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Growth performance and body composition of *Clarias gariepinus* fingerlings fed graded levels of blanched cassava (*Manihot esculenta*) root meal

Adesina, S.A.* and Alabi, O.

Department of Fisheries and Aquaculture Technology, Faculty of Agriculture, Food and Natural Resources, Olusegun Agagu University of Science and Technology, Okiti-pupa, Nigeria

*Corresponding Author (Email:adesinasimon@yahoo.com; Phone +234(0)8028574784)

ABSTRACT

Excessive demand on cereal grains has caused an unprecedented increase in the cost of fish feeds and has necessitated exploration of cheaper and readily available alternatives. This study examined the effects of substituting Blanched Cassava (*Manihot esculenta*) Root Meal (BCRM) for maize on the growth of *Clarias gariepinus* fingerlings. BCRM was substituted for maize at six inclusion levels of 0% (control), 20%, 40%, 60%, 80% and 100% and labeled as Diet 1, Diet 2, Diet 3, Diet 4, Diet 5 and Diet 6 respectively. The diets were administered twice daily (07:00 - 08:00 hrs and 17:00 - 18:00 hrs) at 5% of body weight to 15 fingerlings stocked in each of eighteen aquaria for eight weeks. The BCRM-supplemented diets and fish carcass samples were proximately analyzed using standard methods. Growth indices such as Mean Weight Gain (MWG), Specific Growth Rate (SGR) and Feed Conversion Ratio (FCR) were determined. Data generated were analyzed using analysis of variance (ANOVA) at $p = 0.05$. Final carcass crude protein (66.74 – 69.73%) significantly ($p<0.05$) surpassed the initial value (60.83%). Best MWG (14.65 g), SGR (2.81%/day) and FCR (0.87) were recorded for fingerlings fed with Diet 4 (60% BCRM) beyond which growth indices gradually diminished towards the least values of MWG (6.77 g), SGR (1.81%/day) and FCR (1.62) in those fed with Diet 6 (100% BCRM). This study revealed that substitution of blanched cassava root meal for maize up to 60% dietary inclusion level effectively improved the growth and feed utilization of *C. gariepinus* fingerlings.

Keywords: *Clarias gariepinus*; Cassava root; Maize; Blanching; Survival rate; Aquaculture

INTRODUCTION

Global aquaculture production has continued to expand in the new millennium, although relatively more slowly than in the 1980s and 1990s (FAO, 2012). As aquaculture production becomes increasingly intensive in Nigeria, fish feed has been identified as a major factor in increasing the productivity and profitability of aquaculture (Akinrotimi *et al*., 2007). According to Gabriel *et al*. (2007), feed cost alone constitutes about 60 – 70 percent of the overall expenses involved in the operation of fish farm enterprises and has in many cases reduced the profit of fish farmers to marginal profit. As a result of the prevailing global economic recession, particularly in Nigeria, the cost of fish feed production is increasing rapidly due to inflationary trend and partly because most of the conventional feedstuffs, such as fishmeal, soybean, maize, sorghum, groundnut cake, etc., used in preparing fish diets often face severe competition from humans and livestock (Dada *et al*., 2015). The growing demand for such feedstuffs and the resultant high prices necessitate an urgent attention of fish nutritionists to explore less competitive, locally available and potentially nutrient-rich feedstuffs that will cost little efforts for incorporation into fish diets. The need to intensify fish culture in an attempt to meet the ever-increasing demand for fish has prompted the development of highly suitable diets either in supplementary forms for pond-raised fish or as complete feed in tanks (Olukunle, 2006).

In an attempt to maximize nutritional and economic benefits, several research efforts have been directed at increasing the use of unorthodox plant and animal by-products to replace conventional feed ingredients such as fishmeal, soybean, groundnut cake and maize in fish feed rations (Sugiura *et al*., 2000; Ali *et al*., 2003; Olukunle, 2006; Olurin *et al*., 2006; Oyelese, 2007; Abu *et al*., 2010; Aderolu and Sogbesan, 2010; Orire and Ricketts, 2013). Maize is a major source of energy in fish diets and constitutes about 10 – 40 percent by weight in most aquaculture feeds (Olurin *et al*., 2006). However, the prohibitive cost and scarcity of maize in formulated feeds have prompted the use of relatively under-utilized energy sources such as cocoyam tuber, sweet potato tuber, cassava root tuber, cassava leaf meal, fruit and seed peel meals.

In this study, blanched cassava root tuber has been considered as very appropriate for this purpose. Cassava root is one of the most important energy sources in the diet of people in the tropics. According to Presston (2004), its starchy roots produce more calories per unit of land than any other crop in the world. Cassava roots generally contain significant amounts of calcium, ascorbic acid, thiamine, riboflavin and niacin (Pedrosa, 2002). Its thickened tuberous roots are a valuable source of cheap calories and their use in animal feed is increasing due to their high energy content and low price (Salami, 2000).

Few literature reports on the substitution of cassava products for maize in fish diets included studies on cassava-rice mixture and mirror carp, *Cyprinus carpio* (Ufodike and Matty, 1983), cassava-rice mixture and rainbow trout, *Salmo gairdneri* (Ufodike and Matty, 1984), cassava peel meal and Nile tilapia, *Oreochromis niloticus* (Faturoti and Akinbote, 1986), cassava root meal and tilapia, *O. mossambicus* (Wee and Ngi, 1986), cassava leaf meal and *O. niloticus* (Ng and Wee, 1989), cassava root flour and *C. gariepinus* fingerlings (Olurin *et al*., 2006), whole cassava root meal and *Heteroclarias* (Abu, *et al*., 2009; Abu *et al*., 2010), sundried cassava peel meal and *O. niloticus* (Ojukannaiye *et al*., 2014), sweet cassava (*Manihot palmata*) root meal and *O. niloticus* (Dada *et al*., 2015), sundried cassava leaf meal and *O. niloticus* (Madalla *et al*., 2016) and enzyme-supplemented fermented cassava root flour and *C. gariepinus* (Bamidele *et al*., 2018). However, there is currently a dearth of literature reports on the use of blanched whole cassava root meal in formulated diets for raising catfish fingerlings to table size. Therefore, this study was undertaken to evaluate the effects of substituting varied dietary levels of blanched cassava (*Manihot esculenta*) root meal for maize on the growth response, feed utilization and body composition of *C. gariepinus* fingerlings.

MATERIALS AND METHODS

Experimental diet preparation

Fresh cassava *(Manihot esculenta*) root tubers were collected from a private farm in Igodan-Lisa, Okitipupa, Ondo State, Nigeria. They were washed, peeled and cut into thin slices of approximately 3 cm thickness. The slices were blanched in boiling water inside a cooking pot for five (5) minutes at 100^oC to remove cyanogenic glycoside as described by Abu *et al*. (2010) and Dada *et al*. (2015). The blanched slices were sun-dried on polyethylene sheets for five (5) days and milled using a local blender into fine powder designated as blanched cassava root meal (BCRM) which was then stored in an air-tight container. Six isonitrogenous diets (each containing 40% crude protein) were formulated from a combination of ingredients using Pearson's square method (Table 1). BCRM was added to the diets as a substitute for maize at varied levels of 0% (control diet), 20% (3.88 g), 40% (7.76 g), 60% (11.65 g), 80% (15.53 g) and 100% (19.41 g) which were labeled as Diet1, Diet 2, Diet 3, Diet 4, Diet 5 and Diet 6 respectively (Table 1). Each diet was separately prepared by carefully mixing the dry ingredients inside a Hobart A-2007 mixer (Hobart Ltd, London, UK) after which palm oil and hot water were added to the dry mixture to obtain a homogenous paste. Each mixed diet paste was pelleted by means of a 2-mm die Hobart pelletizer (A-2007 Model, Hobart Ltd, London, UK). The pellets were sun-dried for 48 hours, cooled to room temperature and stored in separate air-tight containers prior to feeding.

Experimental procedure, fish handling and data collection

The study 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 320 *C. gariepinus* fingerlings were procured from a reputable private fish farm in Okitipupa, Ondo State and conveyed in open plastic bowls to the laboratory. The fingerlings were acclimatized to the laboratory conditions in three fibre tanks (1.5 × 1.5 × 0.5 m^3) for 7 days and hand-fed twice daily with 2 mm Coppens feed to visual satiation. Using completely randomized design, six dietary treatments (each having three replicates) were randomly arranged into eighteen treatment units. At the onset of the experiment, 270 similar-sized fingerlings (initial mean weight: 3.83 ± 0.23 g) were batch-weighed using a high-precision OHAUS balance (OHAUS LS, Model 2000) and randomly distributed into 18 plastic aquaria (50 × 40 × 40 cm^3) at a stocking rate of fifteen (15) fingerlings per aquarium containing 20 litres of water each. Fish were hand-fed twice daily (07:00 - 08:00 hrs and 17:00 - 18:00 hrs) at 5% of their body weight in two equal proportions with continuous aeration in each aquarium through an air-stone connected to a central aquarium air pump (UPETTOOLS HD202, New 4W-2 Outlets, UPETTOOLS Company, Amazon, USA). Fish in each aquarium were batch-weighed and the amounts of diets administered were increased weekly according to increase in weight. Six grams of each diet, six pre-experiment fingerlings and three post-experiment fish samples from each treatment were randomly selected and analyzed for their proximate composition according to the standard methods of AOAC (2012). Water temperature in the culture aquaria was measured with mercury-in-glass thermometer, dissolved oxygen concentration read using DO meter (YSI 55 Incorporated, Yellow Springs, Ohio, 4387, USA) while pH values were determined by means of pH meter (LT-Lutron pH-207, Taiwan).

Table 1: Composition of experimental diets (g/100 g dry matter) containing graded levels of cassava root meal replacing yellow maize meal

Dietary ingredients	Diet1 0% BCRM (Control)	Diet2 20% BCRM	Diet3 40% BCRM	Diet4 60% BCRM	Diet5 80% BCRM	Diet6 100% BCRM
Fishmeal	24.18	24.18	24.18	24.18	24.18	24.18
Groundnut cake	24.18	24.18	24.18	24.18	24.18	24.18
Soybean meal	24.18	24.18	24.18	24.18	24.18	24.18
Maize	19.41	15.53	11.65	7.76	3.88	0.00
Cassava meal	0.00	3.88	7.76	11.65	15.53	19.41
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Vit/min premix*	2.00	2.00	2.00	2.00	2.00	2.00
Palm oil	1.00	1.00	1.00	1.00	1.00	1.00
Table salt	1.00	1.00	1.00	1.00	1.00	1.00
Cassava starch	2.00	2.00	2.00	2.00	2.00	2.00
Total(g)	100	100	100	100	100	100

BCRM = Blanched cassava root meal
*Each kilogram of vitamin/mineral premix contained the following:
Vit. A: 1,000,000 IU; Vit. B_1: 250 mg; Vit. B_2: 1750 mg; Vit. B_6: 875 mg; Vit. B_{12}: 2500 mg; Vit. C: 12,500 mg; Vit D_3: 600,000 IU; Vit. E: 12,000 IU; Vit. K_3: 15 mg; Calcium D-pantothenate: 5000 mg; Nicotinic acid: 3750 mg; Folic acid: 250 mg; Cobalt: 24,999 mg; Copper: 1999 mg; Iron: 11,249 mg; Selenium (Na_2SeO_3. $5H_2O$): 75 mg; Iodine (Potassium iodide): 106 mg; Anti-oxidant: 250 mg.
Producer: DSM Nutritional Products Europe Limited, Basle, Switzerland.

Evaluation of growth performance indices
At the end of the feeding trial, growth indices were calculated according to Nwanna *et al.* (2009) as follows:
Mean Weight Gain (g) =
(Final weight − Initial weight) g…… (1)
Total percentage weight gain (TPWG %) =
$$\frac{\text{Weightgain}}{\text{Initialweight}} \times 100 \ \ldots\ldots\ldots (2)$$

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

Evaluation of feed utilization indices
Feed utilization by fish was calculated according to Iheanacho *et al.* (2017) and Adesina and Ikuyeju (2019) as follows:

Feed intake (g) = $WFI_1 + WFI_2 + WFI_3 + WFI_4 + \ldots\ldots WFI_n$...............(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) =
$$\frac{\text{Mean feed intake (g)}}{\text{Weight gain (g)}} \ldots\ldots\ldots (5)$$

Protein Intake (g of protein in 100g diet/fish) =
$$\frac{\text{feed intake} \times \text{\% crude protein in the diet}}{100} (6)$$

Protein Efficiency Ratio (PER) =
$$\frac{\text{Weight gain}}{\text{Protein intake (g of protein in 100g of diet/fish)}} .(7)$$

Nitrogen Metabolism (NM) =
$$\frac{\mathbf{0.549 \times (Initial\ weight + Final\ mean\ weight)t}}{\mathbf{2}} \ldots (8)$$
where: t = experimental period in days
0.549 = metabolism factor
Percentage survival was calculated according to Owolabi (2011) as follows:
Percentage survival (%) =
$$\frac{\text{Total number of survival}}{\text{Total number of fish stocked}} \times 100 \ldots\ldots (9)$$

Statistical analysis
Data collected from this study were subjected to one-way analysis of variance (ANOVA) using SPSS software (Statistical Package for Social Sciences, 22.0 version). Data were presented as means of triplicate values ± standard deviation. Effects of treatments were considered as being significant at $p<0.05$. Significant differences ($p<0.05$) among means were compared and separated using Tukey's multiple range test (Zar, 1996).

RESULTS

Proximate composition of blanched cassava root meal-supplemented diets and carcass of post-feeding *C. gariepinus* fingerlings
Table 2 contains the proximate components of the experimental diets whose values showed significant ($p<0.05$) variations and exhibited an irregular trend. The mean values of crude protein content varied between 39.84 and 40.86% while crude lipid content ranged from 5.31 to 6.36%.Ash content varied irregularly from 7.24 to 9.36% while crude fibre content (8.21 – 10.98%) showed an increasing pattern. Nitrogen-free extract (NFE) also varied irregularly from 26.71 to 27.60% while moisture content (7.10 - 9.38%) showed a reducing trend. Table 3 presents the carcass composition of *C. gariepinus* fingerlings fed with graded dietary levels of blanched cassava root meal (BCRM). Values of proximate indices varied significantly ($p<0.05$) but did not follow a specific pattern. Post-treatment fish carcass had significantly ($p<0.05$) higher crude protein values (66.74 – 69.73%) above the initial 60.83% in the pre-treatment fish. Crude lipid content insignificantly increased from 4.20% to 4.23 – 4.27%.

Table 2: Proximate composition (%) of blanched cassava root meal-supplemented diets fed to *C. gariepinus* fingerlings

Proximate parameters	Diet1 0% BCRM (Control)	Diet 2 20% BCRM	Diet 3 40% BCRM	Diet 4 60% BCRM	Diet 5 80% BCRM	Diet 6 100% BCRM
Crude protein	40.17±0.13 [a]	40.31±0.05[a]	40.86±0.21 [a]	40.59±0.03[a]	40.27±0.42 [a]	39.84±0.51[a]
Crude lipid	6.12±0.23 [a]	6.32±0.17 [a]	5.52±0.21[ab]	6.36±0.33 [a]	5.97±0.18[ab]	5.31±0.63 [b]
Crude fibre	8.23±0.42[c]	8.21±0.33[c]	9.34±0.12[b]	9.57±0.41[ab]	10.26±0.31 [a]	10.98±0.52[a]
Ash	9.12±0.03 [a]	8.43±0.10[b]	8.35±0.23 [b]	7.24±0.51 [c]	7.67±0.42 [c]	9.36±0.13 [a]
Moisture	9.56±0.12 [a]	9.38±0.22 [a]	9.02±0.13 [a]	8.64±0.03 [b]	9.12±0.81 [a]	7.10±0.41[c]
Nitrogen-free extract	26.80±0.33[ab]	27.35±0.01[a]	26.92±0.04[ab]	27.60±0.54[a]	26.71±0.11[b]	27.44±0.31[a]

Mean values with different superscripts along the same row are significantly different ($p < 0.05$).

BCRM = Blanched cassava root meal

Table 3: Carcass composition of *C. gariepinus* fingerlings fed graded levels of blanched cassava root meal-supplemented diets

Proximate parameters	Initial carcass values	Diet1 0% CRM (Control)	Diet 2 20% CRM	Diet 3 40% CRM	Diet 4 60% CRM	Diet 5 80% CRM	Diet 6 100% CRM
Crude protein	60.83±0.23[d]	66.74±0.23[c]	66.87±0.15[c]	69.73±0.12[a]	68.71±0.23[a]	67.76±0.52[b]	68.32±0.31[ab]
Crudelipid	4.20±0.33[a]	4.23±0.13[a]	4.52±0.27 [a]	4.72±0.31 [a]	4.63±0.33 [a]	4.54±0.15 [a]	4.39±0.43[a]
Ash	8.20±0.51[a]	8.42±0.22 [a]	7.55±0.12[ab]	6.76±0.23 [b]	7.23±0.51[ab]	7.29±0.32[ab]	8.24±0.23 [a]
Moisture	8.58±0.13[a]	7.31±0.42[bc]	6.46±0.42[c]	6.36±0.14[c]	7.51±0.33 [b]	6.62±0.31 [c]	7.62±0.23 [b]
Nitrogen-free extract	18.19±0.54[a]	13.30±0.13[c]	14.60±0.21[b]	12.43±0.14[d]	11.92±0.34[d]	13.79±0.31[bc]	11.43±0.21[e]

Mean values with different superscripts along the same row are significantly different ($p < 0.05$).
BCRM = Blanched cassava root meal

Growth and feed utilization of *C. gariepinus* fingerlings fed blanched cassava root meal-supplemented diets

Table 4 presents the result of growth, feed utilization and survival of post-feeding *C. gariepinus* fingerlings. Mean weight gain (MWG) significantly ($p < 0.05$) improved from 12.21 g in fish fed with Diet 1 (control) to the highest level (14.65 g) in fish fed with Diet 4 (60% BCRM) beyond which it assumed a downward trend from 8.36 g in fish fed with Diet 5 to 6.77 g in fish on Diet 6. Likewise, fish fed with Diet 4 had the highest specific growth rate (SGR) value (2.81%/day) while feed conversion ratio (FCR) ranged between 0.87 and 1.62. Protein intake (PI) and protein efficiency ratio (PER) varied between 4.30 – 5.15 g/100g diet/fish and 1.57 – 2.84 respectively.

Table 5 presents the result of water quality indices in the fish culture aquaria monitored and recorded during the experiment. The mean values of temperature and pH significantly exceeded ($p < 0.05$) the initial values. Temperature varied from 27.60 to 27.73°C, dissolved oxygen from 5.37 to 5.40 mg/L while pH varied from 7.65 to 7.73. Fish survival rate (72.00 - 84.50%) significantly differed ($p < 0.05$) among the treatments.

Table 4: Growth performance and feed utilization of *C. gariepinus* fingerlings fed blanched cassava root meal-supplemented diets

Growth indices	Diet 1 0% CRM (control)	Diet 2 20% CRM	Diet 3 40% CRM	Diet 4 60% CRM	Diet 5 80% CRM	Diet6 100% CRM
Initial mean weight (g)	3.83±0.01[a]	3.83±0.26[a]	3.81±0.07[a]	3.83±0.58[a]	3.82±0.47[a]	3.84±0.61[a]
Final mean weight (g)	16.04±1.01[c]	11.97±0.14[d]	17.14±0.22[b]	18.48±0.43[a]	12.18±0.48[d]	10.61±0.34[e]
Mean weight gain (g)	12.21±1.00[c]	8.14±0.15[d]	13.33±0.23[b]	14.65±0.42[a]	8.36±0.47[d]	6.77±0.34[e]
Percentage weight gain (%)	318.80±2.73[c]	212.53±1.15[e]	348.04±3.94[b]	382.51±2.71[a]	218.28±3.01[d]	176.76±2.97[f]
Specific growth rate (%/day)	2.56±0.05[a]	2.03±0.01[b]	2.69±0.05[a]	2.81±0.16[a]	2.07±0.23[b]	1.81±0.02[c]
Total feed intake (g)	544.50±3.41[c]	500.40±2.12[d]	556.65±2.32[b]	571.05±1.04[a]	503.10±1.32[d]	485.55±3.25[e]
Mean feed intake (g)	12.10±0.02[c]	11.12±0.12[d]	12.37±0.21[b]	12.69±0.42[a]	11.18±0.03[d]	10.79±0.11[e]
Feed conversion ratio	0.99±0.10 [c]	1.37±0.03[b]	0.93±0.13[c]	0.87±0.27[c]	1.34±0.04[b]	1.62±0.13[a]
Protein intake	4.86±0.07[b]	4.48±0.13[c]	5.05±0.04[a]	5.15±0.02[a]	4.50±0.21[c]	4.30±0.14[c]
Protein efficiency ratio	2.51±0.01[b]	1.82±0.03[c]	2.64±0.17[a]	2.84±0.31[a]	1.86±0.02[c]	1.57±0.08[c]
Nitrogen metabolism	305.44±2.23[c]	242.88±1.15[d]	322.66±3.35[b]	342.95±2.20[a]	246.26±1.32[d]	221.82±1.13[e]
Percentage survival (%)	79.50±2.31[b]	74.50±1.24[d]	84.50±0.91[a]	84.50±1.23[a]	77.00±2.25[c]	72.00±1.83[d]

Mean values with different superscripts along the same row are significantly different ($p < 0.05$). BCRM = Blanched cassava root meal

Table 5: Water quality parameters measured during the experimental period

Experimental treatments	pH	DO (mg/l)	Temperature (°C)
Initial values	6.76±0.25^{b}	5.41±0.31^{a}	27.15±0.17^{b}
Diet 1 (0% BCRM)	7.68±0.38^{a}	5.39±0.35^{a}	27.60±0.70^{a}
Diet 2 (20% BCRM)	7.71±0.72^{a}	5.40±0.81^{a}	27.63±0.85^{a}
Diet 3 (40% BCRM)	7.72±0.43^{a}	5.39±0.31^{a}	27.73±0.49^{a}
Diet 4 (60% BCRM)	7.73±0.04^{a}	5.38±0.57^{a}	27.68±0.15^{a}
Diet 5 (80% BCRM)	7.70±0.09^{a}	5.37±0.81^{a}	27.71±0.23^{a}
Diet 6 (100% BCRM)	7.65±0.06^{a}	5.39±0.39^{a}	27.73±0.42^{a}

Mean values with different superscripts along the same row are significantly different ($p < 0.05$). BCRM = Blanched cassava root meal

DISCUSSION

This study appraised the effect of substituting graded dietary levels of blanched cassava (*Manihot esculenta*) root meal (BCRM) for maize on the growth, feed utilization and body composition of *C. gariepinus* fingerlings. Crude protein content (39.84 - 40.86%) of diets in this study conformed to the recommended range of 38 - 42% in practical diets that could support optimal growth rate and feed conversion efficiency in *C. gariepinus*. These values were similar to previously reported values such as 38.95 – 39.65% for cassava flour-based diets (Bamidele *et al*., 2018), 40.87 – 41.74% found in whole cassava root meal-based diets (Abu *et al*., 2010) and 41.75 – 44.54% obtained in cassava root flour-based diets (Olurin *et al*., 2006). Besides, the current values exceeded 29.06 – 29.42% recorded for sweet cassava (*Manihot palmata*) root meal-based diets (Dada *et al*., 2015), 31.33 – 32.02% documented for cassava leaf meal-based diets (Madalla *et al*., 2016) and 31.56 – 34.16% found in sweet cassava peel meal-based diets (Ojukannaiye *et al*., 2014). Crude lipid content values (5.31 - 6.36%) were similar to 4.25 – 5.24%, 5.22 – 5.96% and 6.40 – 7.40% respectively reported by Ojukannaiye *et al*. (2014), Olurin *et al*. (2006) and Bamidele *et al*. (2018) but lower compared to 7.57 – 8.03%, 11.05 – 11.44% and 15.03 – 17.23% documented by Abu *et al*. (2010), Madalla *et al*. (2016) and Dada *et al*. (2015) respectively for closely related diets. Ash content values (7.24 - 9.36%) closely harmonized with 8.83 – 10.64% and 9.46 – 9.69% respectively documented by Dada *et al*. (2015) and Madalla *et al*. (2016) for similar diets. However, these values fell slightly below earlier reported values such as 8.68 – 11.03% (Ojukannaiye *et al*., 2014), 10.50 – 12.50% (Bamidele *et al*., 2018), 10.91 – 11.10% (Abu *et al*., 2010) and11.07 – 13.98% (Olurin *et al*., 2006). Crude fibre content (8.21 – 10.98%) exceeded 2.80 – 3.90%, 5.56 – 7.02%, 6.06 – 8.06% and 6.10 – 8.07% respectively reported by Bamidele *et al*. (2018), Ojukannaiye *et al*. (2014), Madalla *et al*. (2016) and Olurin *et al*. (2006) for closely related diets. The current values of ash and crude fibre content harmonized with 8 – 12% recommended for optimal fish growth (Condey, 2002) since values beyond this range usually reduce the digestibility of other dietary ingredients and cause high waste output which may result in water pollution and stunted growth. NFE values (26.71-27.60%) were similar to 25.40 – 27.21% reported by Olurin *et al*. (2006) but lower when compared with 34.53 – 37.50% and 34.76 – 42.93% observed by Madalla *et al*. (2016) and Ojukannaiye *et al*. (2014) respectively. The current values, however, markedly surpassed 6.51 – 6.68% reported by Abu *et al*. (2010) for related diets. Moisture content (7.10 - 9.38%) exceeded 3.26 – 5.06% obtained by Dada *et al*. (2015) but were below 9.31 – 11.00%, 10.10 – 10.86% and 10.50 -12.60% noted by Ojukannaiye *et* *al*. (2014), Abu *et al*. (2010) and Bamidele *et al*. (2018) respectively. The variations observed between the current proximate values and those obtained in previous studies could be due to the effect of morphological differences in plant species, parts of plants used, processing techniques adopted and different ingredient mixtures.

The increased crude protein content of the post-treatment fish carcass signified that BCRM-based diets evidently enhanced protein synthesis and tissue formation in them as earlier observed by Fountoulaki *et al*. (2003) and Yusuf *et al*. (2016) for gilthead bream (*S. aurata*) fingerlings and *C. gariepinus* juveniles respectively. Such improved tissue protein synthesis usually results in increased body weight and fish growth (Fountoulaki *et al*., 2003; Tiamiyu *et al*., 2015). Similar trends of improved carcass crude protein have been reported such as 59.35 – 59.94% found in *C. gariepinus* fingerlings fed with cassava flour-based diets (Bamidele *et al*., 2018) and 14.72 – 16.23% (on fresh weight basis) recorded for *O. niloticus* juveniles fed with cassava leaf meal-based diets (Madalla *et al*., 2016). The generally low body lipid content suggested poor intake of dietary energy. Fish usually utilize lipid reserves stored in parts of their bodies to sustain their metabolic processes when food energy is inadequate and this condition results in the losses of body lipid (Hepher, (1988). However, these values were lower when compared with 6.66 – 8.35% reported for *O. niloticus* juveniles (Madalla *et al*., 2016) and 7.0 – 11.0% for *C. gariepinus* fingerlings (Bamidele *et al*., 2018) fed with related diets. The discrepancies in carcass composition between this study and previous studies probably resulted from variations in fish species, fish size, different ingredient mixtures, feed processing methods, fish handling and culture conditions. The considerable improvement in fish growth and feed utilization signified that BCRM-supplemented diets supported fish growth regardless of the quantities of BCRM included in the diets. The present MWG values agreed with 3.29 – 20.74 g documented for *O. niloticus* juveniles fed with cassava leaf meal-based diets (Madalla *et al*., 2016), 7.67 – 10.46 g found in *O. niloticus* fingerlings fed with sweet cassava peel meal-based diets (Ojukannaiye *et al*., 2014) as well as 10.31 – 11.6 g observed in *C. gariepinus* fingerlings fed with cassava flour-based diets (Bamidele *et al*., 2018). Besides, the current MWG values superseded and implied better growth when compared with 1.57 – 2.15 g and 1.61 – 2.44 g reported for *C. gariepinus* fingerlings fed with cassava root flour-based diets (Olurin *et al*., 2006) and *O. niloticus* fingerlings fed with sweet cassava root meal-based diets (Dada *et al*., 2015) respectively. However, Abu *et al*. (2010) reported higher MWG values (188.37 – 213.41 g) for hybrid catfish (*Heteroclarias*) fingerlings fed with cassava root meal-based diets which could be attributed to much longer culture duration. The disparities in weight gain could be due to variations in their utilization of the tested dietary ingredients as earlier reported by Shabbi *et al*. (2003).

The current SGR values (1.81 – 2.81 %/day) harmonized with 1.15 – 3.17 %/day documented for *O. niloticus* juveniles (Madalla *et al*., 2016) and connoted superior growth rate when compared to 0.30 – 0.46 %/day and 1.13 – 1.24 %/day respectively reported by Dada *et al*., 2015 and Ojukannaiye *et al*., 2014 for *O. niloticus* fingerlings fed with similar diets. The downward growth trend observed with higher BCRM inclusion above 60% level probably resulted from reduced intake, absorption and utilization of experimental diets at higher levels which could be attributed to residual anti-nutrients in the diets (Adewolu, 2008) and high dietary fiber content. Gatlin (2010) likewise affirmed that increasing fibre content beyond a certain threshold could reduce fish growth due to poor digestion of cellulose while Fakunle *et al.* (2013) maintained that toxic components or anti-nutrients in most agricultural by-products may irritate the gastro-intestinal tract and hamper feed intake and growth. Additionally, Aderolu *et al*. (2011) reported that high dietary fibre content reduces the extent of nutrient absorption and causes growth reduction as earlier observed in *C. gariepinus* which Oyelere *et al*. (2016) had reported to manifest low handling of high fibre levels in its diets. Higher inclusion levels of cassava leaf meal which contained cyanogenic glycosides were reported to depress fish growth and feed utilization efficiency (Okoye and Sule, 2001) as well as cause nutrient imbalance associated with plant protein sources (De-Silva and Gunasekara, 1989).

The lowest FCR value (0.90) recorded in fish fed with Diet 4 attested to their superior feed utilization compared to those placed on the control and other diets. In addition, the present FCR values (0.87 – 1.62) harmonized with the ideal range of 1.2 to 1.8 recommended by De Silva (2001) for fish fed with adequately formulated diets. Lower FCR usually signifies better feed utilization by fish. The present FCR values favourably buttressed 1.35 – 1.46 reported for *C. gariepinus* fingerlings (Bamidele *et al*., 2018) and 1.71 – 1.85 for *Heteroclarias* fingerlings (Abu *et al*., 2010) and also depicted more profitable feed utilization efficiency when compared with 1.62 – 2.22 and 1.75 – 2.04 respectively recorded for *O. niloticus* fingerlings (Dada *et al*., 2015; Ojukannaiye *et al*., 2014) as well as 1.45 – 5.02 found in *O. niloticus* juveniles (Madalla *et al*., 2016). The superior PI and PER values found in fish fed with Diet 4 signified superior dietary protein absorption and assimilation when compared with fish placed on the other diets. Besides, the present PI values (4.30 – 5.15 g/100g diet/fish) favourably confirmed 5.33 – 6.51 g/100g diet/fish reported by Ojukannaiye *et al*. (2014) for *O. niloticus* fingerlings fed with similar diets. Similarly, current PER values (1.57 – 2.84) consistently corroborated previously reported values in related studies such as 0.64 – 2.14 found in *O. niloticus* juveniles (Madalla *et al*., 2016), 1.42 – 1.73 for *O. niloticus* fingerlings (Ojukannaiye *et al*., 2014), 1.54 – 1.98 for *Heteroclarias* fingerlings (Abu *et al*., 2010) and 2.60 – 2.94 for *C. gariepinus* fingerlings (Bamidele *et al*., 2018). According to Davis (2004), protein efficiency ratio is an indication of how efficiently the protein constituents in a certain diet can supply the essential amino acids in the fish fed with such a diet.

Values of water quality indices conformed to the acceptable limits recommended for optimal survival of warm-water fish species (Boyd and Gross, 2000). The values also indicated that fish culture conditions throughout the experimental period were adequate and agreed with Chapman (2000) who maintained that *C. gariepinus* could attain optimum growth within 28 - 30^oC, pH range of 6.5 - 9.0 and at a minimum of 5 mg/L dissolved oxygen concentration in the culture medium. The present result showed that the tested diets did not reduce culture water quality conditions below the acceptable levels by fish as reflected in low fish mortality. Moreover, the present observation confirmed the results from previous studies such as 25.4 – 27.9^oC, 5.0 – 6.5 mg/L and 7.1 – 8.7 reported for *C. gariepinus* fingerlings (Olurin *et al*., 2006), 27.11– 29.14^oC, 4.99 – 7.1 mg/L and 6.6 – 8.55 recorded for *Heteroclarias* fingerlings (Abu *et al*., 2010) as well as 27.9 – 28.4^oC, 7.82 – 7.9 mg/L and 6.88 – 7.29 documented for *C. gariepinus* fingerlings (Bamidele *et al*., 2018).

The high survival rate achieved in this study indicated that feeding *C. gariepinus* with graded quantities of BCRM in the diets did not cause significant mortality. This could be attributed to proper handling, suitable water quality conditions, considerable acceptability of the diets by fish and suitability of blanched cassava root meal as a result of appreciable reduction in its cyanide content by boiling and drying. This observation agrees with the findings of Cardoso *et al*. (2005) who stated that adequate processing of cassava root meal enhances fish growth and survival. These survival rates aligned with 71.43 – 100% reported for *C. gariepinus* fingerlings (Olurin *et al*., 2006), 75.80 – 87.45% for *Heteroclarias* fingerlings (Abu *et al*., 2010) and 79.67 – 98% for *O. niloticus* fingerlings (Ojukannaiye *et al*., 2014). However, higher survival rates earlier reported in similar studies included 93.33 – 97.77% for *O. niloticus* fingerlings (Dada *et al*., 2015), 93.33 – 100% for *C. gariepinus* fingerlings (Bamidele *et al*., 2018) and 95.00 – 100% for *O. niloticus* juveniles (Madalla *et al*., 2016).

CONCLUSION AND RECOMMENDATION

Results from this study revealed that blanched cassava root meal effectively replaced maize up to 60% substitution level (that is, 11.65 g/100 g of diet) in the diet of *C. gariepinus* without adversely affecting fish growth, feed utilization and survival. Further inclusion of blanched cassava root meal beyond 60% substitution level caused progressively reduced growth and feed utilization. In view of the nutritional potential of cassava root meal as a low-cost unconventional ingredient and as a viable substitute for maize in the diets of *C. gariepinus*, further studies on possibly more effective processing methods are recommended to reduce the levels of anti-nutrients in cassava root meal, enhance bio-availability of its inherent nutrients and ultimately maximize aquaculture profitability.

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REFERENCES

Abu, O.M.G., Gabriel, U.U. and Akinrotimi, O. A. 2010. Performance and survival of hybrid catfish (Heteroclarias) fed with whole cassava root meal as a replacement for maize. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*, 9 (3), 176 - 183.

Abu, O.M.G., Sanni, L.O., Tarawali, G., Akoroda, M. and Dixon, A. 2009. The effect of replacing maize with whole cassava root meal on the nutrient utilization of hybrid catfish. *Journal of Aquaculture Feed Science and Nutrition*, 1 (3), 60-67.

Aderolu, A., Adekoya, A. and Aarode, O. 2011. Utilization of graded levels of ripe and unripe banana in the diet of hybrid catfish, *Heteroclarias* (*Heterobranchus longifilis* × *Clarias gariepinus)*. International Research on Food Security, Natural Resource Managementand Rural Development Tropentag, University of Bonn. 57, 1-4.

Aderolu, A.Z. and Sogbesan, O.A. 2010. Evaluation and potential of cocoyam as carbohydrate source in catfish (*Clarias gariepinus* Burchell, 1822) juvenile diets. *African Journal of Agricultural Research*, 5 (6), 453-457. DOI: 105897/AJAR09.416.

Adesina, S.A. and Ikuyeju, M.F. 2019. Effects of replacing soybean meal with graded levels of pawpaw *Carica papaya*) leaf meal in the diets of *Clarias gariepinus* fingerlings. *Coast Journal of Faculty of Science (OSUSTECH)*, 1 (1), 130–142.

Adewolu, M. A. 2008. Potentials of sweet potato (*Ipomoea batatas*) leaf meal as dietary ingredient for *Tilapia zillii* fingerlings. *Pakistan Journal of Nutrition*, 7 (3), 444-449.

Akinrotimi, O.A., Gabriel, U.U., Owhonda, N.K., Onukwo, D.N., Opara, J.Y., Anyanwu, P.E. and Cliffe, P.T. 2007. Formulating an environmentally friendly fish feed for sustainable aquaculture development in Nigeria. *Agriculture Journal*, 2 (5), 606 - 612.

Ali, A., Al-Asghah, N.A., Al-Oghaily, S.M. and Ali, S. 2003. Effect of feeding different levels of alfalfa meal on the growth performance and body composition of Nile tilapia (*Oreochromis niloticus*) fingerlings. *Asian Fisheries Science*, 16 (1), 59-67.

AOAC 2012. Official Methods of Analysis (18th Edition). Association of Official Analytical Chemists, Arlington, VA.

Bamidele, N.A., Obasa, S.O., Taiwo, I.O., Abdulraheem, I., Oladoyin, O.S. and Ovie, I.J. 2018. Utilization of enzyme-supplemented fermented cassava root tuber flour-based diets by *Clarias gariepinus* fingerlings. *International Journal of Fisheries and Aquatic Studies*, 6 (2), 117-122.

Boyd, C.E. and Gross, A. 2000. Water use and conservation for inland aquaculture ponds. *Fisheries Management and Ecology*, 7, 55-63.

Cardoso, A.P., Mirione, E., Ernesto, M.,Massaza, F., Cliff, J., Haque, M.R. and Bradbury, J.H. 2005. Processing of cassava roots to remove cyanogens. *Journal of Food Composition Analyses*, 18, 451-460.

Chapman, F.A. 2000. Farm-raised catfish. Department of Fisheries and Aquatic Sciences, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Circular Number: 1052.

Condey, R.E. 2002. Ingestion and limited growth for aquatic animals: the case for blackman kinetics. *Canadian Journal of Fishery and Aquatic Resources*, 23, 112-120.

Dada, A.A., Adeparusi, E.O. and Malomo, E.O. 2015. Dietary utilization of different portions of sweet cassava (*Manihot palmata*) root meal for the Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758). *Journal of Fisheries and Aquatic Science*, 10 (6), 569-574.

Davis, A.R.2004. Correlation of plasma IGF-I concentrations and growth rate in aquacultured finfish: a tool for assessing the potential of new diets. *Aquaculture*, 236, 583–592.

De Silva, S.S. 2001. Performance of *Oreochromis niloticus* fry maintained on mixed feeding schedules of different protein levels. *Aquaculture and Fisheries*, 16, 621-633.

De-Silva, S.S. and Gunasekara, RM. 1989. Effect of dietary protein levels and amount of plant ingredient (*Phaseolus aureus*) incorporated into the diets on consumption, growth performance and carcass composition in *Oreochromis niloticus* (L) fry. *Aquaculture*, 80, 121-133.

Fakunle, J.O., Alatise, S.P., Effiong B.N. and Tiamiyu, K. 2013. Effects of replacing soybean meal with graded levels of boiled Jatropha kernel meal in the diets of *Clarias gariepinus* fingerlings. *Bulletin of Environment, Pharmacology and Life Science*,2 (9), 112-117.

FAO 2012. The State of the World Fisheries and Aquaculture. Food and Agriculture Organization of the United Nations, Rome, Italy, ISBN-13: 9789251072257. Pages: 209.

Faturoti, E.O. and Akinbote, R.E. 1986. Growth responses and nutrient utilization in *Oreochromis niloticus* fed varying levels of dietary cassava peel. *Nigerian Journal of Applied Fisheries and Hydrobiology*,1, 47-50.

Fountoulaki, E., Alexis, M.N., Nengas, I. and Venon, B. 2003. Effects of dietary arachidonic acid (20:4n-6) on growth, body composition and tissue fatty acid profile of gilthead bream (*Sparus aurata* L.) fingerlings. *Aquaculture*, 225, 309-323.

Gabriel, U.U., Akinrotimi, O.A., Bekibele, D.O., Onunkwo, D.N. and Anyanwu, P.E. 2007. Locally produced fish feeds: potentials for aquaculture development in Sub–Saharan African. *Journal of Agricultural Research*, 2 (7), 287–295.

Gatlin, D.M.2010. Principles of fish nutrition. Southern Regional Aquaculture Centre, New York. Publication no. 5003.

Hepher, B.C. 1988. Nutrition of Pond Fishes. Cambridge University Press, England City, United Kingdom. 338 pp.

Iheanacho, S.C., Ogunji, J.O., Ogueji, E.O., Nwuba, L.A., Nnatuanya, I.O., Ochang, S.N., Mbah, C.E., Usman, I.B. and Haruna, M. 2017. Comparative assessment of ampicillin antibiotic and ginger (*Zingiber officinale*) effects on growth, haematology and biochemical enzymes of *Clarias gariepinus* juveniles. *Journal of Pharmacognosy and Phytochemistry.* 6 (3), 761-767.

Madalla, N., Agbo, N.W. and Jauncey, K. 2016. Evaluation of ground - sundried cassava leaf meal as protein source for Nile Tilapia (*Oreochromisniloticus*L) juveniles' diet. *Tanzania Journal of Agricultural Sciences*,15 (1), 1-12.

Ng, W.K. and Wee, K.L. 1989. The nutritive value of cassava leaf meal in pelleted feed for Nile tilapia. *Aquaculture*, 83 (1-2), 45-58.

Nwanna, L.C., Falaye, A.E., Olarewaju, O.J., and Oludapo, B.V. 2009. Evaluation of Nile Tilapia (*Oreochromis niloticus* L) fed dietary potato peels as replacement for yellow maize. FISON Conference proceedings (pp. 156-159).

Ojukannaiye, A.S., Mogaji, O.Y. and Asuwaju, F.P. 2014. Growth response of Nile Tilapia (*Oreochromis niloticus*) fed graded levels of sundried cassava peel meal. *Journal of Fisheries and Aquatic Science*, 9 (5), 382–386.

Okoye, F.C. and Sule, O.D. 2001. Agricultural by-products of arid zone of Nigeria and their utilization in fish feed. In: Eyo A.A. (ed.) Proceedings of 1st National Symposium on Fish Nutrition and Fish Feed Technology, Fisheries Society of Nigeria, Lagos (pp. 8-13).

Olukunle, O. 2006. Nutritive potential of sweet potato peel and root meal replacement value for maize in the diets of Africa catfish (*Clarias gariepinus*) advanced fry. *Journal of Food Technology*, 4 (4), 289-293.

Olurin. K.B., Olojo, E.A.A. and Olukoya, O.A. 2006. Growth of African catfish *Clariasgariepinus* fingerlings fed different levels of cassava. *World Journal of Zoology*, 1 (1), 54 -56.

Orire, A.M, and Ricketts, O.A. 2013. Utilisation of melon shell as dietary energy source in the diet of Nile Tilapia (*Oreochromis niloticus*) *International Journal of Engineering and Science*, 2 (4), 5-11.

Owolabi, O.D. 2011. Haematological and serum biochemical profile of the upside-down catfish (*Synodontis membranacea* Geoffroy Saint Hilaire) from Jebba Lake, Nigeria. *Comparative Clinical Pathololology*, 20, 163-172.

Oyelere, E.A., Balogun, J.K. and Abubakar, B.Y. 2016. Growth and nutrient utilization of African catfish (*Clarias gariepinus* Burchell, 1822) fed varying levels of *Albizia lebbeck* (Benth) leaf meal. *Agrosearch*, 16 (1), 15–24.

Oyelese, O.A. 2007. Utilization of processed snail meal and supplementation with conventional fish meal in the diet of *Clarias gariepinus*. *Journal of Fisheries International*, 2 (2), 140–146.

Pedrosa, G. J. 2002. Evaluation of cassava as potential energy source in animal feed. *Livestock Research for Rural Development*,10 (4), 11-16.

Presston, T.R. 2004. Potential of cassava in integrated farming systems. *Livestock Research for Rural Development*, 10 (8), 20-28.

Salami, R.I. 2000. Preliminary studies on the use of parboiled cassava peel meal as a substitute for maize in layers. *Journal of Aquaculture Nutrition*,10, 20-30.

Shabbir, S., Salim, M. and Rashid, M. 2003. Study on the feed conversion ratio (FCR) in major carp (*Cirrhinus mrigala*) fed on sunflower meal, wheat bran and maize gluten (30%). *Pakistan Veterinary Journal*, 23 (1), 1-3.

Sugiura, S.H., Babbitt, J.K., Dong, F.M. and Hardy, R.W. 2000. Utilization of fish and animal by-product meals in low-pollution feeds for rainbow trout *Oncorhynchus mykiss* (Walbaum). *Aquaculture Research*, 31, 585-593.

Tiamiyu, O.L., Okomoda, T.V. and Agbese, E.V. 2015. Growth performance of *Clarias gariepinus* fingerlings fed *Citrullus lanatus* seed meal as a replacement for soybean meal. *Journal of Aquaculture Engineering and Fisheries Research,* 1, 49-56.

Ufodike, E.B.C. and Matty. A.J. 1983. Growth responses and nutrient digestibility in mirror carp (*Cyprinus carpio*) fed different levels of cassava and rice. *Aquaculture*, 31, 41-46.

Ufodike, E.B.C. and Matty, A.J. 1984. Nutrient digestibility and growth responses of rainbow trout (*Salmo gairdneri*) fed different levels of cassava and rice. *Hydrobiologia*, 119, 83-88.

Wee, K.L. and Ngi, L.T. 1986. Use of cassava as an energy source in a pelleted feed for tilapia (*Oreochromis mossambicus* L). *Aquaculture and Fisheries Management*, 17, 129-138.

Yusuf, A., Umar, R., Micah, D.A. and Akpotu, J.O. 2016. Growth response and feed utilization of *Clarias gariepinus* (Burchell, 1822) juveniles fed graded levels of boiled *Senna obtusifolia* L. seed meal as a replacement for soybean meal. *Journal of Advanced Veterinary and Animal Research*, 3 (4), 345-352.

Zar, J.H. 1996. Biostatistical analysis (3rd Edition). Prentice-Hall International Inc., Upper Saddle River, New Jersey, US. pp. 282-283.