DIETARY EFFECT OF SUBSTITUTING DIFFERENTLY PROCESSED MANGO (*Mangifera indica*) SEED MEAL FOR MAIZE ON GROWTH, FEED UTILIZATION AND BODY COMPOSITION IN *Clarias gariepinus* FINGERLINGS

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ABSTRACT

Rapidly increasing cost of cereal grains, most especially maize, used in fish feed production has resulted in high feed cost and has necessitated consideration for cheaper and locally available substitutes. This study assessed the effect of substituting mango (Mangifera indica) seed meal for maize on the growth performance, feed utilization and body composition in Clarias gariepinus fingerlings. Oven-dried mango seed meal (OMSM), soaked mango seed meal (SMSM), boiled mango seed meal (BMSM) and ash-treated mango seed meal (AMSM) were substituted for maize. Five isonitrogenous diets (at 40% crude protein) were formulated in which four of them had OMSM, SMSM, BMSM and AMSM respectively substituted for maize while the fifth diet (control) lacked mango seed meal. The five dietary treatments were each randomly arranged in triplicates to constitute fifteen treatment units. The diets were fed 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 fifteen glass tanks (50 × 40 × 40 cm^3) for eight weeks. Diets and fish samples were analyzed using standard procedures. Data obtained such as Mean Weight Gain (MWG), Specific Growth Rate (SGR) and Feed Conversion Ratio (FCR) were subjected to descriptive statistics and one-way analysis of variance at p = 0.05. Post-treatment fish carcass crude protein (63.01 – 65.52%) significantly (p<0.05) exceeded the initial value (60.12%). The best MWG (18.34 g), SGR (2.78%/day) and FCR (0.76) were recorded for fingerlings fed with SMSM-supplemented diet and the least MWG (6.34 g), SGR (1.56%/day) and FCR (1.49) in those fed with OMSM-supplemented diet. This study indicated that processed mango seed meal improved fish growth and soaked mango seed meal produced the best growth and feed utilization in C. gariepinus fingerlings.

Keywords: Mango seed kernel; Clarias gariepinus; Anti-nutrients; Processing; Survival rate

INTRODUCTION

Aquaculture has developed rapidly in the past few decades in response to increasing demand for fish, a major source of animal protein globally (Akinrotimi *et al.*, 2007a). This is because fish supply from capture fisheries has reached its maximum capacity as evident in declining daily catch quantities (Gabriel *et al.*, 2007). Consequently, fish supply from capture fisheries will be inadequate to meet the escalating global demand for aquatic food products (FAO, 2006). This situation necessitates a viable alternative fish production system that can sufficiently meet this demand and aquaculture offers a promising option for this role. As aquaculture production becomes progressively intensive in Nigeria, adequate supply of fish feed is highly essential in increasing the productivity and profitability of aquaculture enterprises (Akinrotimi *et al.*, 2007b). According to Gabriel *et al.* (2007), feed cost has been identified as a major factor which determines the viability of aquaculture as it constitutes about 60 – 70 percent of the overall expenses involved in the operation of fish farm enterprises and has in many cases resulted to marginal profits for fish farmers. The need to intensify fish culture with a view to meeting the ever-increasing demand for fish has motivated the search for and development of highly suitable diets as supplementary feeds.

In a bid to maximize nutritional and economic benefits, several research attempts have focused on increasing the use of plant and animal by-products to replace conventional feed ingredients such as fishmeal, soybean, groundnut cake and maize in fish diets (Abu *et al*., 2010; Souza *et al*., 2013; Tiamiyu *et al*., 2015; Ogunji *et al*., 2016; Yusuf *et al*., 2016; Soltanzadeh *et al*., 2017). Maize is readily available and highly digestible in nature; hence it is often used as the major source of metabolizable energy in most formulated diets for catfish species (Olurin *et al.*, 2006). However, the increasingly high cost of maize has prompted a search for alternative sources of energy. FAO (2006) identified shortage in the production of cereals as a crucial food security problem in many countries including Nigeria. Utilization of cereal products, especially maize, in fish feeds is becoming increasingly unjustifiable in economic terms due to their ever-increasing cost (Tewe, 2004) resulting from their increasing demand for humans and livestock consumption. Therefore, in an attempt to maximize aquaculture profit, it is highly imperative to consider cheaper energy sources to replace expensive cereals in fish feed formulation.

Mango (*Mangifera indica*) seed kernel is one of the major by-products of mango fruit. Porter (2011) reported that mango seed kernel has a higher gross energy value of 3527.34 Kcal/Kg than that of maize (3390 Kcal/Kg) reported by Tuleun *et al.* (2005). However, the 6.20%, 6.67% and 6.74% crude protein values respectively were reported for mango seed kernel by Odunsi (2005), Emshaw *et al.* (2012) and Alaily *et al.* (1976) were lower than the 8.80% found in maize as reported by Emshaw *et al*. (2012). In addition, the total carbohydrate (nitrogen-free extract) content earlier reported for mango seed kernels such as 67.4% (Odunsi (2005), 68.1% (Emshaw *et al*., 2012), 77.46% (Alaily *et al*., 1976) and 79.0% (Naveen *et al*., 2006) were similar to 79.1% documented by Emshaw *et al*. (2012) for maize.

Few available literature reports on the substitution of mango seed meal and leaf by-products for maize in fish diets included studies on mango seed meal and Nile tilapia (*Oreochromis niloticus*) fingerlings (Obasa *et al*., 2013; Souza *et al*., 2013) as well as mango leaves and *Clarias gariepinus* fingerlings (Olusola *et al*., 2019, 2020). However, there are few literature reports on the use of mango seed meal as substitute for maize in formulated practical diets for *Clarias gariepinus.* Therefore, this study was conducted to evaluate the effects of substituting mango seed meal for maize on growth performance, feed utilization and body composition in *Clarias gariepinus* fingerlings.

MATERIALS AND METHODS

Processing of mango seed kernels into meals

Fresh ripe mangoes of two (2) mixed local varieties (Alphonso and Kanbiri, mixed in the ratio 1:1) were obtained from Okitipupa market in Okitipupa Local Government Area, Ondo State, Nigeria. The mangoes were peeled using local sharp knives to remove the succulent pulp after which the stony seeds were obtained. The seeds were then split open to extract the solid kernels which were washed in clean water and sliced into smaller pieces to increase their surface area for processing. Four (4) kilograms of the sliced kernels were divided into four portions which were processed by oven-drying, soaking, boiling and ash treatment as follows:

Preparation of oven-dried mango seed meal (OMSM): One (1) kilogram of sliced mango seed kernels was oven-dried at 50°C for 48 hours to obtain a constant weight as described by Afe and Omosowone (2019). The oven-dried kernels were removed and ground into fine powder designated as oven-dried mango seed meal (OMSM) prior to incorporation into the diet.

Preparation of soaked mango seed meal (SMSM): One (1) kilogram of sliced mango seed kernels was soaked in 5 litres of water in a plastic container for 72 hours as illustrated by Rafiu *et al.* (2014). Soaking water was changed at regular intervals of 8 hours for 3 days after which the kernels were removed, drained, sundried to a constant weight for 3 days and ground into fine powder labeled as soaked mango seed meal (SMSM) before inclusion in the diet.

Preparation of boiled mango seed meal (BMSM): One (1) kilogram of sliced mango seed kernels was put in 5 litres of boiling water at 100°C for 20 minutes as demonstrated by Rafiu *et al.* (2014). The boiled kernels were removed, drained, sundried and milled into fine powder referred to as boiled mango seed meal (BMSM) before incorporation into the diet.

Preparation of ash-treated mango seed meal (AMSM): A filtrate obtained from a mixture of wood ash and water (at 500 g wood ash in 5 litres of water) was used to soak one (1) kilogram of sliced mango seed kernels for 48 hours as exemplified by Rafiu *et al*. (2014). The ash-treated kernels were then removed, drained, sundried and milled into fine powder designated as ash-treated mango seed meal (AMSM) before being added to the diet.

Chemical analysis of differently processed mango seed meals

Proximate composition, minerals and metabolizable energy contents of the differently processed mango seed meals were determined according to the recommended procedures of the Association of Official Analytical Chemists (AOAC, 2012).

Experimental diet preparation

Five isoproteic diets comprising a control diet and four test diets (each containing 40% crude protein) were formulated using Pearson's square method (Table 1). The control diet lacked mango seed meal while test diets contained processed mango seed meals as substitute for maize and were designated as oven-dried mango seed meal (OMSM), soaked mango seed meal (SMSM), boiled mango seed meal (BMSM) and ash-treated mango seed meal (AMSM)-based diets respectively. Each diet was separately prepared by thoroughly mixing the dry ingredients inside a bowl after which palm oil and hot water were added to the dry mixture to obtain a homogenous paste. Each mixed diet paste was pelleted using a 2-mm die Hobart pelletizer. The pellets were sun-dried for 48 hours, cooled and stored in separate air-tight containers prior to feeding.

Experimental layout and fish handling

The study was conducted 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 260 *C. gariepinus* fingerlings were bought from a reputable private fish farm in Okitipupa, Ondo State and transported 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 the control diet. Five dietary treatments (each having three replicates) were randomly arranged into fifteen treatment units. At the start of the experiment, 225 same-sized fingerlings (initial mean weight: 4.64 ± 0.31 g) were batch-weighed using a high-precision OHAUS balance (OHAUS LS, Model 2000) and randomly distributed into 15 glass tanks (50 × 40 × 40 cm^3) at a stocking rate of fifteen (15) fingerlings per tank 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 which was divided into two equal portions (2.5%) with continuous aeration in each tank through an air-stone connected to a central glass tank air pump (UPETTOOLS HD202, New 4W-2 Outlets, UPETTOOLS Company, Amazon, USA).

Fish in each tank were batch-weighed and diet quantities administered were increased weekly according to increase in weight. Six (6) grams of each diet, six pre-treatment fingerlings and six post-treatment fish samples from each treatment were randomly selected and analyzed for their proximate composition by standard methods of AOAC (2012). Water temperature was measured with mercury-in-glass thermometer, dissolved oxygen concentration was measured 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: Ingredient composition (g/100 g) of the experimental diets for *C. gariepinus* fingerlings

Dietary ingredients	Dietary treatments				
	Control Diet	OMSM Diet	SMSM Diet	BMSM Diet	AMSM Diet
Mango seed meal	---------	7.82	7.76	7.85	7.73
Yellow maize	15.85	7.82	7.76	7.85	7.73
Fish meal	25.05	25.12	25.16	25.10	25.18
Soybean meal	25.05	25.12	25.16	25.10	25.18
Groundnut cake	25.05	25.12	25.16	25.10	25.18
Bone meal	2.00	2.00	2.00	2.00	2.00
Palm oil	1.50	1.50	1.50	1.50	1.50
Salt	1.50	1.50	1.50	1.50	1.50
Cassava starch	3.00	3.00	3.00	3.00	3.00
Vit/mineral premix*	1.00	1.00	1.00	1.00	1.00
Total (g)	100.00	100.00	100.00	100.00	100.00

*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.
Source: DSM Nutritional Products Europe Limited, Basle, Switzerland
OMSM = Oven-dried mango seed meal; SMSM = Soaked mango seed meal; BMSM = Boiled mango seed meal; AMSM = Ash-treated mango seed meal

Assessment 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, %) = $\frac{\text{Weight gain}}{\text{Initial weight}} \times 100$ ……………… (2)

Specific Growth Rate (%/day) = $\frac{(\text{Ln final weight} - \text{Ln initial weight})}{\text{Time (experimental period in days)}} \times 100$… (3)

where:

Ln = natural logarithm

Assessment 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) = $WFI_1 + WFI_2 + WFI_3 + WFI_4 + \ldots WFI_n$………… (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) = $\frac{\text{Mean feed intake (g)}}{\text{Weight gain (g)}}$ ……………………... (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) = $\frac{0.549 \times (\text{Initial weight} + \text{Final mean weight})t}{2}$ …..(8)

where:

t = experimental period in days

0.549 = metabolism factor

Percentage survival was calculated according to Owolabi (2011) as follows:

Percentage survival (%) = $\frac{\text{Total number of survival}}{\text{Total number of fish stocked}} \times 100$ …… (9)

Statistical analysis

Data generated from this study were subjected to one-way analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2004; Guide Version 9.0). Data were computed as mean of triplicate values ± standard deviation. Effects of treatments were considered as significant at $p<0.05$ while significant differences among means were compared and separated using Duncan's Multiple Range Tests.

RESULTS AND DISCUSSION

Proximate composition of mango seed meals, experimental diets and carcass of *C. gariepinus* fingerlings fed mango seed meal-supplemented diets

Table 2 shows the proximate, mineral and metabolizable energy contents of differently processed mango seed meals. Table 3 presents the proximate components of the experimental diets. The mean values of crude protein content ranged between 39.81 and 40.51 % and were not significantly different ($p>0.05$) among the diets. These values agreed with the range recommended by Degnani *et al*. (1989) and NRC (2011) who reported that dietary protein requirements for warm water fish species ranged from 38 - 42% and 38 - 55% respectively. The current finding also harmonized with 40% protein requirement for *C. gariepinus* as reported by Nwanna *et al*. (2014). Moreover, these values were consistent with 40.03 – 41.22% previously reported for diets supplemented with mango leaf, *Chrysophyllum albidium* seed and Faba bean (*Vicia faba*) seed meals (Jimoh *et al*., 2014; Soltanzadeh *et al*., 2017; Olusola *et al*., 2020) but exceeded 34.63 – 36.78% recorded for diets containing mango seed kernel and flamboyant (*Delonix regia*) seed meals (Obasa *et al*. 2013; Bake *et al*., 2014).

Table 2: Analyzed chemical composition (%) of differently processed mango seed meals and maize

Proximate parameters	OMSM	SMSM	BMSM	AMSM	Maize
Moisture content	9.20^b	9.21^b	10.80^a	8.58^c	8.98^b
Crude protein	6.05^c	6.84^b	6.85^b	6.01^c	8.95^a
Crude lipid	3.01^b	3.62^b	5.36^a	5.15^a	3.32^b
Crude fibre	8.17^a	7.17^b	6.52^c	7.17^b	8.28^a
Ash	9.15^a	8.15^b	8.72^b	7.05^c	9.52^a
Nitrogen-free extract	64.42^c	65.02^b	72.48^a	66.04^b	70.10^a
Calcium (mg/g)	0.30^b	0.41^a	0.37^a	0.29^b	0.04^c
Phosphorus (mg/g)	0.25^a	0.31^a	0.32^a	0.27^a	0.28^a
Metabolizable energy (Kcal/kg)	3165.51^c	3526.24^a	3178.25^c	3285.23^b	3420.16^a

Mean values with different superscripts along the same row were significantly different ($p < 0.05$).
OMSM = Oven-dried mango seed meal; SMSM = Soaked mango seed meal; BMSM = Boiled mango seed meal; AMSM = Ash-treated mango seed meal

Lipids as energy sources are essentially added to formulated diets in order to maximize their protein-sparing effect. The observed crude lipid values (8.78 - 9.23%) aligned with Ross (1985) who reported that 10 – 20% of lipid in diets for some of the freshwater fish families (Cichlidae, Clariidae, Cyprinidae and Clupeidae) usually enhances optimal growth without producing an excessively fatty carcass. The present lipid values were similar to 9.24 – 10.83% reported by Obasa *et al*. (2013) and Bake *et al*. (2014) but exceeded 4.24 – 7.12% recorded for diets supplemented with African yam bean (*Sphenostylis stenocarpa*), mango leaf and watermelon (*Citrullus lanatus*) seed meals (Babale, 2016; Ogunji *et al*., 2016; Olusola *et al*., 2020).

Crude fibre content ranged between 9.86 and 10.32 % and harmonized with the finding of Jauncey (2000) who stated that fibre content above 12% is not desirable in most of the formulated fish diets. High inclusion rate of fibre in fish diets will ultimately result in decrease in nutrient quality. The observed levels of crude fibre content of diets in this study were within the recommended dietary limit for most freshwater fishes. However, these values were higher than 3.13 – 5.98% observed for related diets by other authors (Obasa *et al*., 2013; Jimoh *et al*., 2014; Babale, 2016; Ogunji *et al*., 2016; Olusola *et al*., 2020). Nitrogen-free extract (NFE) which varied from 20.47 to 22.36% aligned with 21.77 – 26.09% obtained in *Tamarindus indica* seed meal-based diets (Bashir and Suleiman, 2018) but were lower compared to previously reported range of 26.72 – 42.45% (Obasa *et al*., 2013; Jimoh *et al*., 2014; Ogunji *et al*., 2016; Soltanzadeh *et al*., 2017; Olusola *et al*., 2020).

The disparities between the current proximate values and values obtained by other authors were probably due to the effect of morphological differences in plant species, parts of plants used, processing methods and different ingredient combinations.

Table 3: Percentage proximate composition of experimental diets

Proximate parameters	Control Diet	Experimental OMSM Diet	Dietary treatments SMSM Diet	BMSM Diet	AMSM Diet
Crude protein	40.43±0.15[a]	39.99±0.71[a]	40.28±0.29[a]	39.81±0.32[a]	40.51±0.09[a]
Crude lipid	9.61±0.35[a]	9.01±0.08[b]	9.12±0.04[b]	9.23±0.41[b]	8.78±0.01[b]
Crude fibre	10.25± 0.31[a]	10.32± 0.41[a]	9.86± 0.12[b]	10.12± 0.42[a]	9.91±0.22[b]
Ash	9.65±0.11[a]	9.18±0.02[b]	9.55±0.23[a]	9.04±0.41[b]	10.17±0.32[a]
Moisture	9.35±0.14[b]	9.27±0.01[b]	10.08±0.21[a]	9.44±0.16[b]	10.16±0.41[a]
Nitrogen-free extract	20.71±0.51[b]	22.23±0.25[a]	21.13±0.43[a]	22.36±0.12[a]	20.47±0.31[b]

Mean values with different superscripts along the same row were significantly different ($p < 0.05$).
OMSM = Oven-dried mango seed meal; SMSM = Soaked mango seed meal; BMSM = Boiled mango seed meal; AMSM = Ash-treated mango seed meal

Table 4 contains the carcass composition of *C. gariepinus* fingerlings fed with mango seed meal-supplemented diets. Values of proximate indices varied significantly ($p<0.05$) across the treatments which suggested that processing methods affected carcass composition. Carcass crude protein values (64.53 – 65.52%) of post-treatment fish fed with diets containing mango seed meal significantly ($p<0.05$) exceeded 63.01% in the control treatment and 60.12% initial value. The observed increase in carcass protein content signified that mango seed meal-supplemented diets obviously enhanced protein synthesis and tissue formation in them as previously reported 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 generally results in increased body weight and fish growth (Fountoulaki *et al*., 2003; Tiamiyu *et al*., 2015). Similar patterns of enhanced carcass crude protein have been reported such as 41.72 – 67.51% found in *C. gariepinus* fingerlings fed with diets containing *C. lanatus* seed, *S. stenocarpa* seed and mango leaf meals (Babale, 2016; Ogunji *et al*., 2016; Olusola *et al*., 2020) as well as 49.99 – 61.29% observed in *O. niloticus* fingerlings fed diets blended with *T. indica* seed and mango seed meals (Obasa *et al*., 2013; Bashir and Suleiman, 2018).

Besides, the present finding also corroborated the earlier observation of Jokthan *et al.* (2003) who reported higher crude protein content in rabbits fed with mango leaves. Post-treatment fish carcass lipid content ranged between 7.99 and 8.73%. This fairly high lipid content implied considerable intake of dietary energy and suggested improved lipid formation in the fish as earlier observed in gilthead bream fingerlings that lipid production was associated with increased efficiency of metabolism (Fountoulaki *et al*. 2003). Fish generally utilize lipid reserves stored in parts of their bodies to sustain their metabolic processes when dietary energy is inadequate and this condition results in the losses of body lipid (Hepher, (1988). The present values closely harmonized with 7.01 – 10.15% recorded for *O. niloticus* fingerlings (Obasa *et al*., 2013; Bashir and Suleiman, 2018) but superseded 3.09 – 6.57% reported for *C. gariepinus* fingerlings (Jimoh *et al.*, 2014; Babale, 2016; Olusola *et al.*, 2020; Ogunji *et al.*, 2016) as well as 5.03 – 6.68% recorded for *O. niloticus* fingerlings fed with flamboyant seed meal-based diets (Bake *et al.*, 2014). The observed differences in carcass composition between this study and previous studies could be due to variations in fish species, fish size, different ingredient mixtures, feed processing methods, fish handling and culture conditions.

Table 4: Carcass proximate composition of *C. gariepinus* fingerlings fed mango seed meal-supplemented diets

Proximate parameters	Initial carcass values	Control Diet	Experimental OMSM Diet	Dietary SMSM Diet	Treatments BMSM Diet	AMSM Diet
Crude protein (%)	60.12±0.5^{c}	63.01±0.30^{b}	65.10±0.05^{a}	64.71±0.58^{a}	64.53±0.81^{a}	65.52±0.8^{a}
Crude lipid (%)	8.51±0.17^{a}	8.48±0.34^{a}	8.25±0.16^{a}	8.16±0.17^{a}	8.73±0.54^{a}	7.99±0.36^{b}
Ash (%)	9.47±0.02^{a}	9.52±0.11^{a}	8.04±0.01^{b}	8.77±0.12^{ab}	8.84±0.01^{ab}	8.41±0.02^{b}
Moisture	9.59±0.0^{a}	8.72±0.12^{ab}	8.29±0.40^{b}	8.98±0.12^{ab}	8.49±0.05^{b}	8.65±0.1^{b}
Nitrogen-free extract (%)	12.31±0.3^{a}	10.27±0.13^{b}	10.45±0.41^{b}	9.38±0.14^{c}	9.42±0.30^{c}	9.44±0.11^{c}

Mean values with different superscripts along the same row were significantly different ($p < 0.05$).
OMSM = Oven-dried mango seed meal; SMSM =Soaked mango seed meal; BMSM = Boiled mango seed meal; AMSM = Ash-treated mango seed meal

Table 5 shows that the values of water quality parameters showed no significant difference ($p > 0.05$) throughout the experimental period except for temperature. Temperature ranged from 27.65 to 28.20°C, dissolved oxygen from 5.29 to 5.70 mg/L while pH varied from 6.58 to 7.52. These values conformed to the recommended limits for optimal fish survival and supported the result obtained by Chapman (2000) who stated that the optimum growth of *C. gariepinus* could be achieved within 28 – 30 °C, pH range of 6.5 – 9.0, and at a minimum of 5 mg/L dissolved oxygen concentration in the culture medium. The present finding signified that the tested diets did not reduce water quality parameters below the tolerance levels to fish and consequently the high percentage survival of *C. gariepinus* recorded could be ascribed to ideal water quality and diets applied. Moreover, the present values agreed with 29.0 – 30.5°C, 6.5 – 8.4 mg/L and 7.6 – 8.7 documented for *O.niloticus* fingerlings fed with mango seed meal-supplemented diets (Obasa *et al*., 2013).

Table 5: Water quality parameters measured during the feeding trial

Dietary treatments	pH	DO (mg/L)	Temperature (°C)
Initial values	6.25 ± 0.08^{a}	5.25 ± 0.01^{a}	25.35 ± 0.47^{b}
Control treatment	6.85 ± 0.35^{a}	5.67 ± 0.01^{a}	27.83 ± 0.20^{a}
OMSM treatment	7.10 ± 0.62^{a}	5.70 ± 0.01^{a}	27.79 ± 0.35^{a}
SMSM treatment	7.52 ± 0.13^{a}	5.35 ± 0.01^{a}	28.20 ± 0.25^{a}
BMSM treatment	6.58 ± 0.42^{a}	5.29 ± 0.01^{a}	27.65 ± 0.60^{a}
AMSM treatment	7.35 ± 0.16^{a}	5.52 ± 0.01^{a}	27.80 ± 0.10^{a}

Mean values with different superscripts along the same row were significantly different at $p < 0.05$. OMSM = Oven-dried mango seed meal; SMSM = Soaked mango seed meal; BMSM = Boiled mango seed meal; AMSM = Ash-treated mango seed meal

Growth and feed utilization of *C. gariepinus* fingerlings fed mango seed meal-supplemented diets

Table 6 contains the result of growth, feed utilization and survival of post-treatment *C. gariepinus* fingerlings. Dietary supplementation with processed mango seed meal in this study generally improved fish growth performance and supported previous findings reported by other authors on similar studies (Omoregie *et al*., 1991; Omoregie, 2001; Obasa *et al*., 2013; Souza *et al*., 2013; Olusola *et al*., 2019, 2020). Mean weight gain (MWG) was highest (18.34 g) in the fish fed with soaked mango seed meal-supplemented diet (SMSM) and lowest (6.34 g) in those placed on oven-dried mango seed meal-supplemented diet (OMSM). The present MWG values (6.34 – 18.34 g) harmonized with 6.98 – 7.11 g reported for *C. gariepinus* (Olusola *et al*., 2020) and 7.95 – 15.74 g in *O. niloticus* (Obasa *et al*., 2013; Bake *et al*., 2014) while it signified better growth when compared with 1.95 – 8.0 g observed in *C. gariepinus* (Jimoh *et al*., 2014; Ogunji *et al*., 2016) as well as 2.25 – 8.58 g in *O. niloticus* fingerlings (Bashir and Suleiman, 2018).

The observed disparities in weight gain in this study and previous studies could be due to variations in their utilization of the tested diets as earlier reported by Shabbir *et al.* (2003). The SGR values (1.56 – 2.78 %/day) closely aligned with 1.19 – 3.32 %/day reported for *C. gariepinus* (Jimoh *et al*., 2014; Babale, 2016; Ogunji *et al*., 2016), 1.31 – 1.74 %/day for *O.niloticus* (Obasa *et al*., 2013) and 1.89 – 2.77 %/day for Beluga (*Huso huso*) fed *V. faba* seed meal-based diets (Soltanzadeh *et al*., 2017). Moreover, the values obtained in this study implied better growth rate in comparison with 0.25 – 0.85 %/day recorded for *O. niloticus* (Bashir and Suleiman, 2018) and 0.93 – 0.94 %/day reported for *C. gariepinus* (Olusola *et al*., 2020). However, Bake *et al.* (2014) reported higher SGR values (3.41 – 4.31 %/day) for *O. niloticus*.

The considerable growth observed in this study also corroborated the findings of Teguia (1995) and Odunsi (2005) who reported significant increase in the body weight of broilers fed diets in which 10% and 20% mango fruit waste respectively replaced maize. In a related study, Rafiu *et al*. (2014) reported better growth rate and feed conversion ratio in layers fed at 15% inclusion level of parboiled and ash-treated mango seed kernel meals. However, Diarra *et al.* (2008) reported reduced growth in broilers fed 5 – 10% inclusion levels of mango seed meal which they attributed to high levels of tannins in mango seed kernels.

Tannins are known to interfere with efficiency of feed utilization which often results in poor feed conversion ratio and reduced growth (Diarra *et al.*, 2008). El Boushy and Vender-Poel (1990) reported that soaking (fermentation) proved most effective in reducing tannins. FCR as an important indicator of feed efficiency in aquaculture is used to assess feed utilization, absorption and conversion to flesh by the fish. FCR values ranged from 0.76 to 1.49 and the least value observed in fish fed with SMSM-supplemented diet indicated better feed utilization compared to those placed on the control and other diets. These FCR values corresponded to 0.73 – 0.8 recorded for *H. huso* (Soltanzadeh *et al*., 2017), 0.75 – 0.97 for *O. niloticus* (Bake *et al*. (2014) and 1.11 – 1.78 for *C. gariepinus* (Jimoh *et al*., 2014;

Babale, 2016). Furthermore, the lower FCR values obtained in this study evidently suggested better feed utilization when compared with 1.63 – 2.78 reported for *O. niloticus* (Obasa *et al*., 2013; Bashir and Suleiman, 2018) and 1.71 – 2.11 reported for *C. gariepinus* (Olusola *et al*., 2020).

The best protein intake (PI) (5.59 g/100 g diet/fish) and protein efficiency ratio (PER) (3.29) recorded for fish fed with SMSM-supplemented diet reflected their superior dietary protein absorption and assimilation compared with fish groups fed with the other diets. The PI values obtained in this study (3.77 – 5.59 g/100 g diet/fish) almost corresponded to 5.37 – 6.79 g/100 g diet/fish reported for *C. gariepinus* juveniles fed with related diets (Olusola *et al*., 2020). PER as an indicator of the quality of dietary protein is also a measure of growth using the dietary protein as an index. Therefore, high weight gain is directly associated with high PER value which in turn depends on the dietary protein intake. The highest PER value observed in the fingerlings fed with SMSM-supplemented diet suggested that the fish could better utilize dietary protein and could also be due to a balance in the composition of amino acids in the diet as observed by Sarker *et al.* (2012). The present PER values (1.68 – 3.28) harmonized with 1.63 – 1.8 reported for *C. gariepinus* (Jimoh *et al*., 2014; Babale, 2016) as well as 2.14 – 2.6 found in *O. niloticus* (Bake *et al*., 2014) but were superior to 0.03 – 1.65 obtained in *O. niloticus* fingerlings and *C. gariepinus* juveniles (Obasa *et al*., 2013; Bashir and Suleiman, 2018; Olusola *et al*., 2020). According to Davis (2004), PER connotes how efficiently the protein components in a particular diet can supply the essential amino acids in the fish fed with such a diet.

The fairly high percentage survival (69.50 – 79.50%) recorded in this study attested to the considerable acceptance of the mango seed meal-supplemented diets by fish. This could be attributed to proper handling, suitable water quality conditions and suitability of processed mango seed meal. Besides, the high survival rate may be linked with the presence of some bioactive compounds, such as polyphenols and xanthones, embedded in the mango seeds that have anti-oxidant properties which may neutralize free radicals in various disease mechanisms as reported by Rodríguez (2006) and Rocha *et al.* (2007). Mango seed kernels have been extensively used in Ayurvedic medicines for treatment of different ailments (Berardini *et al*., 2005). These survival rates agreed with 72.5 – 86.87% reported for *C. gariepinus* (Jimoh *et al*., 2014; Olusola *et al*., 2020) but were lower than 90.6 – 98.0% documented for *O. niloticus* fingerlings (Obasa *et al*., 2013; Bake *et al*. 2014) and 100% for *H. huso* juveniles (Soltanzadeh *et al*., 2017) fed with related diets.

Table 6: Growth and feed utilization of *C. gariepinus* fingerlings fed mango seed meal-supplemented diets

Growth indices	Control Diet	Experimental Dietary Treatments			
		OMSM Diet	SMSM Diet	BMSM Diet	AMSM Diet
Initial mean weight (g)	4.60±0.10^{a}	4.55±0.21^{a}	4.90±0.18^{a}	4.65±0.30^{a}	4.50±0.14^{a}
Final mean weight (g)	11.70±0.20^{d}	10.89±0.11^{e}	23.24±0.17^{a}	12.78±0.31^{c}	14.24±0.29^{b}
Mean weight gain (g)	7.10±0.21^{d}	6.34±0.32^{e}	18.34±0.02^{a}	8.13±0.41^{c}	9.74±0.33^{b}
Percentage weight gain (%)	154.35±0.12^{d}	139.34±0.21^{e}	374.29±0.13^{a}	174.84±0.06^{c}	216.44±0.34^{b}
Specific growth rate (%/day)	1.67±0.11^{d}	1.56±0.04^{e}	2.78±0.23^{a}	1.81±0.21^{c}	2.06±0.10^{b}
Total feed intake (g)	436.95±1.23^{d}	423.90±0.54^{e}	624.15±0.61^{a}	454.50±0.45^{c}	478.35±0.58^{b}
Mean feed intake (g)	9.71±0.01^{c}	9.42±0.13^{c}	13.87±0.31^{a}	10.10±0.21^{b}	10.63±0.01^{b}
Feed conversion ratio	1.37±0.10^{a}	1.49±0.21^{a}	0.76±0.11^{c}	1.24±0.12^{b}	1.09±0.12^{b}
Protein intake	3.93±0.03^{c}	3.77±0.20^{c}	5.59±0.21^{a}	4.02±0.22^{b}	4.31±0.14^{b}
Protein efficiency ratio	1.81±0.43^{c}	1.68±0.32^{c}	3.28±0.15^{a}	2.02±0.51^{b}	2.26±0.18^{b}
Nitrogen metabolism	250.56±0.58^{d}	237.34±1.15^{e}	432.57±0.65^{a}	267.93±1.25^{c}	288.07±1.43^{b}
Percentage Survival (%)	70.00±1.01^{c}	67.50±0.61^{d}	77.50±0.54^{a}	70.00±1.23^{c}	72.50±1.02^{b}

Mean values with different superscripts along the same row were significantly different ($p < 0.05$).
OMSM = Oven-dried mango seed meal; SMSM = Soaked mango seed meal; BMSM = Boiled mango seed meal; AMSM = Ash-treated mango seed meal

CONCLUSION

Results from this study revealed that processed mango seed meal effectively replaced maize in the diet of *C. gariepinus* without adversely affecting growth, feed utilization and survival. Apart from the fish fed with oven-dried mango seed meal whose growth indices fell slightly below those placed on the control diet, the fish fed diet supplemented with soaked mango seed meal manifested the highest values of growth and feed utilization parameters followed by those fed with ash-treated mango seed meal and boiled mango seed meal-based diets. Considering the dietary potential of mango seed meal as an inexpensive unconventional ingredient and as a feasible substitute for maize in the diets of *C. gariepinus*, further studies on other processing methods as well as levels of inclusion are recommended in an attempt to expand the scope of its utilization in aquafeed and ultimately boost aquaculture profitability.

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