±0.02), T_2 (0.43±0.05), T_3 (0.42±0.01), T_4 (0.43±0.02) and T_5 (0.49±0.02); Performance index (PI): T_1 (158.99±2.76), T_2 (208.99±25.84), T_3 (210.98±2.28), T_4 (203.85±11.87) and T_5 (213.13±4.30). The fish fed the Bambara nut diets (T_2-T_5) had enhanced net profit, profit index and benefit cost ratio, but lower economic weight gain. Bambara nut is unarguably a better feed ingredient than Soybean in the culture of *Clarias gariepinus.*

Keywords: Clarias gariepinus; Bambara nut; growth performance; cost benefits.

1. INTRODUCTION

Aquaculture is the rearing of aquatic organism such as plants, fish, mollucks etc in a conducive and controlled or semi-controlled environment using simple techniques (Ugwumba & Okoh, 2010; Ukwe & Deekae, 2022). Fish and fisheries products are most reliable source of protein especially in the underdeveloped and developing countries such as Nigeria. The demand for fish and fish products is increasing each passing year as a result of increase in population, and this has led to the decline in the wild as a result of overfishing, and environmental pollution (Otene & Ukwe, 2018), with the environmental pollution affecting fish flesh quality (Ukwe, Otene, & Wayas, 2018). There is therefore, the need to produce fish outside it's natural environmental to meet up the market demand for fish and fish products.

The most cultured fish species in Africa are Nile tilapia (*Oreochronus niloticus),* common carp (*Cyprinus carpio)* and African catfish (*Clarias gariepinus),* but the wide range of feeding and it's ability to convert varieties of by products to flesh with minimal or no mortality makes the catfish best choice for culture outside it's environment (Anoop et al., 2009; Emokaro, Ekunwe, & Achille, 2010).

Fish feed at the right proportions and adequate nutritional contents is needed for fish to grow, reproduce and carry out other activities (Oluwashina & Solomon, 2012). The quality of feed depends on the ingredients used in formulating the feed. Some of the factors to consider when selecting feed ingredients includes the nutritional requirements of the fish; life stage of the fish; anti-nutritional content of the feed ingredient; availability of the ingredient; processing methods; benefit and cost of ingredients; taste etc. Considering these factors will reduce cost and enhance flexibility when making choice of feed ingredients to use in formulating feed.

The cost of feed and feed ingredients, and the quality of the feed determine to a great extend the success of a aquaculture (Afia & David, 2017; Ukwe, 2018). At every stage of the fish culture, feeding account for over 60% of the cost (Fagbenro et al., 2005). Low cost but good quality and local ingredients will reduce the cost of feed and enhance productivity in acquaculture. The need for farmers to produced local feeds to promote production is inevitable, since restrictions on importation and devaluation of our currency have contributed to high price of imported feeds.

The most expensive component of the fish feed is protein and fishmeal and Soybean are the major source of protein in feed formulation for fish. While the fish meal is regarded as animal protein, Soybean is the most used plant protein in fish feeds (Pratiwy & Triyani, 2022), but the cost is increasing in every passing day because of its use as food by human and other farmed animals. The use of other plant protein could be a favourable alternative in the production of cheap and readily available fish feed that will enhances fish production.

Barbara nut (*V. subterranea)* is rich in carbonhydrate, protein, fat, fibre and minerals (Azman et al., 2019), and these minerals are essential in feed formulation (Amarteifio, Tibe, & Njogu, 2006). This research is titled towards replacing Bambara nut with Soybean in the formulation of diets that will enhance growth and productivity in the production of farmed fish such as *C. gariepinus.*

2. MATERIALS AND METHODS

2.1 Location of Experiment

The experiment was conducted in the fish farm of the Department of Fisheries and Aquatic Environment, Rivers State University, Nigeria.

2.2 Fish Acclimatization

The fish was acclimatized for two weeks and observed for disease presence, within the two weeks, the fish was fed with commercial feed to satiation twice a day, and the water qualities were monitored accordingly.

2.3 Bambara Nut (*Vigna Subterranea)* Powder

Bambara nut (*Vigna subterranea)* was procured at the popular Bori Camp Market in Rumuokoro along East West Road in Obio/Akpor Local Government Area of Rivers State, Nigeria. It was grounded into powered form using locally fabricated grounding machine.

2.4 Experimental Diets

35% crude protein feed was formulated using local ingredient (Table 1). Five different diets were prepared from the formulated feed using various inclusion levels of Bambara nuts powder as follows: T_1 (100%SB); T_2 (25% SB: 75BN); T_3 (50% SB:50%BN); T_4 (75%SB:25%BN) and T_5 (100%BN).

2.5 Experimental Design and Feeding Trials

A total of 150 sub-adult *Clarias gariepinus* were divided into five groups (T_1 – T_5), thirty fish per group in triplicates. They were distributed to 15 aquaria of 50 – liter volume (10 fish/aquarium). The fish were acclimatized in the aquaria for two weeks and fed to satiation with commercial feed. After the acclimatization, the fish were fed with the experimental diets (T_1-T_5) accordingly for eight (8) weeks. Complete water replacement was once a day. Temperature and pH were determined daily, and other water parameters were monitored twice a week. Measurement of growth parameters was one done fortnightly.

2.6 Determination of Physico-Chemical Parameters of the Experimental Water

Temperature and pH were monitored daily before and after changing the experimental waters using mercury-in-glass thermometer and pocket pen pH meter respectively. Dissolved oxygen (DO), Conductivity and Total dissolve solids (TDS) were determined twice weekly using ammonia test kit.

Table 1. Composition of feed ingredients

Diets Ingredients	T1	T2	T3	T4	T5
Fish meal	31.87	31.87	31.87	31.87	31.87
Soya bean	15.93	11.95	7.97	3.98	-
Groundnut cake	15.93	15.93	15.93	15.93	15.93
Corn	15.64	15.64	15.64	15.64	15.64
Wheat bran	15.64	15.64	15.64	15.64	15.64
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Palm oil	0.5	0.5	0.5	0.5	0.5
Vitamin C	0.5	0.5	0.5	0.5	0.5
Premix	1.0	1.0	1.0	1.0	1.0
Starch	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	31.87	31.87
Bambara nut (*V. subterrenea)*	-	3.98	7.97	11.95	15.93

2.7 Determination of Growth Parameters

Weight and length of fish were determined using a weighting balance and meter rule calibrated in centimeters (CM) respectively and other parameters were determined using the methods in (Ukwe, Amachree, & Jamabo, 2019; Micheal, Sogbesan, & Onyia, 2023 and Mohanty, 2009). The growth parameters were determined as follows:

- **Weight gain (WG)**

WG(g) = $W_2 - W_1$

Where W_2 = Final weight

W_1 = Initial Weight

- **Specific Growth Rate (SGR)**

$$\frac{Log\,W_2\;Log\,W_1}{t}$$

Where t= Period in days

- **Length Increase (LI)**

LI(cm) = L_2-L_1
Where = L_2 = Final length
= L_1 = Initial length

- **Feed intake (FI)** = Quantity of feed consumed within a given period

- **Survival Rate** = $\frac{No.of\ Survival\ fish}{Initial\ fish\ stock} x100$

- **Percentage Weight Gain (PWG)**

PWG = $\frac{W_2 - W_1}{t} x100$

- **Performance Index (PI)**

PI = $\frac{\%\ Survival\ \ x W_2\,(g)\ W_1(g)}{t(days)}$

2.8 Condition Factor (K)

K = $\frac{W\ x\ 100}{L^3}$

Where W = Weight (g)

L = Length (cm)

2.9 Organoleptic Assessment of the Experimental Diets

The was conducted using the methods in (Efrizal, Indra, & Lubis, 2021).

2.10 Chemical Assessment of Experimental Diets

This was conducted using the methods in (Antia, Assian, & Akpan, 2021).

2.11 Cost Benefit of Diets

The economic analysis of producing *Clarias gariepinus* using the experimental diets (T_1-T_5) was assessed to determine the cost benefits of the diets. Using the cost of diets and experimental fish, the cost benefits were determined using the methods of (Afia & David, 2017; Oratiwy & Triyani, 2022) as follows:

- **Economic Weight Gain (EWG)**

EWG = $\frac{Cost\ of\ \ feed}{Weight\ gain(G)}$

- **Profit Index (PI)**

PI = $\frac{Weight\ of\ \ fish}{Cost\ of\ \ feed}$

- **Incidents Cost (IC)**

IC = $\frac{Cost\ of\ \ feed}{Weight\ of\ \ fish\ produced}$

- **Net profit (NP)**

NP = Sales - Expenditure

- Benefit Cost Ration (BCR)

- BCR = $\frac{Total\ Sales}{Total\ Expenditure}$

- **Total Cost (TC)**

TC = Fixed Cost (FC) –Total Variable Cost (TVC)

Where FC = Cost of Fish

TVC = Cost of producing different diets.

2.12 Data Analysis

The data analysis were express as means for each of the variables. The statistical significance ($P<0.05$) of the determined variables were tested using one – way ANOVA followed by a Turkey multi-comparism text with SPSS 170 package software.

3. RESULTS

3.1 Physico-chemical Parameter of the Experimental Waters

The results for the physico-chemical parameters of the experimental waters are shown in Table 2. The dissolve oxygen (DO) was similar across the experimental tanks, but lower in T_4 (4.90±1.10) and higher in T_1 (5.26±0.06). The values for the temperature and pH were similar across the experimental tanks (25.67±0.58 - 29.13±0.15) and (5.23±0.18 - 5.93±0.16) respectively. The values for conductivity were significantly lower in T_1 and T4 (265.33±92.80 and 278.67±22.47 respectively) and significantly higher in T_2 (308.33±14.57), T_5 (318.00±51.15) and T_3 (326.33±19.04). The values for TDS were similar in T_1 (83.00±12.7) and T_2 (92.33±11.06), but were significantly higher in T_3 (102.33±5.03), T_4 (100.38±31.64) and T_5 (104.67±22.22).

3.2 Proximate Composition of Feed Ingredients

The result in the proximate composition of the feed ingredients is shown in Table 3. The values for the moisture content are similar across the ingredients. The Ash was significantly lower on Bambara nut (3.74±0.21), followed by Soybean and groundnut cake (5.74±1.63 and 5.37±0.75) respectively and higher in fish meal (15.71±2.52). The %crude protein was significantly lower in Bambara and (15.62±0.089), followed by Soybean (39.35±0.58) and groundnut cake (34.94±0.83), while fish meal was significantly higher (54.63±0.59). Lipid was significantly lower in Bambara and (6.14±0.27) and fishmeal (8.09±2.04), followed by Soybean (27.49±2.09), while Groundnut cake was the highest (44.36±10.49).

3.3 Organoleptic Assessment of the Experimental Diets

The results for the organoleptic assessment of the experimental diets are shown in Table 4. Diets T_1 – T_3 were fibrous, while diets T_4 and T_5 were less fibrous. The fishy smell reduces in the diets T_1 – T_5 as quantity of Bambara nut increases. The color of the diets losses brown colouration in diets T_1 – T_5 as the quantity of Soybean reduces in the diets.

Table 2. Physicochemical parameters of water in the tanks during the experimental period (Mean ±SD)

Treatments	Parameters				
	DO (mg/L)	Temperature (^{0}C)	pH	Conductivity (μ/cm)	TDS(ppm)
T_1	5.26±0.06^a	25.67±0.58^a	5.93±0.16^a	265.33±92.80^a	83.00±12.17^a
T_2	5.20±0.10^a	28.53±0.15^a	5.43±0.11^a	308.33±14.57^b	92.33±11.06^a
T_3	5.07±0.15^a	28.77±0.32^a	5.45±0.18^a	326.33±19.04^b	102.33±5.03^b
T_4	4.90±0.10^a	28.97±0.23^a	5.73±0.06^a	278.67±22.47^a	100.38±31.64^b
T_5	5.07±0.21^a	29.13±0.15^a	5.23±0.18^a	318.00±51.15^b	104.67±22.72^b

Means within the same column with different superscripts are significantly different (P<0.05)

Table 3. Proximate Composition of Feed Ingredients (Mean ±SD)

Feed Ingredients	Proximate Parameters (%)			
	Moisture	Ash	Crude Protein	Lipid
Fishmeal	9.90±1.45^a	15.71±2.52^c	54.63±0.59^c	8.09±2.04^a
Soybean	8.91±0.75^a	5.74±1.63^b	39.35±0.58^b	27.49±2.09^b
Groundnut Cake	7.30±0.70^a	5.37±0.75^b	34.94±0.83^b	44.36±10.49^c
Bambaranut Meal	7.11±0.72^a	3.74±0.21^a	15.62±0.89^a	6.14±0.27^a

Means within the same column with different superscripts are significantly different (P<0.05)

3.4 Chemical Assessment of the Experimental Diets

The results of the chemical assessment of the experimental diets are shown in Table 5 the moisture content was the same across experimental diets. The Ash content was similar across the diets as follows: T_1 (12.86±1.49), T_2 (12.88±1.00), T_3 (12.48±0.47), T_4 (14.21±0.79) and T_5 (14.00±0.21). The percentage protein reduces as the quantity of Soybean reduces in the diets, it was significantly lower in T_4 (28.75±1.10) and T_5 (26.31±1.30) followed by T_3 (30.47±0.85) and significantly higher in T_2 (32.27±1.79) and T_1 (35.15±0.22). The lipid content were significantly lower in T_4 (10.13±0.24) and T_5 (10.99±0.12) and significantly higher in T_3 (11.11±0.01), T_2 (12.35±0.19) and T_1 (12.69±0.20). The fibre contents were lower in T_3 – T5 (9.29±0.91, 6.43±1.17 and 8.98±1.24 respectively). The carbohydrate content were significantly lower in T_1 (19.15±0.28), T_2 (20.52±1.13), followed by T_3 (24.41±0.95), but significantly higher in T_4 (26.74±1.17), and T_5 (29.81±1.23).

3.5 Growth Parameters in *C. gariepinus* fed Experimental Diets for Eight Weeks

The results for the growth parameters are shown in Table 6. There was increase in weight gain in the fish fed Bambara nut compared to the fish fed the diet without Bambara nut (T_1). The values were significantly lower in fish fed T_1 (54.61±2.11), followed by T_3 (67.38±0.63), and significantly higher in T_4 (70.90±5.90) and T_2 (70.96±8.47) T_5 (77.35±3.31). The values for the length increase reduces as the quantity of Soybean in the diet reduces, it was significantly lower in T_4 (3.89±1.21) and similar in T_3 (4.16±0.21), T_5 (4.23±3.11), T_2 (4.29±0.03) and T_1 (4.59±0.62). The values for the percentage weight gain was significantly higher in fish fed T_2 (40.66±1.46), the values were similar in the other treatments, but it was lower in the fish fed T_1 (30.76±0.77). The values for the survival rate were significantly higher in fish fed T_1 (100±0.00), T_2 (96.67±5.77), T_3 (95.00±5.00) and T_4 (91.67±2.89), but significantly lower in fish fed T_5 (87.50±3.53). The values for the specific growth rate was significantly lower in fish fed T_1 (0.34±0.02) and similar in fish fed T_2 – T_5 (0.43±0.05 - 0.49±0.02) respectively). The values for the feed intake increased with increase the quantity of Bambara nut in the diet, the value was significantly lower in T_1 (89.46±2.03), followed by T_2 (94.98±4.43), but were significantly higher in T_5 (100.87±1.87), T_4 (101.48±5.61) and T_3 (101.54±2.99). The values for the performance index shows that the growth performance was significantly lower in the fish fed T_1 (158.99±2.79), but significantly higher and similar in fish fed T_2 – T_5 (208.99±25.84 - 213.13±4.30).

3.6 Cost Benefit of Dietary Bambara Nut on *C. gariepinus*

The cost benefit of the dietary Bambara nut on *C. gariepinus* is Tables 7 and 8. The net profit was significantly lower in fish fed T_1 (302.98±8.02),

Table 4. Organoleptic Assessment of the Experimental Diets

Parameters	Experimental Diets				
	T_1	T_2	T_3	T_4	T_5
Texture	Fibrous	Fibrous	Fibrous	Less Fibrous	Less Fibrous
Aroma	Fishy Smell	Fishy Smell	Less Fishy Smell	Lesser Fishy Smell	Fish Smell almost absent
Color	Deep Brown	Deep Brown	Brown	Light Brown	Lighter Brown

Table 5. Chemical Assessment of the Experimental Diets

Treatments	Experimental Diets				
	T_1	T_2	T_3	T_4	T_5
% Moisture	11.30±0.42^a	11.12±0.30^a	11.46±0.82^a	11.49±0.60^a	11.65±0.39^a
% Ash	12.86±1.49^a	12.88±1.00^a	12.48±0.47^a	14.21±0.79^a	14.00±0.21^a
% Protein	35.15±0.22^c	32.27±1.79^b	30.47±0.85^b	28.75±1.10^a	26.31±1.30^a
% Lipid	13.69±0.29^b	13.35±0.19^b	11.11±0.01^b	10.13±0.24^a	10.99±0.12^a
% Fiber	13.01±3.14^b	10.98±0.92^b	9.29±0.91^a	6.43±1.17^a	8.98±1.24^a
% Carbohydrate	19.15±0.28^a	20.52±1.13^a	22.41±0.95^b	25.74±1.17^c	25.81±1.23^c

Means within the same column with different superscripts are significantly different (P<0.05)

Table 6. Growth Parameters in *C.gariepinus* fed with Dietary Bambara nuts for Eight Weeks (Mean ± SE)

Treatments	Initial Weight (g)	Final Weight (g)	Weight Gain (g)	Initial Length (cm)	Final Length (cm)	Length Increase	Percentage Weight Gain (%)	Condition Factor (CF)	Feed Intake (FI)	PI	Survival (%)	Specific Growth Rate
T_1	177.50±2.50^{a}	232.10±4.70^{a}	54.61±2.11^{a}	29.83±0.32^{a}	34.74±0.19^{a}	4.59±0.62^{b}	30.76±0.77^{a}	0.55±0.13^{a}	89.46±2.03^{a}	158.99±2.76^{a}	100.00±0.00^{b}	0.34±0.02^{a}
T_2	174.50±4.50^{a}	245.50±12.12^{a}	70.96±8.47^{b}	30.16±0.11^{b}	34.05±1.46^{a}	4.29±0.03^{b}	40.66±1.46^{b}	0.62±1.02^{a}	94.98±4.43^{b}	208.99±25.84^{b}	96.67±5.77^{a}	0.43±0.05^{b}
T_3	189.00±10.00^{a}	256.40±10.60^{b}	67.38±0.63^{c}	30.34±0.13^{b}	33.20±0.45^{a}	4.16±0.21^{b}	35.64±1.64^{a}	0.70±0.41^{a}	101.54±2.99^{c}	210.92±2.28^{b}	95.00±5.00^{a}	0.42±0.01^{b}
T_4	189.00±10.00^{b}	259.90±6.31^{b}	70.90±5.90^{b}	30.67±0.32^{b}	34.46±0.33^{a}	3.89±1.21^{a}	37.46±1.13^{a}	0.64±11.4^{a}	101.48±5.61^{a}	208.85±11.87^{b}	91.67±2.89^{a}	0.43±0.02^{b}
T_5	172.50±2.50^{a}	251.22±3.46^{b}	77.35±3.81^{c}	29.95±6.00^{a}	44.84±0.47^{a}	4.23±3.11^{b}	39.61±10.30^{a}	0.64±4.30^{a}	100.87±1.82^{c}	213.13±4.30^{b}	87.50±3.53^{a}	0.49±0.02^{b}

Means within the same column with different superscripts are significantly different (P<0.05)

Table 7. Economic Analysis of the Experimental Diets (Mean ±SD)

Parameters	Experimental Diets				
	T_1	T_2	T_3	T_4	T_5
Cost of Fish (₦)	115.00±0.00^{a}	115.00±0.00^{a}	115.00±0.00^{a}	115.00±0.00^{a}	115.00±0.00^{a}
Cost of Feed/Kg (₦)	560.60±0.00^{b}	553.97±0.00^{b}	547.35±0.00^{a}	540.72±0.00^{a}	534.11±0.00^{a}
Mean Feed Intake (g)	89.46±2.04^{a}	94.98±4.44^{b}	101.55±2.99^{b}	101.49±5.62^{c}	100.88±1.88^{c}
Feeding Cost (₦)	50.72±1.59^{a}	52.61±2.46^{a}	55.58±1.64^{b}	56.87±3.04^{b}	53.87±1.00^{a}
Total Cost (₦)	165.01±0.98^{a}	167.61±2.46^{a}	170.58±1.64^{a}	169.87±3.04^{a}	168.87±1.00^{a}
Cost of Fish/Kg (₦)	1800.00±0.00^{a}	1800.00±0.00^{a}	1800.00±0.00^{a}	1800.00±0.00^{a}	1800.00±0.00^{a}
Total Sales (₦)	468.00±9.00^{b}	488.70±20.70^{b}	494.64±14.04^{c}	506.55±12.41^{b}	500.05±3.97^{d}
Net Profit (₦)	302.98±8.02^{a}	321.09±18.24^{b}	324.06±12.41^{b}	336.80±34.40^{c}	331.18±2.98^{c}

Means within the same row with different superscripts are significantly different (P<0.05)

Table 8. Economic Indices and Cost Benefit Ratio of the Experimental Diets (Mean ±SD)

Parameters	Experimental Diets				
	T_1	T_2	T_3	T_4	T_5
Economic Weight Gain (g)	0.90±0.01^{a}	0.84±0.05^{a}	0.82±0.02^{a}	0.77±0.02^{a}	0.69±0.09^{2a}
Profit Index (₦)	4.10±0.99^{a}	4.63±0.01^{a}	4.61±0.06^{a}	4.73±0.03^{a}	4.60±0.12^{a}
Incident Cost (₦)	0.215±0.001^{a}	0.214±0.001^{a}	0.216±0.002^{a}	0.211±0.001^{a}	0.234±0.036^{a}
Benefit Cost Ratio	2.83±0.04^{a}	2.91±0.08^{a}	2.80±0.06^{a}	2.97±0.17^{a}	2.96±0.06^{a}

Means within the same row with different superscripts are significantly different (P<0.05) but similar in fish fed T_1 – T_5, with the highest net profit in T_4 (336.80±34.40), (Table 7). The economic weight gain was similar across the diets but lower in T_5 (0.69±0.09) and higher in T_1 (0.90±0.01), the profit index and the incident cost were similar across the diets and the benefit cost ratio was similar across the diets, but increase slightly with increase in Bambara nut inclusion in the diet (Table 8).

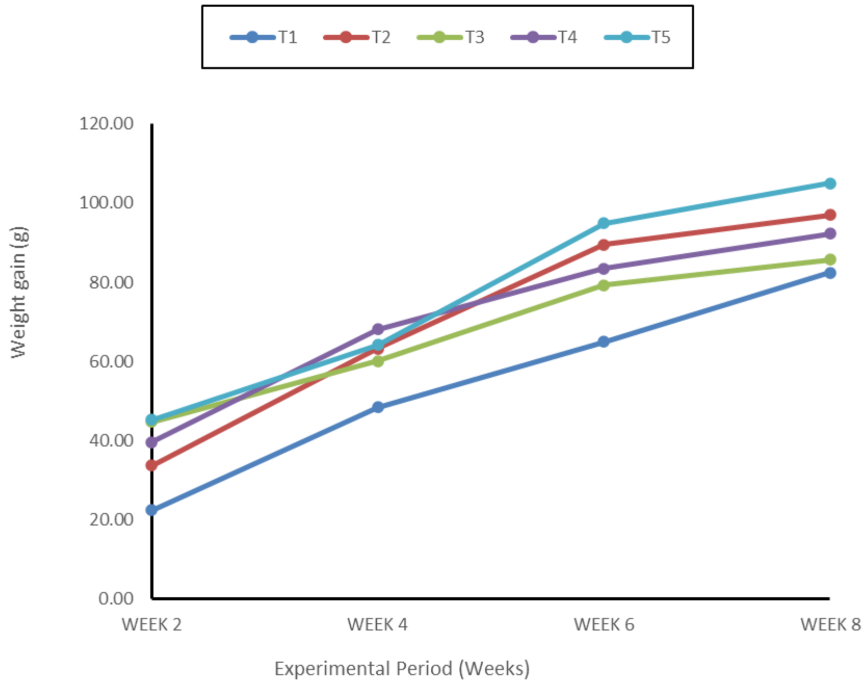

Fig. 1. Comparative values of Weight gain in *C. gariepinus* fed dietary Bambara nuts for eight weeks

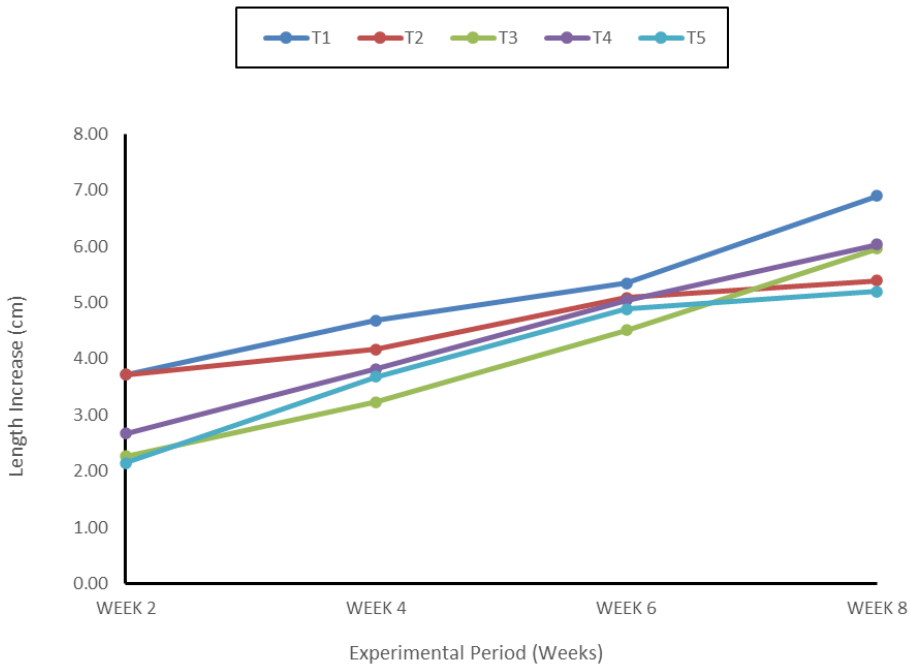

Fig. 2. Comparative values of Length Increase in *C. gariepinus* fed with dietary Bambara nuts for eight weeks

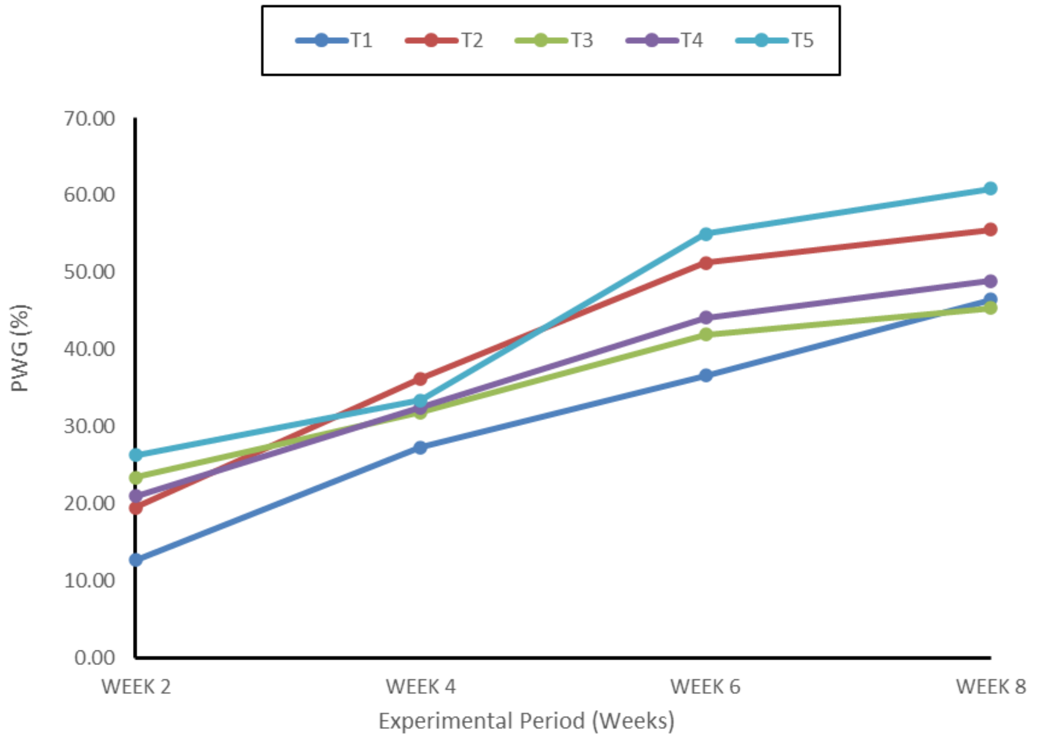

Fig. 3. Comparative values of Percentage Weight Gain (PWG) in *C. gariepinus* fed with dietary Bambara nuts for eight weeks

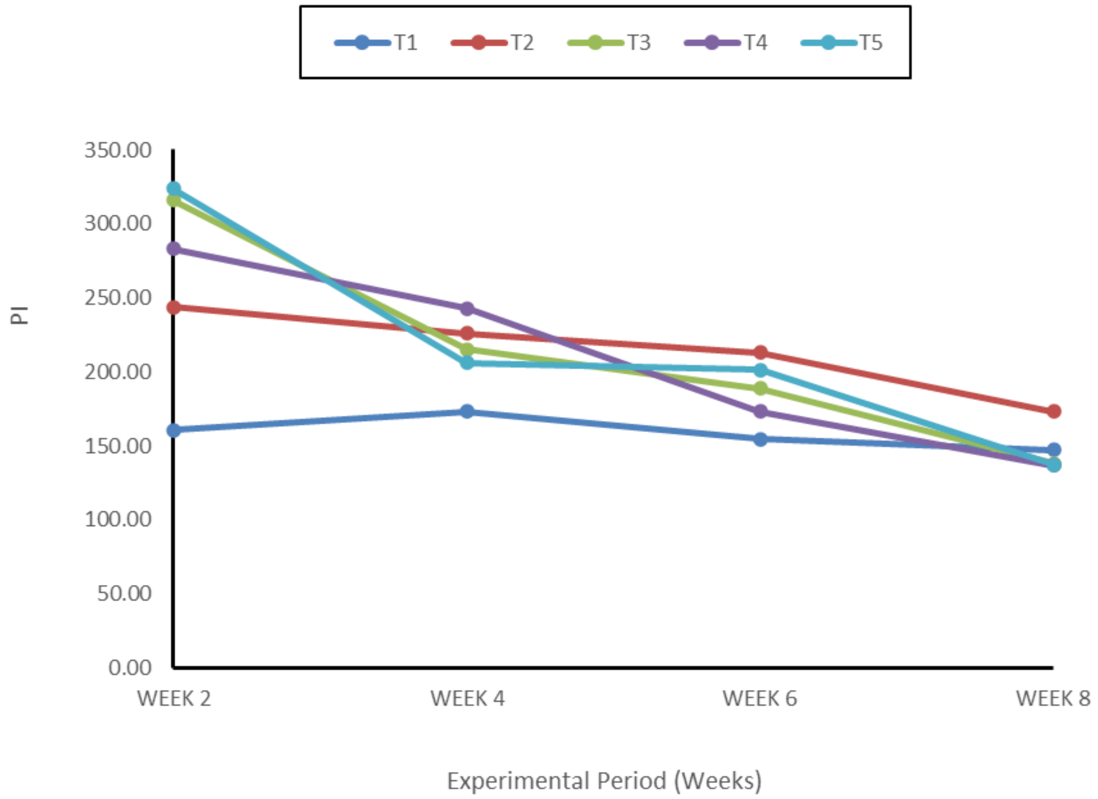

Fig. 4. Comparative values of PI in *C. gariepinus* fed with dietary Bambara nuts for eight weeks

3.7 Comparative Values in the Growth Parameters of *C. gariepinus* Fed Dietary Bambara Nuts

The results of the weight gain within the eight weeks feeding trials are shown in Fig. 1. The results revealed that the fish fed T1 (0% BN) maintained a steady growth rate from weeks two to eight of the experiment, while the fish fed T_2-T_5 (Bambara nut diets) maintain a steady growth rate up to the week six, and had a reduced growth rate from week six to eight. The comparative results for length increase are shown in Fig. 2. The fish fed, the various experimental diets (T_1 – T_5) had a stead length increase from week two to week eight. Comparatively, the percentage weight gain had similar trend with the weight gain (Fig. 3). The performance index (PI) was reducing across the diets from week two to week eight of the feeding trials (Fig. 4).

4. DISCUSSION

4.1 Physico-chemical Parameters of the Experimental Waters

The quality of water in the culture environment promotes or retard the growth and survival of the culture organism (Sogbesan et al., 2004). Mbagwu (Ukwe & Abu, 2016) and Ukwe (Mbagwu, Keke, & Okorie, 2020) agreeded that physico-chemical parameters such as dissolve oxygen, pH, temperature, conductivity and total dissolve solid (TDS) affects fish growth. The results of the water qualities such as temperature, dissolve oxygen and pH observed in this work are within the values accepted for proper growth and productivity in aquaculture (Sogbesan et al., 2004; Ukwe & Deekae, 2024; Stone & Thornforde, 2015). This is an indication that the experimental diets did not affect these parameters. Conductivity and total dissolve solid (TDS) in water is caused by the presence of minerals and inorganic matters in the water (Momoh & Solomon, 2007). The conductivity and total dissolve solid (TDS) in this work increases in T_2-T_5 compared to T_1, this could be as a result of the minerals and inorganic matters contained in the Bambara nut diets, arising from the processes involved in the production. It could also be as a result of low water stability of the experimental diets (T_2-T_5) (Momoh & Solomon, 2007), arising from the granularity of the feed ingredients (Fondriest Environment Inc., 2019).

4.2 Organoleptic Assessment of the Experimental Diets

Feed is an essential component of aquaculture, and acceptability of the feed is crucial to the growth and survival of the culture organism. The quality and quantity of the ingredients used in formulating fish feed determines the effectiveness of the feed to improve fish performance and the feed effectiveness can be evaluated when the feed is accepted by the fish. Aroma and colour are two major feed qualities that influences acceptability (Johnson & Johnston, 2007; Efrizal et al., 2019). The two feed ingredients that differentiates the organoleptic and nutritive value of the various experimental diets ((T_1-T_5) in this research work are Bambara nut (*V. subterrenea*) and Soybean. The texture of the feed was less fibrous as the content of Bambara nut increases in the feed, this is because of the less fibre content of Bambara nut compared to Soybean (Amelia, Zakaria, & Efrizal, 2021). One of the ingredient that enhances aroma in fish feed is the fishmeal. Haryono (Okafor & Umeh, 2021) reported that reduction in fishy aroma in feed reduces feed intake by fish. The experimental diets (T_1-T_5) reduces in fishy aroma as the quantities of Bambara nut increases in the diets. This is suggestive to the fact that inclusion of Bambara nut in the diets eliminates the fishy smell of the diet faster than the soybean. The result of the organoleptic assessment also shows that the experimental diet (T_1) is deep brown in colour, and the brown coloration of the feed becomes lighter as the inclusion of Bambara nut increases (T_3-T_5). Verma (Haryono et al., 2015) reported that brown coloration in diets depicts high protein level as a result of the interaction between amino acids and lipid oxidation products. The content of lipid in Soybean is over 80% higher than the content of lipid in Bambara nut in this research work (Table 2). This was also reported by Okafor (Amelia, Zakaria, & Efrizal, 2021). The deep Brown coloration in diets T_1 and T_2 could be as a result of the high soybean content, which promotes reactions between the lipid oxidation products and the amino acids in the diets. The brown coloration in the diets T_3-T_5 reduced as a result of the reduced lipid content in the diets due to the reduction in Soybean content in the diets.

4.3 Chemical Assessment of the Experimental Diets

The quantity of protein in the diets ranges from 26.31 ± 1.30 – 35.15 ± 0.22, and it decreases with increase in Bambara nut inclusion (T_1-T_5). Eyo (Verma, Singh, & Yadav, 2019) recommended 35-42% crude protein (CP) feed for fish, while Aliu (Eyo & Olatunde, 2001) observed that 25-30% CP feed is appropriate for the culture of catfish. Oluyinka (Aliu & Olomu, 2020) stated that increase in the protein content of the feed has a positive effect on the growth of the fish, while Vasquez-Torres (Oluyinka, Ajani, & Richards, 2015) reported that feed with required protein content increases the economy of fish production and safe guard the environment. Ukwe (Vasquez-Torres, Pereira-Filha, & Arias-Castellanos, 2011) observed that not only quantity, but the quality of protein in the feed determines the growth rate of the fish. Carbohydrate is a readily available source of energy for fish (Ukwe, Edun, & Akinrotinu, 2018). Craig (NRC, 1993) reported that 20% of carbohydrate is required for the production of catfish feed, but Robinson (Craig & Helfrich, 2002) stated that there is no exact quantity of carbohydrate required in the diet of catfish, because they can synthesize energy from lipids and proteins. The quantity of carbohydrate in the diets (T_1-T_5) ranges from 19.15$\pm$0.28 – 29.81$\pm$1.23 and it increases with increase in Bambara nut inclusions, and this could be the reason for the improve texture of diets T_3 - T_5 (Ukwe, Edun, & Akinrotinu, 2018). There was no significant difference in the moisture content of the diets T_1-T_5 and they were within the acceptable range in aquaculture (Ukwe, Amachree, & Jamabo, 2019). Inappropriate water content in feed will lead to feed damage, encourage disease presence and reduce the feed shelf life (Robinson & Li, 2015; Simon, 2019). Ash content in feeds depicts the quantity of minerals in the feed (Ruscoe et al., 2005). Though there was no significant difference in the ash content in T_1-T_5, the values of T_4 and T_5 were higher. This is indicative of the fact that there may be more minerals in Bambara nut than Soybean, since they are the only determining variables in the various fish diets (T_1 – T_5). The lipid contents in the experimental diets (T_1-T_5) were within the acceptable range in aquaculture, but the significantly higher fat in T_1 – T_3 could be as a result of the high Soybean content in these diets. Fat is a source of essential fatty acids and dissolves fat – soluble micronutrients. The fat requirements in fish depends among other things the growth stage and the aquatic environment (Powell et al., 2017; Quentero et al., 2011). Fibre plays a crucial role in the growth of fish especially in the healthy performance of digestive tract and nutrient absorption (Haryono et al., 2015; Okafor & Umeh, 2021). Excess fibre in fish diet (> 10) will retard fish growth as a result of decrease in digestion and nutrient absorption, and enhanced water pollution (Johnson & Johnston, 2007). (Amarteifio, Tibe, & Njogu, 2006) also reported that increase in fibre retards fish growth, due to low feed intake. The fibre contents in the experimental diets were >10 in T_1 and T_2, but <10 in T_3 – T_5.

4.4 Growth Parameters and Performance Index of the Experimental Fish

The quality of a feed is determined by the product of all the interactions among the various ingredients that makes up the feed. In a view to attain cheap and quality feed for the enhancement of aquaculture and other meat productions, Bambara nuts (*V. subterrancea*) as plant protein source have been used to replace animal protein such as fish meal in feed formulation, and the results have been encouraging (Adewumi & Odeyemi, 2018; Oso et al., 2013; Nana et al., 2019). This study investigated the replacement of Soybean, a plant protein source with Bambara nut in the formulation of feed for *Clarias gariepinus.* The results revealed that diets with Bambara nuts inclusion (T_2-T_5) performed better in all the assessed growth parameters such as; weight gain, length increase, percentage weight gain, specific weight gain, condition factor and performance index, apart from the survival rate (Table 5). The improvement of the above growth parameters in the fish fed T_2-T_5 compared to the fish fed T_1 (control) could be as a result of one or more of the following:

- The Bambara nuts enhanced palatability of the feed, thereby increasing feed intake (Amarteifio, Tibe, & Njogu, 2006; Oso et al., 2013; Nana et al., 2019);
- Since Soybean and Bambara nut were the determining variables in the experimental diets, the improve growth parameters in T_2-T_5 could be that the presence of Bambara nuts in the diet enhanced bioavailability of nutrients compared to the presence of Soybean (Adewumi & Odeyemi, 2018).
- Bambara nut influences the production of digestive enzymes more than soybean, thereby facilitating nutrient absorption.
- The increase in the fibre content in T_1 (control feed) with 100% soybean (Table 4) may have negatively affected the rate of feed intake and absorption (Johnson & Johnston, 2007; Forbes, 2011);

- It could also be as a result of the increase lipid content of T_1 (100% SB) which can reduce the digestibility of the feed, by interfering with the actions of the digestive enzymes and lowering the absorption rate of other nutrients, forming complex molecules with them. This argument is supported by Fan (Parada & Aguilera, 2007) who reported reduction in growth parameters when dietary lipid levels were increased in the diet of common carp (*cypronus carpio),* and Amadou (Fan et al., 2021) who reported significant reduction in growth parameters when Nile Pearch (*L. niloticus)* juveniles were fed dietary lipid above eleven percent (11%).

The result of this research is a confirmation of the report of (45,46) who stated that Bambara nut is a good protein source for the formulation of feed for *C. gariepinus.* At the end of eight (8) weeks feeding, the feed intake was significantly higher ($P<0.05$) in fish fed T_2 – T_5, with less fishy smell, this could be that the diets T_2 – T_5 with Bambara nut inclusion were more palatable than T_1 0% BN: 100% SB. This is contrary to the report of (30) who stated that high growth performance of *C. gariepinus* could be traceable to the fishy smell of feed. The result of this research in Tables 4 and 5 depicts that the fishy smell of a diet/feed could attract a fish to the diet, but palatability determines the quantity of feed consumed by the fish, hence the improve performance in the fish fed T_2-T_5 compared to fish fed T_1. The growth rates with regards to weight gain, percentage weight gain, length increase were increasing in T_2-T_5 till the end of week six, but there were slight reduction in growth rate of these parameters at the end of week eight (Figs. 1-3). This is probably due to the fact that the efficacy of the experimental diets (T_2-T_5) reduced with prolong feeding period, and this can be attributed to the method of storage or temperature of the storing facility.

4.5 Cost Benefit of the Experimental Diets

The purpose of every aquaculturist is to make profit, and feed constitute the major expenses in the business of aquaculture. The two feed ingredients that determined the results in this research are Soybean and Bambara nut. The replacement of Soybean with Bambara nut as feed ingredient for the production of *C. gariepinus* was investigated*.* This research is necessitated by the fact that Bambara nut is cheaper than Soybean and readily available in this part of the world. The cost of the fish and all other ingredients in the experimental diets were the same, the determining factors in the economy and cost benefit of the various diets were Soybean and Bambara nut (Tables 7 and 8). The cost of producing one kilogram (1kg) of feed reduces as the level of Bambara nut inclusion increases in the experimental diets (T_1-T_5) with the highest cost recorded in T_1 (0%BN) and the least cost recorded in T_5 (100% BN). But the feeding cost was higher in fish fed (T_2 – T_5), this is as a result of the high feed intake record in fish fed T_2-T_5. This depicts the fact that feed intake affects the cost of feeding in aquaculture. The total cost of production was similar across the various treatment (T_1-T_5), but increases slightly as the Bambara nut inclusion in the diets increases, due to high feed intakes. But the total sales/kg was significantly higher in the fish fed T_4 and T_5, this can be traced to the increase in weight gain since fish is sold per weight (kilogram). The net profit which is the difference between the total sales and the total cost of production was significantly higher in the fish fed T_2-T_5, and increases with increase in Bambara nut inclusion in the diets. Benefit cost ratio (BCR) of one or greater than one (≥ 1) indicates profit break even, while the one less than one indicates loss (Amadou, 2014). The BCR across the fish fed T_1-T_5 were above one with fish fed T_4 and T_5 recording the highest values. This connotes the fact that all the experimental diets T_1-T_5 yielded profit. The higher values of BCR, profit index, Net profit, and the lower values recorded in Economic Weight Gain (EWG) in fish fed T_2-T_5 depicts the fact that the fish fed Bambara nut inclusion diets yielded more profit compared to the control diet T_1(0%BN) (Oratiwy & Triyani, 2022; Mustapha et al., 2014; Olagunju, Adesinyun, & Ezekiel, 2007).

5. CONCLUSION

The results of this research work shows that Bambara nut which is lower in cost and protein content is a better replacement for Soybean in the production of *C. gariepinus* fish feed, since it enhances fish growth and profitability. The result revealed fact that the quantity of protein in the feed alone does not determine the performance of feed in terms of fish growth and profitability, but other factors such as: quality of protein, interaction among the feed ingredients, bioavailability of the nutrients, stimulation of digestive enzymes, feed lipid content among others greatly determines the efficacy of fish feed. Palatability of feed determines to great extent the quantity of feed consumed by the fish.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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