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Growth performance and feed utilization of C*larias gariepinus* fingerlings fed diets with different levels of orange fleshed *Ipomea batatas* peel

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Abstract
The current exorbitant prices of conventional energy feedstuffs for fish diet due to its global scarcity and fierce competition between human and animals calls for concerted efforts in finding alternative, cheap and sustainable aquaculture feed. This study was conducted for 16 weeks to assess the effect of the inclusion of orange fleshed sweet potato peels in the diets of Clarias gariepinus fingerlings. The experimental set up consisted of 6 treatments (0%, 20%, 40%, 60%, 80%, 100% inclusion) and 3 replicates each, making up 18 tanks. Each tank was stocked with 10 fish to determine the effect of dietary inclusion on both growth and feed utilization of fingerling. Fish were fed twice daily at 5% body weight, and water quality was monitored using standard procedures. Results showed significant reduction in growth performance (p<0.05) with increased in the percentage of orange fleshed Ipomoea batatas peel meal inclusion. The control diet had the greatest mean final weight (120.58 ± 0.07 g) and weight gain (117.91 ± 0.80 g), while the diet with 100% peel meal inclusion (D6) had the lowest growth parameters (final weight: 95.31 ± 2.40 g, weight gain: 92.25 ± 0.28 g). While growth and feed consumption were reduced, treatments did not differ significantly (p>0.05) with respect to protein efficiency ratio (PER) and feed conversion ratio (FCR). Survival across all treatment groups was high (96.67%-100%), which attests to the safety of the diets. The results indicate that although the incorporation of orange fleshed Ipomoea batatas peel meal can lower growth performance, it is a cost-effective substitute for traditional feed materials, which presents a sustainable aquaculture solution, particularly where sweet potatoes are extensively grown. The reduction in growth could be due to the high carbohydrate content and the anti-nutritional factors in the peels.

Keywords: *Orange fleshed Ipomea batatas peel, Clarias gariepinus, fingerlings, Growth, and feed utilization.*

Introduction and Literature Review

With the world's population continuing to increase, expected to reach about 10 billion in 2050 (United Nations, 2017), the challenge of ensuring global food security has become more daunting. The United Nations Food and Agriculture Organization (FAO) approximates that it will take higher production of animal proteins, specifically fish, to eradicate hunger and attain food security by the year 2030 (FAO, 2022). Fish is a source of high-quality protein, essential fatty acids, and bioavailable micronutrients and constitutes part of the world's diet for millions of individuals. More than 3.3 billion humans depend on fish for more than 20% of their total animal protein source, especially in developing nations (Neumann et al., 2014). Aquaculture has proven to be an alternative that can fill the increasing need for fish. Nevertheless, increased demand for fish in developing nations, especially sub-Saharan Africa, is generally restricted by the cost of feed. The price of commercial fish feed, which makes up 60-70% of the aquaculture total cost of production (Igoche et al., 2019), is a major problem to small farmers. Hence, there has been increased interest in looking for local, alternative, and cheaper sources of feed ingredients, which save on the production cost but assure maximum growth performance.One of such choices is orange-fleshed orange fleshed *Ipomea batatas* peels, which are a waste product from sweet potato processing. They have a high concentration of carbohydrates, dietary fiber, and other nutrients, and they are also readily accessible in the majority of regions on the planet. orange fleshed *Ipomea batatas,* also has other nutritional benefits as it is highly endowed with provitamin A carotenoids, which make it of great significance to human and animal nutrition (Oshoke et al., 2019). Nonetheless, the potential for using orange fleshed *Ipomea batatas* peels to substitute traditional feed components like maize and soybean meal in fish feed has not yet been widely studied. This study will assess growth and feed performance of *Clarias gariepinus* fingerlings fed various amounts of orange fleshed *Ipomea batatas* peel meal. Aquaculture sustainability highly depends on having alternative feed sources that are affordable and nutritionally sufficient. A number of plant ingredients, such as cassava, yam, and sweet potato, have previously been suggested as possible sources of energy and nutrients in fish feed (Omoregie et al., 2009). Of these, sweet potatoes, especially the orange fleshed sweet potato, have been considered because of their nutrient composition, such as carotenoids like β-carotene, which are important in fish health and growth (Oshoke et al., 2019). Sweet potato peels, otherwise a waste product, are rich in fiber and carbohydrates that fish can use as energy. Like in the majority of plant feed, though, sweet potato peels also have anti-nutritional factors such as phytates and saponins that will impede nutrient absorption and adversely affect fish growth (Francis et al., 1999). However, past research has proven that the effects of such anti-nutritional substances can be minimized by using appropriate processing techniques, including drying and grinding, thereby making sweet potato peels a good feedstuff (Ajiboye et al., 2019).

In *Clarias gariepinus*, an important aquaculture fish in Africa, diets were demonstrated to replace fish and animal protein with plant constituents without sacrifice in performance if appropriate formulations and inclusion rates are employed (Gabriel et al., 2007). Little has been documented on supplementation of orange fleshed *Ipomea batatas* peels into the diet of *C. gariepinus*. The study endeavors to bridge the gap by considering the impact of different inclusion levels of orange fleshed *Ipomea batatas* peel meal in *C. gariepinus* fingerling feeding, intake and growth.

Materials and Methods

Preparation of orange fleshed (*Ipomea batatas*) peels meal

Fresh orange fleshed *Ipomea batatas* were collected from local farmers. The peels were washed, sun-dried for two weeks, and then milled into fine powder using a hammer mill. The powdered peels were sieved to remove coarse particles, and a fine uniform powder was produced. The dry orange fleshed *Ipomea batatas* peel powder was subsequently incorporated into experimental diets at varying inclusion levels.

Formulation of Experimental Diets

Six exerimental diets were formulated using fish meal, orange fleshed *Ipomea batatas* peel meal, soybean cake, maize, cassava flour, palm oil, blood meal, mineral and vitamin mix, and chromic oxide (for digestibility analysis). The diets included different levels of orange fleshed *Ipomea batatas* peel meal: 0%, 20%, 40%, 60%, 80%, and 100%. These diets were prepared by thoroughly mixing the ingredients in a stainless-steel pot and pelleting the mixture using a meat mincer (Omoregie et al., 2009). The pellets were made with a diameter of 2mm to suit the size of the fingerlings.

Experimental Design

Eighteen 20-liter plastic tanks were used in a completely randomized design, with three tanks per diet treatment. Each tank contained ten fish. The fish were fed their respective diets at 5% of their body weight, twice a day. Growth performance (mean final weight and mean weight gain) and feed utilization (feed intake) were measured bi-weekly. Water quality factors such as temperature, pH, dissolved oxygen, and ammonia were checked from time to time, and excess feed and feces were removed daily for water quality maintenance.

Feeding and Management

Fish were fed twice a day at 5% of body weight for 16 weeks. Feeding was regulated weekly on the basis of average body weight of fish. Water quality factors such as temperature, pH, dissolved oxygen, and ammonia were checked from time to time, and excess feed and feces were removed daily for water quality maintenance.

Growth and Feed Utilization Assessment

After the end of the feeding trial, fish growth performance was assessed on the basis of the following parameters:

Growth Indices

A. Percentage Weight gain

$$\text{Weight Gain (g)} = \frac{\text{Initial weight (g)}}{\text{Initial weight (g)}} \times 100 \quad \text{........... Equation 1}$$

(Ahmad, 2012).

Specific Growth Rate (SGR)

This the percentage increase in body weight per day over any given time interval. The Specific Growth Rate (SGR) was calculated using the formula below:

$$SGR = \frac{\text{Loge } w2 - \text{Loge } w1}{T2 - T1} X100 \quad \text{................. Equation 2}$$

Where,

W2= Final weight of fish at time T_2

W_1- Initial weight of fish at time T_1

e= Base of natural logarithm

(Samuel, Ayanwale & Mohammad, 2021).

Survival rate (SR%) = 100 x (fish No. at the end÷ fish No. stocked at the beginning) Equation 3

Food Utilization Parameters

Food conversion ratio (FCR)

This is a measure of the quantity of feed required for a unit weight gained by the fish. Thus, the higher the FCR value the better the feed.

$$FCR = \frac{\text{Weight of food consumed (g)}}{\text{Weight gain by the fish}} \quad \text{.............................. Equation 4}$$

Where:

Feed intake (FI) (g) = <u>5% Body weight × Experimental period</u>

Number of fish stocked …………………. Equation 5
(Afe & Omosowone, 2019).

B. Protein efficiency ratio (PER)

$$PER = \frac{\text{Live weight gain (g)}}{\text{Protein fed (g)}} \quad \text{……………………………. Equation 6}$$

Where,

$$\textbf{Protein fed (g)} = \frac{\text{Protein (\%) in feed x Total weight (g) of diet consumed}}{100} \quad \text{Equation 7}$$

Apparent Net Protein Utilization (ANPU)

This indicates the efficiency of transforming the dietary protein into tissue protein by the fish. It was calculated thus:

$$ANPU (\%) = \frac{\text{Final carcass protein–Initial Carcass Protein}}{\text{Protein Fed}} \text{ X 100……… Equation 8}$$

Survival was also confirmed at the end othe trial. Analysis was carried out by one-way ANOVA, and Tukey's post-hoc test was used to make multiple comparisons.

Results

Differences were drastic ($p<0.05$) in growth performance among diets. Control diet (D1), without orange fleshed *Ipomea batatas* peel meal, recorded the highest mean final weight (120.58 ± 0.07 g) and mean weight gain (117.91 ± 0.80 g). Yet, as the inclusion level of orange fleshed *Ipomea batatas* peel meal increased, fish growth performance was reduced, and the lowest growth parameter values were recorded for D6 (100% orange fleshed *Ipomea batatas* peel diet) (final weight mean: 95.31 ± 2.40 g, mean weight gain: 92.25 ± 0.28 g). Highest consumption of feed occurred under the control diet (271.43 ± 2.14 g) and declined when the percentage content of orange fleshed *Ipomea batatas* peel meal rose. Lowest feed consumption was at 197.19 ± 11.33 g for 100% orange fleshed *Ipomea batatas* peel meal. There were no differences between the treatments regarding feed conversion ratio (FCR) or protein efficiency ratio (PER), hence the fish must have digested the feeds equally well despite having differences in growth. Survival in all the treatments was good and varied from 96.67% to 100%, and was not significantly different among the groups, determining that the diets were safe for the fish.

Table 1: Mean Growth Performance and Feed Utilization Indices of *Clarias gariepinus* Fingerlings Fed Diets with Varying Levels of Orange Fleshed (Ipomea batatas) Peels Meal

Treatments Indices	D1	D2	D3	D4	D5	D6	p-value
Mean Initial Weight (g)	2.67±0.00	2.67±0.00	2.66±0.01	2.67±0.01	2.66±0.01	2.66±0.01	1.000
Mean Final Weight (g)	120.58±0.07^{a}	114.43±0.43^{b}	111.65±0.19^{b}	100.06±1.88^{c}	96.98±2.45^{d}	95.31±2.40^{e}	0.000
Mean Weight Gain (g)	117.91±0.80a	111.76±0.36^{b}	108.98±0.19^{c}	97.39±1.88^{d}	94.32±2.40^{e}	92.25±0.28^{f}	0.000
Mean Feed Intake (g)	271.43±2.14^{a}	256.53±0.43^{b}	251.34±2.20^{c}	224.99±4.15^{d}	208.87±1.95^{e}	197.19±11.33^{f}	0.000
SGR (%/day)	1.38±0.005^{a}	1.36±0.005^{b}	1.35±0.005^{c}	1.31±0.005^{d}	1.30±0.01^{e}	1.26±0.005^{f}	0.997
Feed Conversion Ratio	2.30±0.01^{a}	2.30±0.01^{a}	2.31±0.02^{b}	2.31±0.00^{b}	2.21±0.08^{c}	2.13±0.01^{d}	1.000
Protein Efficiency Ratio	1.11±0.01^{c}	0.78±0.48^{e}	1.12±0.00^{b}	1.11±0.00^{c}	1.14±0.04^{a}	1.10±0.01^{d}	0.476
ANPU (%)	0.02±0.005	0.02±0.005	0.02±0.005	0.02±0.005	0.02±0.005	0.02±0.005	0.956
Survival (%)	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	96.67±4.71^{b}	96.67±4.71^{b}	0.571

Means within a column and effect that lack common superscripts differ significantly (Tukey's multiple comparison test, $P \leq 0.05$).

Legend:
SGR= Specific Growth Rate
ANPU=Apparent Net Protein Utilization

Cost and Benefit Analysis of Experimental Diet with Varying Level of Orange Fleshed Sweet Potato Peels Meal Fed to *Clarias gariepinus* Fingerlings

The cost of feed per kg of feed ranged from ₦1, 240 in D6(100%), to ₦1, 970 in D1(0%), with D1(0%) having the highest and D6(100%), the lowest (Table 14). The total input cost ranged from ₦6,040 in D6(100%) to ₦6,770 in D1(0%), with D1(0%) having the highest and D 6(100%) the lowest. Furthermore, the net profit ranged from ₦18,230 in D1(0%) to ₦18,960 in D6 (100%), with D6(100%) having the highest and D1(0%) having the lowest and the incidence cost ranged from 16.71 in D1(0%) to 14.30 in D6(100%), with D1 having the highest and D6(100%), having the lowest. In addition, the profit index ranged from 12.69 in D1(0%) to 20.16 in D6(100%), with D6(100%) having the highest and D1 the lowest.

Table2: Cost and Benefit Analysis of Experimental Diet with Varying Levels of Orange Fleshed Sweet Potato Peels Meal Fed to *Clarias gariepinus* Fingerlings

Parameters	Diets	D1	D2	D3	D4	D5	D6
Weight Gain (g)		117.91	111.76	108.98	97.39	92.66	86.63
Cost of Feed (₦)		1970	1740	1640	1470	1340	1240
Cost of Fingerlings (₦)		1300	1300	1300	1300	1300	1300
Cost of Water (₦)		2000	2000	2000	2000	2000	2000
Cost of Feeding (₦)		1500	1500	1500	1500	1500	1500
Total Input Cost (₦)		6770	6540	6440	6270	6140	6040
Number of Fingerlings		10	10	10	10	10	10
Unit price of Fish/Kg		2500	2500	2500	2500	2500	2500
Total value of Fish (₦)		25000	25000	25000	25000	25000	25000
Net Profit (₦)		18230	18460	18560	18730	18860	18960
Incidence Cost (₦)		16.71	15.57	15.05	15.09	14.46	14.30
Profit Index		12.69	14.37	15.24	17.01	18.66	20.16
Benefit Cost Ratio		0.27	0.26	0.26	0.25	0.25	0.24

Mean Water Quality Parameters of the Experimental Tanks for *Clarias gariepinus* Juveniles Fed Diets with Varying Levels of Orange Fleshed Sweet Potato Peels Meal

The mean water quality parameters of the experimental tanks for juveniles revealed that, there were no significant differences ($p>0.05$) for all the parameters monitored between the control (D1) and the treatment groups except Dissolved oxygen. However, the temperature ranged from 25.09±0.31 to 25.22±0.05 with highest value in D4 and the lowest in D2. The dissolved oxygen ranged from 5.14±0.05 to 5.26±0.03 with D1 having the highest and D5 the lowest. The pH ranged from 6.21±0.03 to 6.24±0.02 with D3 having the highest and D5 the lowest. Free carbondioxide ranged from 7.18±0.07 to 7.23±0.04 with D1 having the highest while D4 with the lowest value.

Alkalinity ranged from 117.24±0.07 to 117.39±0.07 with D2 having the highest and D6 with the lowest (Table 3).

Table3: Water quality parameters of experimental tanks for fingerlings of *clarias gariepinus* fed diets with varying levels of orange fleshed sweet potato peels

Treatments Parameters	D1	D2	D3	D4	D5	D6	p-value
Temperature (ºC)	25.54±0.58[a]	25.22±0.26[a]	25.31±0.08[a]	25.22±0.05[a]	25.21±0.08[a]	25.29±0.40[a]	0.791
DO (mg/L)	5.36±0.07[a]	5.28±0.12[a]	5.31±0.01[a]	5.24±0.06[a]	5.28±0.05[a]	5.32±0.08[a]	0.541
pH	6.25±0.05[a]	6.23±0.04[a]	6.24±0.02[a]	6.10±0.11[a]	6.11±0.19[a]	6.27±0.20[a]	0.37
Carbondioxide (mg/L)	7.68±0.07[a]	7.55±0.18[a]	7.68±0.19[a]	7.57±0.13[a]	7.53±0.15[a]	7.48±0.11[a]	0.986
Alkalinity (mg/L)	126.05±0.31[a]	127.55±0.18[a]	127.13±0.24[a]	127.52±0.08[a]	127.24±0.36[a]	126.14±0.26[a]	0.247

Discussion

Growth and feed utilization performance

In this study, growth rate and feed utilation declined as inclusion level of orange fleshed sweet potato peel meal was enhanced. The lowered growth may be due to elevated carbohydrate content in the diets that were supplemented with higher sweet potato peel. This is in agreement with previous research studies (Omoregie et al., 2009; Olukunle, 2006; Oshoke, Gulbee & Adeniyi, 2019), which demonstrated reduced growth performance in *C. gariepinus* fingerlings as the percentage of sweet potato peel meal were increasing. Similarly, the same trend of substituting soya bean with watermelon bark as an alternative ingredient in African catfish diet has been documented by Samuel et al. (2022). Furthermore, Ajiboye et al. (2019) reported decreased performance when the diet of *C. gariepinus* was incorporated with increased levels of dried pig feces which was attributed to the high microbial content and phytochemicals in the diet.

However, Abdurrazzaq et al. (2022) reported improved weight and feed conversion of *C. gariepinus* fingerlings fed on sweet potato peel meal supplemented with increasing inclusion rates of 0%, 25%, 50%, 75%, and 100%. Similar improved growth performance by *Oreochromis niloticus* on diet supplemented with sweet potato hot-water extract were reported by Baleta et al. (2022). Such conflicting results could be due to variation in the variety, processing type, condition, and trial duration of the sweet potato.

Water quality parameters of the experimental tanks

Maximum fish production is greatly influenced by the physical, chemical, and biological properties of water (Bhatnagar & Devi, 2019). The experimental tank water quality parameters for fish production were at their best, according to Nzeagwu et al. (2017). The optimal values of temperature (26.53 ± 0.57), dissolved oxygen (5.37–5.57 ± 0.03), and pH (6.22–6.50 ± 0.03) were in compliance with optimum requirements for fish rearing, according to Anita and Pooja (2013). Dissolved oxygen (3–8 mg/l), according to Ayoola and Fedrick (2012), was within its optimal limit. Therefore, the quality of the test tank water provided optimum conditions for *C. gariepinus* culture, as reported by Olurin et al. (2006). fish production is greatly influenced by the physical, chemical, and biological properties of water (Bhatnagar & Devi, 2019). The experimental tank water quality parameters for fish production were at their best, according to Nzeagwu et al. (2017). The optimal values of temperature (26.53 ± 0.57), dissolved oxygen (5.37–5.57 ± 0.03), and pH (6.22–6.50 ± 0.03) were in compliance with optimum requirements for fish rearing, according to

Anita and Pooja (2013). Dissolved oxygen (3–8 mg/l), according to Ayoola and Fedrick (2012), was within its optimal limit. Therefore, the quality of the test tank water provided optimum conditions for *C. gariepinus* culture, as reported by Olurin et al. (2006).

Cost benefit analysis of experimental diets

The cost benefit analysis of feeding *C. gariepinus* fingerlings with different percentages of orange fleshed sweet potato peels meal shows that inclusion of orange fleshed sweet potato peels meal to fish feed is cost-reducing and profitable. The feed cost per kilogram was lower in 100% orange fleshed sweet potato peel meal diets than in the control (D1) showing the economic viability of the use of orange fleshed sweet potato peel meal as a replacement feed ingredient, as similarly reported by Adesina et al. (2020). Similarly, total cost of input was less with 100% orange-fleshed sweet potato peels meal diet than control D1, indicating that orange-fleshed sweet potato peels meal reduces the overall cost of production, as similarly noted by Ali et al. (2024) when they feed hatchlings of *Clarias gariepinus* different levels of maca (*Lepidium meyenii* Walp.) root powder as feed additive. Maximum net profit was realized in 100% orange fleshed sweet potato peel meal, where lower-priced feeds did not hinder fish growth and even could improve it, as indicated by Abdurrazzaq et al. (2022). The incidence cost, or cost to revenue ratio, was less for the 100% orange fleshed sweet potato peels meal (D6) than the control (D1), and this indicates more cost efficiency, as reported by Abdurrazzaq et al. (2022). The profit index, or return on investment, was also higher for the 100% orange-fleshed sweet potato peels meal (D6) than for the control diet D1, indicating a more rewarding return from the use of orange-fleshed sweet potato peels meal, as reported by Salisu et al. (2024) when they used graded levels of bambara groundnut (*Vigna subterranea L.)* meal to replace fishmeal in feeding *Clarias gariepinus* fingerlings. In general, utilizing orange fleshed sweet potato peel meal as fish feed minimizes costs and maximizes profitability, and hence it is an available and sustainable choice for aquaculture, particularly for countries where the conventional feed ingredients are costly or unaffordable.

Conclusion

This study demonstrated that up to 100% inclusion of orange fleshed Ipomoea batatas peels meal in the diet was capable of sustaining the growth of *Clarias gariepinus* fingerling. Growth performance, however, reduced with increased in the levels of inclusion, which may be attributed to increase in the dietary carbohydrate and the content of anti-nutritional factors present in the peels. The findings indicate that while orange fleshed *Ipomea batatas* peel is an economically efficient feedstuff, high inclusion levels (especially at 100%) can lead to reduced growth performance, suggesting that an optimal 20 % level of inclusion is best for good health and performance.

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