Ife Journal of Agriculture, 2025, Volume 37, Number 1

DIETARY SUBSTITUTION OF DIFFERENTLY PROCESSED PLANTAIN (*Musa paradisiaca*) PEELS FOR MAIZE ENHANCED GROWTH PERFORMANCE, FEED UTILIZATION, BODY COMPOSITION, AND SURVIVAL IN *Clarias gariepinus* FINGERLINGS

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ABSTRACT

An eight-week feeding trial was conducted to appraise the effect of substituting differently processed plantain (Musa paradisiaca) peels for maize on the growth response, feed utilization, body composition, and survival in Clarias gariepinus fingerlings. Soaked Plantain Peel Meal (SPPM), Boiled Plantain Peel Meal (BPPM), and Oven-dried Plantain Peel Meal (OPPM) were substituted for maize. Four isonitrogenous diets (40% crude protein) were formulated with SPPM, BPPM, and OPPM, each substituted for maize, while the fourth diet (tagged control treatment) was without plantain peel meal. The diets were administered twice daily (07:00 - 08:00 AM and 4:00 - 5:00 PM) at 5% of body weight to 15 fingerlings randomly stocked in each of 12 glass tanks for eight weeks. Diets and fish samples were analyzed using standard procedures. Data on Mean Weight Gain (MWG), Specific Growth Rate (SGR), and Feed Conversion Ratio (FCR) were analyzed using analysis of variance (ANOVA) at p = 0.05. Post-experimental fish carcass crude protein significantly (p<0.05) surpassed the initial value in the pre-experimental fish. The best MWG, SGR, and FCR were obtained for fingerlings fed with a boiled plantain peel meal-supplemented diet, and the least MWG, SGR, and FCR were observed in those placed on the control diet. Fish percentage survival was fairly high in both the test treatments and the control treatment. This study revealed that differently processed plantain peel meals enhanced fish growth, and boiled plantain peel meal produced the best growth and feed utilization in C. gariepinus fingerlings.

Keywords: ***Plantain peel; Clarias gariepinus; Growth performance; Feed utilization; Fish survival***

INTRODUCTION

The ever-increasing cost of conventional fish feed ingredients such as fishmeal, soybean meal, groundnut cake, maize, and many others has necessitated attempts to consider alternative feed resources that are hitherto readily available, relatively cheaper, and not being directly utilized for human consumption. A major hindrance to the growth of Nigeria's aquaculture sector is the supply of practically affordable fish feed. The kind of feed, feeding rate, feed intake, and the fish's ability to absorb nutrients affect growth and survival rate (Arebu *et al.,* 2017). To ensure viable and profitable aquaculture enterprises, adequate feed supply is a major determinant as it constitutes as much as 60-80% of the total cost of fish production (Jamabo *et al*., 2013; Ada *et al*., 2020). For many aspiring fish farmers in Nigeria, the selection of a suitable fish feed has often been a major concern. If fish farming is to be profitable and sustainable, immediate remedies must be sought (Paul *et al*., 2013). An ideal feed should provide all essential nutrients to satisfy the nutritional needs of the cultured animal for maintaining vital physiological functions, including growth, reproduction, and health (Bhilave *et al*., 2010).

Cereals and grains are indispensable components of both human and livestock diets, and this has caused a persistent increase in the demand for these products for human and livestock consumption. Maize provides a major energy source in formulated feeds for fish and terrestrial animals (Omovwohwovie *et al*., 2018). It commands high prices as a result of its acceptability as a staple food for many livestock species and humans. In Nigeria, maize has been extensively used as the principal energy source in monogastric animals, including fish. However, the keen competition for this ingredient by man, livestock, and industries makes its cost to reducing the profit margin of an average livestock farmer. This is coupled with the fact that maize production is dwindling (Omovwohwovie *et al*., 2018). This necessitates efforts to make use of agricultural by-products that are often considered less useful for human consumption in fish feed formulation. Several studies have been conducted to replace maize with such agricultural by-products (Ochang *et al*., 2014; Agbebi *et al*., 2018; Aliyu *et al*., 2019). Furthermore, several attempts have been made to either totally replace or supplement the maize component of fish feed with cheaper unconventional energy sources (Wilfred-Ekperikpo, 2017; Omovwohwovie *et al*., 2018).

Considering the present rate of maize utilization and increasing cost, there is an urgent need to search for alternative underutilized energy sources, which include plantain peel. Available data on the plantain peel as a promising feed ingredient showed that Nigeria produced 3.16 million tonnes of plantain in the year 2016 from the 39.24 million world's total (FAO, 2017), representing about 8% of the world's total plantain production. About 30% of the total production of bananas and plantains was potentially available for livestock feeding as a result of their rejection as export commodities. Preliminary investigation revealed an abundant production of plantain peels in some designated parts of Nigeria. For instance, Ajebamidele Area of Aramoko Ekiti, Ekiti State, produces substantial quantities of plantain peels because the locals mainly engage in the processing of plantains into plantain powder/flour. Heaps of discarded plantain peels left after processing the pulp into flour constitute a major nuisance to the environment in terms of pollution build-up, generation of obnoxious smell, and disposal problems in this region.

In terms of chemical composition, reports have shown that plantain peels are moderately balanced in the ratio of protein to calories, containing about 12% crude protein, 16% crude fibre, and metabolizable energy ranging from 1300 – 1900 kcal/kg (Uwalaka *et al*., 2013). Generally, plantain peels have been reported to have better protein, energy, calcium, and phosphorus composition as well as more crude fibre and ether extract than maize (Agbabiaka *et al.,* 2013). The use of plantain peels in compounding fish diet will reduce the cost of feed supply and solve the associated pollution menace. However, there is scant available information on the utilization of processed plantain peels as a dietary energy source and a substitute for maize in fish feed production.

Therefore, this study investigated the comparative effects of diet supplementation with differently processed plantain peels on feed utilization, growth performance, body composition, and survival rate in *C. gariepinus* fingerlings.

MATERIALS AND METHODS

Collection and processing of ripe plantain peels into meals

Wet plantain peels used in this study were collected from a few plantain processors (women roasting plantains, frying plantain chips, and sun-drying plantains into plantain flour) within Okitipupa town, Ondo State, Nigeria. The peels were washed in clean water and cut into 5 – 7 mm thin slices to facilitate further processing. The sliced peels were divided into three portions (of 2 kg each) and further processed respectively as follows:

Soaked Plantain Peel Meal (SPPM): Two (2) kilograms of plantain peels were soaked in 5 litres of water in a plastic container for 72 hours as described by Rafiu *et al*. (2014). Soaking water was changed at regular intervals of 8 hours for 3 days, after which the peels were removed, drained, sundried to a constant weight for 3 days, and ground into fine powder labeled as Soaked Plantain Peel Meal (SPPM) before incorporation in the diet.

Boiled Plantain Peel Meal (BPPM): Two (2) kilograms of plantain peels were put in 5 litres of boiling water at 100°C for 20 minutes, as illustrated by Rafiu *et al*. (2014). The boiled peels were removed, drained, sundried for 3 days, and milled into fine powder referred to as Boiled Plantain Peel Meal (BPPM) before inclusion in the diet.

Oven-dried Plantain Peel Meal (OPPM): Two (2) kilograms of plantain peels were oven-dried at 50°C for 48 hours to obtain a constant weight as described by Afe and Omosowone (2019). The oven-dried peels were removed, sundried for 3 days, and ground into fine powder designated as Oven-dried Plantain Peel Meal (OPPM) prior to supplementation in the diet.

Preparation of experimental diets

Four isonitrogenous diets consisting of a control diet and three test diets (each containing 40% crude protein) were formulated using Pearson's square method (Table 1). The control diet lacked plantain peel meal, while the test diets contained processed plantain peel meals as substitutes for maize and were designated as Soaked Plantain Peel Meal (SPPM), Boiled Plantain Peel Meal (BPPM), and Oven-dried Plantain Peel Meal (OPPM)-based diets, respectively. Each diet was prepared separately by thoroughly mixing the ingredients inside a bowl, after which palm oil and warm water were added to produce a homogenous paste. Each mixed diet paste was pelleted using a 2-mm die Hobart pelletizer (A-2007 Model, Hobart Ltd, London, UK). The pellets were sun-dried for 72 hours and stored in separate air-tight containers before feeding.

Experimental arrangement and fish husbandry

This feeding trial was carried out for eight weeks (56 days) in the Fish Nutrition Laboratory of the Department of Fisheries and Aquaculture Technology, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria. A total of 240 *C. gariepinus* fingerlings were procured from a reputable farm, conveyed, and acclimated to laboratory conditions for 7 days, during which time they were fed a 2 mm commercial diet twice daily. After acclimatization, 180 uniformly-sized fingerlings (initial mean weight: 3.56 ± 0.05 g) were batch-weighed on a high-precision top-loading balance (OHAUS LS, Model 2000) and randomly distributed into 12 glass tanks (50 × 40 × 40 cm^3) at a stocking rate of fifteen (15) fingerlings per tank containing 20 litres of water each. The four diets were hand-fed twice daily (07:00 - 08:00 am and 4:00 - 5:00 pm) to triplicate groups of fish at 5% of their body weight in two equal proportions, and the tanks were continuously aerated through air-stones connected to a central air pump (UPETTOOLS HD202, New 4W-2 Outlets, UPETTOOLS Company, Amazon, USA). Fingerlings in each tank were batch-weighed, while diet quantities administered were adjusted weekly according to the increase in weight.

Proximate composition of experimental diets and fish was determined according to AOAC (2011). Water temperature was measured via a mercury-in-glass thermometer, dissolved oxygen concentration was measured using a DO meter (YSI 55 Incorporated, Yellow Springs, Ohio, 4387, USA), while pH values were determined by means of a pH meter (LT-Lutron pH-207, Taiwan).

Table 1: Gross ingredient composition (g/100 g dry matter) of control and test diets containing differently processed plantain peel meals

Dietary Ingredients	Control Diet	SPPM-based Diet	BPPM-based Diet	OPPM-based Diet
Plantain peel meal	0.00	19.56	18.54	20.14
Yellow maize meal	18.00	0.00	0.00	0.00
Fish meal	24.10	23.48	23.82	23.29
Groundnut cake	24.10	23.48	23.82	23.29
Soybean meal	24.10	23.48	23.82	23.29
Shrimp meal	3.00	3.00	3.00	3.00
Vitamin premix	0.50	0.50	0.50	0.50
Lysine	0.50	0.50	0.50	0.50
Palm oil	2.50	2.50	2.50	2.50
Salt	0.50	0.50	0.50	0.50
Cassava starch	3.00	3.00	3.00	3.00
Total (g)	100	100	100	100
Calculated crude protein (%)	40.00	40.00	40.00	40.00

Vitamin/mineral premix: Vit. A: 1,000,000 IU; Vit. B_1: 250mg; Vit B_2: 1750mg; Vit B_6: 875mg; Vit. B_{12}: 2500mg; Vit. C: 12,500mg; Vit D_3: 600,000 IU; Vit. E: 12,000 IU; Vit. K_3: 15mg; Calcium D-pantothenate: 5000mg; Nicotinic acid: 3750 mg; Folic acid: 250mg; Cobalt: 24,999 mg; Copper: 1999 mg; Iron: 11,249mg; Selenium ($Na_2SeO_3 . 5H_2O$): 75mg; Iodine (Potassium iodide): 106mg; Anti-oxidant: 250mg.
SPPM - Soaked plantain peel meal; BPPM - Boiled plantain peel meal; OPPM – Oven-dried plantain peel meal

Evaluation of growth performance and feed utilization indices

At the end of the feeding experiment, growth indices were calculated according to Adesina and Ikuyeju (2019) as follows:

Mean Weight Gain (g)

$$= (\text{Final weight} - \text{Initial weight})\ \text{g} \ldots(1)$$

Total percentage weight gain (TPWG, %)

$$= \frac{\text{Weight gain}}{\text{Initial weight}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Specific Growth Rate (%/day)

$$= \frac{(\text{Ln final weight} - \text{Ln initial weight})}{\text{Time (experimental period in days)}} \times 100 \ldots.(3)$$

where: Ln = natural logarithm

Feed intake (g)

$= WFI_1 + WFI_2 + WFI_3 + WFI_4 + \ldots WFI_n$………(4)

where: WFI= weekly feed intake of fish per treatment (g); 1, 2, 3, 4,…n = number of weeks of the experimental duration

Food Conversion Ratio (FCR)

$$= \frac{\text{Mean feed intake (g)}}{\text{Mean weight gain (g)}} \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Protein Intake (g of protein in 100g diet/fish)

$$= \frac{\text{Feed intake} \times \text{\% crude protein in the diet}}{100} \ldots\ldots(6)$$

Protein Efficiency Ratio (PER)

$$= \frac{\text{Mean weight gain}}{\text{Protein intake (g of protein in 100g of diet/fish)}} \ldots\ldots(7)$$

Nitrogen Metabolism (NM)

$$= \frac{0.549 \times (\text{Initial mean weight} + \text{Final mean weight})t}{2} \ldots(8)$$

where: t = experimental period in days, and 0.549 = metabolism factor

Percentage survival was calculated as follows:

Percentage survival (%)

$$= \frac{\text{Total number of surviving fish}}{\text{Total number of fish stocked}} \times 100 \ldots\ldots(9)$$

Statistical analysis

Data obtained from this study were subjected to analysis of variance (ANOVA) using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS, 2004). Data were computed as the mean of triplicate values ± standard deviation. Effects of treatments were considered significant at p<0.05, and differences among means wer+63.e compared and separated using Duncan's Multiple Range Tests (Duncan, 1955).

RESULTS AND DISCUSSION

Table 2 shows that the proximate composition of raw plantain peel meal and the differently processed plantain peel meals varied significantly ($p < 0.05$). The values of the proximate parameters in the test ingredients correspond to the range of nutrients earlier reported for processed plantain peels (Omole *et al*., 2008). The crude protein values (9.89 – 11.54%) of the processed plantain peel meals obtained in this study agree with 9.63 - 13.73% earlier reported by other authors (Ogunsipe and Agbede, 2010; Agbabiaka *et al*., 2013; Uwalaka *et al*., 2013; Oyedeji *et al*., 2015; Aderolu *et al*., 2016; Robert *et al*., 2020). The crude lipid values (4.47 - 6.23%) align with 4.64 – 6.22% previously documented (Ogunsipe and Agbede, 2010; Okeke *et al*., 2015; Robert *et al*., 2020) but surpass 1.24 – 3.61% obtained by other researchers (Okoruwa and Ikhimioya, 2014; Okareh *et al*., 2015). The values of crude fibre (16.39 - 18.56%) exceed 5.0 - 14.31% previously archived in literature (Ogunsipe and Agbede, 2010; Agbabiaka *et al*., 2013; Uwalaka *et al*., 2013; Okoruwa and Ikhimioya, 2014; Okeke *et al*., 2015; Okareh *et al*., 2015; Oyedeji *et al*., 2015; Abubakar *et al*., 2016; Aderolu *et al*., 2016; Robert *et al*., 2020).

Ash content values (5.77 - 7.44%) conform to 6.52 recorded by Okoruwa and Ikhimioya (2014) but are lower than 8.63 – 19.5% previously observed in similar peel meals (Ogunsipe and Agbede, 2010; Agbabiaka *et al*., 2013; Uwalaka *et al*., 2013; Okareh *et al*., 2015; Oyedeji *et al*., 2015; Abubakar *et al*., 2016; Aderolu *et al*., 2016; Robert *et al*., 2020). Nitrogen-free extract values (48.93 - 51.98%) are similar to 42.9 – 52.25% observed by Agbabiaka *et al*. (2013) and Robert *et al*. (2020) and exceed 27.18 - 42.95% found by other investigators (Okeke *et al*., 2015; Oyedeji *et al*., 2015; Abubakar *et al*., 2016). However, higher NFE values (63.16 - 78.51%) have been earlier reported

(Ogunsipe and Agbede, 2010; Okoruwa and Ikhimioya, 2014; Okareh *et al*., 2015). The disparities between the present values and previously reported values could be due to variations in plantain varieties/species, soil types, locations, stages of ripening, peel processing methods and other environmental factors that influence the availability of nutrients in plants.

Table 2: Proximate composition (%) of raw and differently processed plantain peel meals

Proximate Parameters	RPPM	SPPM	BPPM	OPPM
Crude protein	9.33±0.54^{b}	10.86±0.81^{ab}	11.54±0.52^{a}	9.89±1.14^{b}
Crude lipid	5.5±0.60^{ab}	4.47±0.42^{b}	6.23±0.22^{a}	5.14±1.26^{ab}
Crude fibre	16.77±0.79^{b}	17.75±0.69^{ab}	18.56±0.79^{a}	16.39±0.67^{b}
Total ash	4.91±0.09^{c}	5.77±0.80^{bc}	6.62±0.65^{ab}	7.44±0.39^{a}
Moisture	11.04±0.06^{a}	9.17±0.20^{c}	8.12±0.53^{d}	10.02±0.05^{b}
Nitrogen-free extract	52.46±1.96^{a}	51.98±1.16^{ab}	48.93±0.98^{c}	51.12±0.83^{b}

Superscripts a,b,c, etc. indicate that mean values with different superscripts along the same row are significantly different ($p < 0.05$). RPPM – Raw plantain peel meal; SPPM - Soaked plantain peel meal; BPPM - Boiled plantain peel meal; OPPM – Oven-dried plantain peel meal

Table 3 presents the proximate composition of the experimental diets. Proximate compositions of the diets conformed to the range of nutrient requirements for catfish fingerlings and juveniles as recommended by FAO (2006). The crude protein values (39.31 - 40.62%) are comparable to 40.49 – 40.81% observed in sundried plantain peel meal-supplemented diets fed to *C. gariepinus* fingerlings (Agbabiaka *et al*., 2013), whose protein requirements were met by the quantities provided in the experimental diets. According to Adegbesan *et al*. (2018), an ideal growth rate and feed conversion efficiency in *C. gariepinus* could be attained with diets containing 38 - 42% crude protein.

The crude lipid values (8.71% - 10.46%), which varied significantly among the diets, exceed 3.47 – 3.61% found in fermented unripe plantain peel meal-supplemented diets (Obasa *et al*., 2017) and 4.27 – 5.27% in sundried plantain peel meal-supplemented diets (Agbabiaka *et al*., 2013). The crude showed non-significant variations ($p > 0.05$) but differed significantly ($p < 0.05$) from the control diet. These values surpass 3.51 – 5.39% found in related diets (Agbabiaka *et al*., 2013; Obasa *et al*., 2017). The values of the ash content (11.59 - 12.43%) were not significantly different ($p > 0.05$) between the control and test diets. These values closely harmonize with 12.08 – 12.37% reported by Obasa *et al*. (2017) and are above 8.14 – 9.61% obtained by Agbabiaka *et al*. (2013). Similarly, the values of nitrogen-free extract (21.96 - 23.19%) were not significantly different ($p > 0.05$) but lower than 32.24 – 38.74% observed in similar diets (Agbabiaka *et al*., 2013; Obasa *et al*., 2017). Moreover, these fairly high values possibly confirm the dietary potential of processed plantain peel meal as an unconventional energy feedstuff. The low values of the moisture content (8.06 – 9.02%) indicate that the diets were properly dried to prevent fungal growth.

Table 3: Proximate composition (%) of experimental diets containing differently processed plantain peel meals

Proximate Parameters	Control Diet	SPPM-based Diet	BPPM-based Diet	OPPM-based Diet
Moisture	9.02 ± 0.32^{ab}	9.30 ± 0.31^{a}	8.06 ± 0.85^{b}	8.88 ± 0.85^{ab}
Crude protein	39.80 ± 1.07^{a}	39.31 ± 1.16^{a}	40.62 ± 0.51^{a}	40.27 ± 0.75^{a}
Crude lipid	9.34 ± 0.51^{ab}	10.46 ± 0.63^{a}	10.38 ± 0.96^{a}	8.71 ± 0.58^{b}
Ash	11.20 ± 0.76^{a}	11.97 ± 0.74^{a}	11.59 ± 0.84^{a}	12.43 ± 1.03^{a}
Crude fibre	8.19 ± 0.84^{a}	6.79 ± 0.39^{b}	6.48 ± 0.52^{b}	7.81 ± 0.60^{a}
Nitrogen-free extract	22.45 ± 1.23^{a}	22.38 ± 0.91^{a}	23.19 ± 1.17^{a}	21.96 ± 1.43^{a}

Superscripts a,b,c, etc. indicate that mean values with different superscripts along the same row are significantly different ($p < 0.05$).
SPPM - Soaked plantain peel meal; BPPM - Boiled plantain peel meal; OPPM – Oven-dried plantain peel meal

Table 4 displays significant variations ($p < 0.05$) in the carcass proximate composition of the experimental fish, which suggest that the differently processed plantain peel meals in the diets possibly affected fish body composition. The carcass crude protein levels (68.18 – 69.53%) in the post-treatment fish significantly ($p < 0.05$) surpassed the initial pre-treatment value (65.81%). This outcome could be ascribed to an improvement in the synthesis of tissue protein in the experimental fish as posited by Tiamiyu *et al*. (2015). This observation agrees with Obasa *et al*. (2017), who also reported significantly higher carcass protein levels in *Oreochromis niloticus* fingerlings fed fermented unripe plantain peel meal-supplemented diets. The final carcass crude lipid values (11.84 – 12.49%) were not significantly different ($p > 0.05$) from the initial content (12.19%). These lipid values plausibly suggest an improved lipid production in the experimental fish (Fountoulaki *et al*., 2003). Moreover, these values exceed 6.38 – 6.71% found in *O. niloticus* fingerlings fed similar diets (Obasa *et al*., 2017). The values of ash content (6.43 - 7.61%) are lower than 12.23 – 13.28% recorded for *O. niloticus* fingerlings (Obasa *et al*., 2017), while the values of their moisture content are almost similar.

Table 4: Carcass proximate composition (%) of *C. gariepinus* fingerlings fed plantain peel meal-supplemented diets

Proximate parameters	Initial fish Sample	Control treatment	SPPM-based treatment	BPPM-based treatment	OPPM-based treatment
Moisture	8.01±0.04^{a}	7.12±0.34^{a}	7.24±0.29^{a}	7.81±0.88^{a}	7.82±0.77^{a}
Crude protein	65.81±0.90^{b}	68.18±0.82^{a}	69.51±1.44^{a}	69.53±0.78^{a}	68.91±0.96^{a}
Crude lipid	12.19±0.36^{a}	12.11±0.10^{a}	12.49±0.70^{a}	11.84±0.17^{a}	11.93±0.08^{a}
Ash	7.72±0.81^{a}	6.51±0.30^{ab}	6.43±0.42^{b}	6.61±0.69^{ab}	7.61±0.54^{a}
Nitrogen-free extract	6.28±0.77^{a}	6.09±0.20^{a}	4.33±0.26^{b}	4.23±0.92^{b}	3.74±0.28^{b}

Superscripts a,b,c*,* etc. indicate that mean values with different superscripts along the same row are significantly different ($p < 0.05$). SPPM - Soaked plantain peel meal; BPPM - Boiled plantain peel meal; OPPM – Oven-dried plantain peel meal

Table 5 indicates the values of water quality parameters determined during the experiment. Water quality conditions in the fish culture tanks showed no variations throughout the experimental period except for final pH values (7.44 – 7.75), which were significantly ($p < 0.05$) higher than the initial value (6.68). Initial dissolved oxygen concentration (5.61 mg/litre) was not statistically ($p > 0.05$) different from the final values (5.36 mg/litre - 5.43 mg/litre). Similarly, the initial temperature (27.15 ºC) was not statistically ($p > 0.05$) different from the final values (27.63 ºC - 27.75 ºC). These values conformed to the recommended optimal limits reported by Devi (2013) and Jimoh *et al*. (2022) as suitable for warm-water fish culture. The observed values indicated that incorporating differently processed plantain peel meals in the test diets, coupled with proper fish handling, did not impair the physico-chemical quality of the rearing medium.

Table 5: Water quality parameters measured during the feeding period

Dietary treatments	pH	DO (mg/L)	Temperature (ºC)
Initial values	6.68 ± 0.71^{b}	5.61 ± 0.11^{a}	27.15 ± 0.32^{a}
Mean weekly values			
Control treatment	7.75 ± 0.13^{a}	5.38 ± 0.14^{a}	27.63 ± 0.03^{a}
SPPM-based treatment	7.44 ± 0.29^{a}	5.41 ± 0.03^{a}	27.69 ± 0.46^{a}
BPPM-based treatment	7.74 ± 0.08^{a}	5.36 ± 0.04^{a}	27.75 ± 0.02^{a}
OPPM-based treatment	7.75 ± 0.03^{a}	5.43 ± 0.03^{a}	27.67 ± 0.09^{a}

Superscripts a,b,c*,* etc. indicate that mean values with different superscripts along the same row are significantly different ($p < 0.05$). SPPM - Soaked plantain peel meal; BPPM - Boiled plantain peel meal; OPPM – Oven-dried plantain peel meal

Table 6 shows the feed utilization and growth response of *C. gariepinus* fingerlings fed differently processed plantain peel meal-supplemented diets. Acceptance of all the test diets by *C. gariepinus* fingerlings in this study connotes that the inclusion of variously processed plantain peel meals in the diets significantly affected diet palatability. The reason could be the processing methods used, which made the diets palatable. This agrees with the finding of Kwari *et al*. (2019), who reported that a decrease in anti-nutrient content due to various processing methods culminated in better feed palatability, growth, and development in fish. The growth performance and feed utilization efficiencies in *C. gariepinus* fingerlings exhibited significant variations ($p < 0.05$) as shown by a general increase in mean weight gain (MWG). The increased MWG observed across all the treatments confirms that *C. gariepinus* fingerlings responded positively (though differently) to all the diets and effectively converted feed protein into flesh, a development that is consistent with the findings by Eyo and Olatunde (2001). MWG (8.38 g) was significantly higher ($p < 0.05$) in the fish fed boiled plantain peel meal (BPPM)-based diet, followed by the fish fed soaked plantain peel meal (SPPM)-based diet (8.12 g) and oven-dried plantain peel meal (OPPM)-based diet (7.46 g), while the least MWG (6.85 g) was recorded in the fish fed the control diet.

This finding suggests that differently processed plantain peel meals have enhanced fish growth, which agrees with improved growth responses as earlier observed in *C. gariepinus* fingerlings and juveniles fed processed plantain peel meal-supplemented diets (Agbabiaka *et al*., 2013; Aderolu *et al*., 2016). By contrast, these values are much lower when compared with 54.73 – 80.98 g reported for *C. gariepinus* fingerlings fed graded levels of sundried plantain peel meal-supplemented diets (Agbabiaka *et al*., 2013) and 57.81 – 74.71 g achieved by *C. gariepinus* juveniles fed varied levels of sundried ripe and unripe plantain peel meal-incorporated diets (Aderolu *et al*., 2016). Similarly, the fish fed boiled plantain peel meal-based diet had the best values of specific growth rate (SGR), feed conversion ratio (FCR), protein intake (PI) and protein efficiency ratio (PER), followed by those fed soaked and oven-dried plantain peel meal-based diet while the least values were recorded for the fish placed on the control diet. The SGR values (2.01 – 2.16 %/day) slightly surpass 1.12 – 1.4%/day and 1.31 – 1.56 %/day, respectively, reported for *C. gariepinus* fingerlings and juveniles fed related diets (Agbabiaka *et al*., 2013; Aderolu *et al*., 2016).

The lower FCR values (0.93, 0.95, and 0.99, respectively) exhibited by *C. gariepinus* fingerlings fed boiled, soaked, and oven-dried plantain peel meal-based diets suggested that they effectively utilized and efficiently converted the diets to flesh when compared to 1.05 recorded for the fish in the control treatment. This was corroborated by Adikwu (2003) that the more efficiently a feed is utilized by the fish, the lower the feed conversion ratio. Furthermore, these values are consistent with 0.87 – 1.28 reported for *C. gariepinus* juveniles (Aderolu *et al*., 2016).

The higher values of protein intake (3.15, 3.11, and 2.98 g/100g diet/fish, respectively) observed in the fish fed boiled, soaked and oven-dried plantain peel meal-based diets signify optimal intake of dietary protein, though not significantly different, when compared with 2.9 g/100g diet/fish recorded for the fish in the control treatment. However, these values are lower than 23.04 – 30.31 g/100g diet/fish earlier reported for *C. gariepinus* juveniles (Aderolu *et al*., 2016).

The higher PER values (2.69, 2.58, and 2.5, respectively) found in the fish fed boiled, soaked, and oven-dried plantain peel meal-based diets reflect better dietary protein utilization, although not significantly different, when compared with 2.36 recorded for the fish in the control treatment. These values correspond to 2.07 – 3.04 reported for *C. gariepinus* juveniles (Aderolu *et al*., 2016) but are lower than 4.71 – 7.89 documented for *C. gariepinus* fingerlings (Agbabiaka *et al*., 2013) fed comparable diets. PER is an indicator of how adequately the protein sources in a particular diet meet the essential amino acid requirements of the fish and is associated with fat deposition in fish muscles. The present PER values suggest that they could favor fat deposition in *C. gariepinus* in line with the findings of Qamer *et al*. (2014), who examined the growth-enhancing potential of gelatinized and non-gelatinized corn on *Labeo rohita*.

The fairly high percentage survival (73.33 – 78.5%) of *C. gariepinus* fingerlings fed variously processed plantain peel meal-supplemented diets in this study supports previous reports of considerably high survival rates (90.0 – 100%) exhibited by *C. gariepinus* fingerlings placed on similar diets (Agbabiaka *et al*., 2013). These relatively high survival rates possibly indicate high acceptability of the processed plantain peel meal-supplemented diets by the fish, coupled with careful fish handling, adequate water quality management, proper feed processing, and suitability of processed plantain peel meal incorporation in the diet of *C. gariepinus*. The acceptance of the plantain peel meal-supplemented diets, as revealed by the growth, feed utilization, carcass composition, and survival indices, has further authenticated the pliability of *C. gariepinus* fingerlings to efficiently utilize a wide range of unorthodox feedstuffs.

Table 6: Growth and feed utilization of *C. gariepinus* fingerlings fed differently processed plantain peel meal-supplemented diets

Growth and feed utilization parameters	Control treatment	SPPM-based treatment	BPPM-based treatment	OPPM-based treatment
Initial mean weight (g)	3.55 ± 0.04^{a}	3.56 ± 0.06^{a}	3.57 ± 0.06^{a}	3.57 ± 0.05^{a}
Final mean weight (g)	10.40 ± 0.01^{c}	11.64 ± 0.47^{a}	11.95 ± 0.56^{a}	11.03 ± 0.18^{b}
Mean weight gain (g)	6.85 ± 0.14^{b}	8.12 ± 0.10^{a}	8.38 ± 0.93^{a}	7.46 ± 0.41^{ab}
Percentage weight gain (%)	191.88 ± 2.86^{d}	227.45 ± 2.56^{b}	234.73 ± 3.72^{a}	208.96 ± 1.24^{c}
Specific growth rate (%/day)	1.92 ± 0.01^{a}	2.12 ± 0.13^{a}	2.16 ± 0.18^{a}	2.01 ± 0.14^{a}
Total feed intake (g)	322.65 ± 0.36^{d}	345.60 ± 1.11^{b}	350.10 ± 1.11^{a}	333.45 ± 0.70^{c}
Mean feed intake (g)	7.17 ± 0.08^{a}	7.68 ± 0.18^{a}	7.78 ± 0.37^{a}	7.41 ± 0.60^{a}
Feed conversion ratio	1.05 ± 0.04^{a}	0.95 ± 0.03^{a}	0.93 ± 0.08^{a}	0.99 ± 0.13^{a}
Protein intake	2.90 ± 0.15^{a}	3.15 ± 0.26^{a}	3.11 ± 0.06^{a}	2.98 ± 0.03^{a}
Protein efficiency ratio	2.36 ± 0.35^{a}	2.58 ± 0.57^{a}	2.69 ± 0.40^{a}	2.50 ± 0.31^{a}
Nitrogen metabolism	214.44 ± 1.73^{d}	234.27 ± 1.96^{b}	238.57 ± 2.34^{a}	224.43 ± 1.38^{c}
Percentage Survival (%)	73.33 ± 1.68^{b}	76.67 ± 1.85^{a}	78.50 ± 2.36^{a}	73.33 ± 1.16^{b}

Superscripts a,b,c, etc. indicate that mean values with different superscripts along the same row are significantly different ($p < 0.05$). SPPM - Soaked plantain peel meal; BPPM - Boiled plantain peel meal; OPPM – Oven-dried plantain peel meal

CONCLUSION

Results from this study have shown that differently processed plantain peel meals efficiently replaced maize in the diet of *C. gariepinus* and enhanced growth, feed utilization, carcass composition, and survival. The fish fed with boiled plantain peel meal (BPPM)-based diet attained the highest values of growth and feed utilization parameters, followed by those fed with soaked plantain peel meal (SPPM)-based diet and oven-dried plantain peel meal (OPPM)-based diet while the least values were observed in the fish placed on the control diet. In view of the dietary potential of processed plantain peel meal as a readily available unconventional ingredient and as a feasible alternative for maize in the diets of *C. gariepinus*, further investigations on other processing methods and levels of inclusion are recommended in a bid to widen the scope of its utilization in fish feed and eventually enhance aquaculture productivity.

ACKNOWLEDGEMENT

The authors are sincerely grateful to the Tertiary Education Trust Fund (TETFUND) for fully funding this research through TETFUND Intervention in Research Projects (2022-2023 Merged Batch).

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