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GROWTH RESPONSE AND FEED UTILIZATION IN *Clarias gariepinus* FINGERLINGS FED DIETS SUPPLEMENTED WITH PROCESSED FLAMBOYANT (*Delonix regia*) LEAF MEAL

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ABSTRACT
Expanding utilization of conventional fish feed ingredients by man and fish feed industries has necessitated consideration of cheaper and locally available alternatives. A 70-day feeding trial was conducted to assess the effect of substituting graded levels of sundried flamboyant (Delonix regia) leaf meal (SFLM) for groundnut cake on growth and feed utilization of 240 Clarias gariepinus fingerlings at six substitution levels of 0 (control), 20, 40, 60, 80 and 100% in 12 plastic aquaria (50 × 40 × 40 cm). Each dietary treatment was randomly assigned in two replicates each to the aquaria making 12 treatment units and each aquarium had 20 fish. SFLM-supplemented diets and fish carcass were proximately analyzed using standard procedures. Mean weight gain (MWG), specific growth rate (SGR) and feed conversion ratio (FCR) were determined. Data obtained were analyzed using descriptive statistics and ANOVA at $p \leq 0.05$. Crude protein was highest (68.89%) in fish fed with diet 4, least (64.61%) in fish fed with diet 1 (control) and significantly ($p < 0.05$) exceeded 60.54% of the pre-treatment fish carcass. Fish fed with diet 3 had significantly ($p < 0.05$) higher values of MWG (11.73 g), SGR (2.13%/day) and superior FCR (0.451) above which growth and feed utilization indices progressively declined with increase in the substitution level of SFLM. This study revealed that 40% substitution level of the SFLM resulted in the best growth and feed utilization in C. gariepinus. The study demonstrated the considerable potential of flamboyant leaf meal as an alternative protein source, therefore other processing methods are recommended to increase its utilization, reduce feed cost and maximize aquaculture profitability.

Key words: flamboyant leaf meal, *Clarias gariepinus*, nutrition, survival, growth performance

INTRODUCTION
As the need to improve and sustain human food security particularly among economically challenged developing countries is highly imperative, aquaculture has been identified as an increasingly suitable option for improving animal protein intake from 40 to about 60% in order to achieve expected sustainable development goal (Afe and Omosowone, 2019). This target can only be feasible through identification and utilization of high-quality feedstuffs which are rich in protein and other essential nutrients in a bid to improving growth without compromising the animal's general wellbeing (Soltan and El-Laithy, 2008). Efforts to sustain the consistent global growth of aquaculture industry have necessitated a corresponding increase in high-quality fish feed production (Francis *et al*., 2001). The cost of feed production alone accounts for 40-65% of total operating costs of finfish aquaculture production in Africa, hence the search for cheap and locally available alternative feed ingredients (Bake *et al*., 2014). Protein is the most important nutrient and expensive component of fish feed and protein sources usually constitute about 60% or more in the cost of aqua feed production. According to Tacon (1993), fishmeal has been the most conventionally preferred dietary protein source for many farmed fish and is cherished for its balanced amino acid profile, vitamin content, palatability and unknown growth factors. However, Bake *et al*. (2014) reported that inadequate supply, rising demand and high cost of fishmeal are among several challenges facing the sustainable development of aquaculture industry, hence the need to attempt broader utilization of cheaper protein-rich ingredients from plant and animal sources for the production of cost-effective and eco-friendly fish feeds. Besides, there has been significant emphasis on the utilization of conventional plant protein sources which include soybean seeds (Koumi *et al*., 2009), groundnut seeds (Ovie and Ovie, 2007), cotton seeds (El-Saidy and Gaber, 2004) and rapeseed meal (Burel *et al*., 2000). However, the increasing scarcity of these protein sources and competitive demand from other sectors for human use, livestock consumption and industrial purposes continue to heighten their costs far beyond the reach of most fish farmers and fish feed manufacturers (Fasakin *et al*., 1999).

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Therefore, in order to achieve a more economically sustainable, environmentally friendly and viable fish feed production, research efforts have been geared towards possible consideration and utilization of unconventional sources of protein, particularly those from plants and their by-products such as fruits, seeds, leaves as well as other important agro-allied by-products (Ali *et al*., 2003; Bake *et al*., 2009).

Flamboyant (*Delonix regia*), a leguminous plant belonging to the bean family *Fabaceae* (Subfamily *Caesalpinioideae*; Order *Fabales*), is a wild, beautiful and semi-deciduous tree otherwise known as flame-of-the-forest which originated from Madagascar but is now found wild or grown as an ornamental tree in Nigeria and many parts of the globe (Purseglove, 1994). It can be easily propagated from seeds but takes a long time to germinate. It grows to 12-15 m with its elegant slightly flat or curved wide-spreading umbrella-like crown/canopy sometimes tending to be wider than its height. Its leaflets are less than 12 mm long, opposite in arrangement and are borne on long stalks. Its flowering is spontaneous and usually produces conspicuous scarlet, red or sometimes paler orange-red flowers, being regarded as one of the most spectacular flowering trees of the tropics (Bake *et al*., 2014). During its fruiting season, it produces numerous 25-40 cm long pods/fruits which dangle from the branches, are green and flaccid when young and later turn dark brown or black and hard when mature (Grant *et al*., 1991). On ripening, the mature dry fruit or pod splits open by explosive mechanism into two halves to release the 7-10 elongated hard seeds. Previous studies reported on the use of parts of flamboyant tree in fish nutrition included boiled flamboyant seed meal and Nile tilapia (*Oreochromis niloticus*) fingerlings (Balogun *et al*., 2004), toasted and cooked flamboyant seed meal and *O. niloticus* fingerlings (Bake *et al*., 2013; 2014) as well as raw, fermented and cooked flamboyant seed meal and *Heterobranchus bidorsalis* fingerlings (Oyegbile *et al*., 2017). However, there is a dearth of information on the utilization of flamboyant leaves as a dietary protein ingredient in fish feed formulation. Therefore, this study was conducted to assess the suitability and effect of incorporating sundried flamboyant leaf meal in the formulated diet of *Clarias gariepinus* fingerlings through their growth response and feed utilization.

MATERIALS AND METHODS

Experimental Diet Formulation and Preparation

Eight kilograms of fresh leaves of flamboyant (*Delonix regia*) tree were collected within the campus of Ondo State University of Science and Technology, Okitipupa and taken to the Department of Biological Sciences where they were identified and authenticated by a plant taxonomist. The leaves were sundried for five days and ground into a powdery form using a locally-fabricated grinder. Six iso-nitrogenous (40% crude protein) experimental diets were formulated from commercial ingredients using Pearson's square method (Table 1). Sundried flamboyant leaf meal (SFLM) was substituted for groundnut cake at varied levels of 0 (control diet), 20, 40, 60, 80 and 100% in the diets and were designated as 0% SFLM (Diet 1), 20% SFLM (Diet 2), 40% SFLM (Diet 3), 60% SFLM (Diet 4), 80% SFLM (Diet 5) and 100% SFLM (Diet 6) respectively. The diets were separately prepared by thoroughly mixing the dry ingredients inside a Hobart A-2007 mixer (Hobart Ltd, London, UK) after which palm oil and warm water (at a proportion of 1:2, that is, water to dry diet mixture) were added to the dry mixture to produce a homogenous paste. Each of the separately mixed diet pastes was steam-pelleted through a 2-mm die Hobart pelletizer (A-2007 Model, Hobart Ltd, London, UK). The pellets were dried at 50°C for 48 h in an electric oven (Fan Azma Gostar, BM 55 Model), cooled to room temperature and stored in separate airtight containers prior to use.

Experimental Procedure and Fish Feeding Trial

The ten-week feeding trial was conducted in the Fish Nutrition Research Laboratory of Fisheries and Aquaculture Unit, Department of Biological Sciences, Ondo State University of Science and Technology, Okitipupa, Nigeria. A total of 280 *C. gariepinus* fingerlings (initial body weight: 5.11±0.01 g) were purchased from a reputable local commercial hatchery in Okitipupa, Ondo State. Prior to the feeding trial, the fingerlings were acclimatized to the experimental conditions in four separate plastic tanks with dimension 1 m × 1 m × 0.5 m for 7 days and fed twice daily with 2 mm Coppens commercial feed to visual satiation. At the start of the experiment, 240 closely-sized fingerlings (initial body weight: 5.11±0.01 g) were batch-weighed using a sensitive weighing balance (OHAUS LS, Model 2000) and randomly distributed into 12 plastic aquaria (50 × 40 × 40 cm) at 20 fish per aquarium containing 20 litres of water each. Using completely randomized design, six dietary treatments were randomly assigned in two replicates each to the experimental aquaria making twelve treatment units. Fish were manually fed twice daily (07:00 and 17:00 h) at 5% of their body weight administered in two equal portions with continuous aeration in each aquarium through an air-stone connected to a central UPETTOOLS aquarium air pump (HD202 New 4W-2 Outlets, manufactured by UPETTOOLS Company, Amazon, USA). Temperature of the water culture medium in the aquaria was measured using mercury-in-glass thermometer, dissolved oxygen values measured using Hydrolab Model "Multi 340I/SET" while pH values were determined by means of pH meter (Jenway 3015 pH meter).

Table 1: Ingredient composition (g/100 g diet) of experimental diets containing graded levels of sundried flamboyant leaf meal

Dietary ingredients	Dietary treatments					
	Diet 1 0% SFLM (control)	Diet 2 20% SFLM	Diet 3 40% SFLM	Diet 4 60% SFLM	Diet 5 80% SFLM	Diet 6 100% SFLM
Fishmeal	20.47	20.47	20.47	20.47	20.47	20.47
Soybean meal	20.47	20.47	20.47	20.47	20.47	20.47
Groundnut cake	40.94	32.75	24.56	16.38	8.19	-------
Flamboyant leaf meal	-------	8.19	16.38	24.56	32.75	40.94
Yellow maize	10.14	10.14	10.14	10.14	10.14	10.14
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix	1.50	1.50	1.50	1.50	1.50	1.50
Palm oil	1.00	1.00	1.00	1.00	1.00	1.00
Salt	1.00	1.00	1.00	1.00	1.00	1.00
Starch	2.50	2.50	2.50	2.50	2.50	2.50
Total (g)	100.00	100.00	100.00	100.00	100.00	100.00

SFLM - sundried flamboyant leaf 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

Determination of Proximate Analyses of Experimental Diets and Fish Carcass

Eight grams each of the diet and sun-dried flamboyant leaf meal, six pre-treatment fish specimens and four post-treatment fish specimens per treatment were randomly collected and kept frozen to determine the proximate composition of experimental diets and fish carcass. Dry matter (at 105°C for 24 h), crude protein (nitrogen × 6.25, using Kjeldahl apparatus), crude lipid (extracted with petroleum ether by Soxhlet apparatus), total ash (by incineration at 600°C for 6 h in a Gallenkamp blast furnace chamber, Gallenkamp, UK), moisture content (by oven-drying to a constant weight in a Gallenkamp oven) and nitrogen-free extract (by subtracting other values from 100%) were analyzed according to the standard methods of AOAC (2011). The analyses were conducted in the Department of Animal Production & Health, Federal University of Technology, Akure, Nigeria. Proximate composition of ingredients used in the experimental diets is presented in Table 2.

Biological Assessment of Fish Growth and Feed Utilization Indices

Growth and feed utilization indices of the fish were calculated as follows:

i. $Mean\ weight\ gain\ (MWG) = (W_2 - W_1)\ g$ (Iheanacho *et al*., 2017); where W_1 is initial mean weight (g), and W_2 is final mean weight (g).

ii. $Percentage\ weight\ gain (\%) = \frac{Mean\ weight\ gain\ (g) \times 100}{Initial\ mean\ weight\ (g)}$ (Adesina and Ikuyeju, 2019)

iii. $\boldsymbol{Feed\ intake\ (g)}$ = $WFI_1 + WFI_2 + WFI_3 + \ldots WFI_n$; where WFI is weekly feed intake of fish per treatment (g), and 1, 2, 3, … *n* represent first week to the last week of the experimental duration.

iv. $\boldsymbol{Feed\ conversion\ ratio\ (FCR)} = \frac{\boldsymbol{Mean\ feed\ intake\ (g)}}{\boldsymbol{Mean\ weight\ gain\ (g)}}$ (Adesina and Ikuyeju, 2019)

v. $Specific\ growth\ rate \left(\frac{\%}{\text{day}}\right) = \frac{(\text{Ln Wf} - \text{Ln Wi}) \times 100}{t\ (days)}$ (Adesina and Ikuyeju, 2019); where Ln W_f is natural logarithm of the fish final weight; Ln W_i is natural logarithm of the fish initial weight; and *t* is experimental duration in days.

vi. $\boldsymbol{Protein\ intake\ \left(g\ of\ protein\ in\ 100g \frac{diet}{fish}\right)} = \frac{\boldsymbol{feed\ intake \times \%\ crude\ protein\ in\ diet}}{\boldsymbol{100}}$ (Adesina and Ikuyeju, 2019)

vii. $\boldsymbol{Protein\ efficiency\ ratio\ (PER)} = \frac{\boldsymbol{Mean\ weight\ gain}}{\boldsymbol{Mean\ protein\ intake\ (g\ of\ protein\ in\ 100g\ of\ diet/fish)}}$ (Adesina and Ikuyeju, 2019)

viii. $Nitrogen\ metabolism\ (NM) = \frac{0.549 \times (Wi+Wf)t}{2}$ (Nwanna, 2003); where W_i is initial mean weight of fish; W_f is final mean weight of fish; *t* is experimental period in days; and 0.549 is metabolism factor.

ix. $\boldsymbol{Percentage\ survival,\ PS}(\%) = \frac{\boldsymbol{Final\ number\ of\ fish\ harvested \times 100}}{\boldsymbol{Initial\ number\ of\ fish\ stocked}}$ (Adesina and Ikuyeju, 2019)

Statistical Analysis

Data obtained on the effects of substituting sundried flamboyant leaf meal for groundnut cake on growth, feed utilization and body composition of *C. gariepinus* fingerlings 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 replicate values ± standard deviation. Effects of treatments were considered as being significant at $p < 0.05$. Significant ($p < 0.05$) differences among means were compared and separated using Tukey's multiple range test (Zar, 1996).

RESULTS

Proximate Composition of Test Ingredient and Experimental Diets

Table 2 shows the proximate composition of sundried flamboyant leaf meal and other ingredients used in the experimental diets. Proximate analysis showed that flamboyant leaf meal had high levels of crude protein and nitrogen-free extract. The result of experimental diets is shown in Table 3. There was no significant difference ($p > 0.05$) in the crude protein values of the experimental diets. However, values of the crude lipid, total ash, crude fibre, moisture and nitrogen-free extract contents in the experimental diets showed significant difference ($p < 0.05$).

Body Composition of *C. gariepinus* Fingerlings Fed Flamboyant Leaf Meal-Based Diets

Chemical composition of experimental fish carcass (Table 4) followed an irregular pattern and exhibited significant ($p < 0.05$) variations among the treated fish, hence indicating that inclusion of sundried flamboyant leaf meal affected body composition of experimental fish. Crude protein values in the experimental fish carcasses were significantly different ($p < 0.05$) from the values of the pre-treatment fish carcass. Likewise, the values of the crude lipid, total ash, nitrogen-free extract and moisture contents observed in the experimental fish carcass showed significant difference ($p < 0.05$).

Physico-Chemical Parameters of Fish Culture Water in Experimental Aquaria

Table 5 shows the results of the physico-chemical parameters of water quality recorded in the experimental units throughout the experimental duration which were not significantly different ($p > 0.05$) among all treatments. Dissolved oxygen varied from 5.84 to 6.39 mg l^{-1}, temperature from 26.49 to 27.53°C and pH from 7.59 to 7.83.

Table 2: Proximate composition (%) of dietary ingredients used in this study

Proximate parameters	Fish meal	Soybean meal	Groundnut cake	Sundried flamboyant leaf meal	Corn meal
Crude protein	70.36	45.12	44.12	24.72	9.86
Crude lipid	10.53	10.15	9.72	5.61	3.25
Crude fibre	----------	6.23	8.25	10.20	20.57
Total ash	9.65	7.52	8.53	8.94	7.68
Moisture	9.46	9.76	10.63	9.67	11.01
Nitrogen-free extract	---------	21.22	18.75	40.86	47.63

Table 3: Proximate composition of sundried flamboyant leaf meal-based experimental diets fed to *C. gariepinus* fingerlings

Proximate parameters	Diet1 (Control)	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Ash (%)	11.56 ± 0.11^{b}	11.69 ± 0.02^{b}	11.74 ± 0.23^{b}	12.13 ± 0.11^{ab}	12.32 ± 0.31^{ab}	13.05 ± 0.02^{a}
Crude protein (%)	40.03 ± 1.01^{a}	39.97 ± 0.51^{a}	39.84 ± 0.41^{a}	40.22 ± 0.49^{a}	40.39 ± 0.41^{a}	39.92 ± 0.60^{a}
Crude lipid (%)	8.22 ± 0.21^{a}	7.63 ± 0.04^{b}	8.71 ± 0.11^{a}	9.01 ± 0.32^{a}	8.92 ± 0.03^{a}	9.04 ± 0.23^{a}
Crude fibre (%)	6.14 ± 0.01^{b}	6.52 ± 0.12^{ab}	$6.64\pm0.11^{a\ b}$	6.88 ± 0.02^{a}	6.32 ± 0.14^{b}	7.31 ± 0.31^{a}
Moisture (%)	8.42 ± 0.31^{b}	9.36 ± 0.23^{a}	9.42 ± 0.11^{a}	8.58 ± 0.13^{b}	8.39 ± 0.21^{b}	9.22 ± 0.02^{a}
Nitrogen-free extract (%)	25.63 ± 0.51^{a}	24.83 ± 0.25^{a}	24.65 ± 0.43^{a}	23.90 ± 0.12^{b}	23.66 ± 0.31^{b}	21.46 ± 0.21^{c}

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

Table 4: Body composition of *C. gariepinus* fingerlings fed flamboyant leaf meal-based diets

Proximate parameters	Initial Pre-treatment carcass values	Diet 1 (control)	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Crude protein (%)	60.54 ± 0.58^{d}	64.61 ± 0.30^{c}	66.32 ± 0.05^{b}	68.58 ± 0.58^{a}	68.89 ± 0.81^{a}	67.48 ± 0.86^{b}	64.72 ± 0.76^{c}
Crude lipid (%)	6.84 ± 0.17^{a}	6.87 ± 0.34^{a}	6.49 ± 0.16^{a}	6.64 ± 0.17^{a}	5.84 ± 0.54^{b}	6.33 ± 0.36^{a}	6.34 ± 0.42^{a}
Ash (%)	5.22 ± 0.02^{a}	5.71 ± 0.11^{a}	5.41 ± 0.01^{a}	4.24 ± 0.12^{b}	4.27 ± 0.01^{b}	5.59 ± 0.02^{a}	6.10 ± 0.01^{a}
Nitrogen-free extract (%)	16.20 ± 0.06^{a}	13.83 ± 0.12^{c}	13.32 ± 0.40^{c}	13.53 ± 0.12^{c}	13.37 ± 0.05^{c}	14.17 ± 0.12^{b}	14.24 ± 0.06^{b}
Moisture (%)	11.22 ± 0.32^{a}	8.98 ± 0.13^{b}	8.46 ± 0.41^{b}	7.01 ± 0.14^{c}	7.63 ± 0.30^{c}	6.43 ± 0.11^{d}	8.60 ± 0.23^{b}

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

Table 5: Physico-chemical parameters of fish culture water in experimental aquaria

Dietary treatments	pH	DO (mg/l)	Temperature (°C)
Initial values	7.35 ± 0.15^{a}	6.43 ± 0.01^{a}	26.15 ± 0.20^{a}
Treatment 1 (0% SFLM)	7.59 ± 0.37^{a}	5.84 ± 0.21^{a}	26.60 ± 0.32^{a}
Treatment 2 (20% SFLM)	7.65 ± 0.25^{a}	6.39 ± 0.37^{a}	27.23 ± 0.15^{a}
Treatment 3 (40% SFLM)	7.74 ± 0.43^{a}	5.87 ± 0.42^{a}	26.78 ± 0.21^{a}
Treatment 4 (60% SFLM)	7.47 ± 0.16^{a}	6.41 ± 0.17^{a}	26.49 ± 0.07^{a}
Treatment 5 (80% SFLM)	7.83 ± 0.35^{a}	6.32 ± 0.41^{a}	27.41 ± 0.28^{a}
Treatment 6 (100% SFLM)	7.71 ± 0.04^{a}	5.95 ± 0.32^{a}	27.53 ± 0.20^{a}

Mean values with similar superscripts along the same row were not significantly different ($p > 0.05$).

Growth and Feed Utilization of *C. gariepinus* Fingerlings Fed Graded Levels of Sundried Flamboyant Leaf Meal-Based Diets

Table 6 shows the growth and feed utilization indices which exhibited significant ($p < 0.05$) variations in the fish exposed to the experimental diets. Acceptability of the experimental diets significantly ($p < 0.05$) increased in fish fed diets 1 to 3 beyond which it then assumed a reducing trend with increase in the substitution level of sundried flamboyant leaf meal. Mean weight gain (MWG) and specific growth rate (SGR) were highest (11.73 g and 2.13% day^{-1}, respectively) in fish fed diet 3 and lowest (9.06 g and 1.82% day^{-1}, respectively) in those fed diet 6. MWG and SGR significantly ($p < 0.05$) increased in fish fed diets 1 to 3 beyond which they assumed a declining trend in those fed diets 4 to 6. Values (0.451-0.514) recorded for the feed conversion ratio (FCR) showed significant ($p < 0.05$) variations across treatments, with fish fed diet 3 indicating efficient feed utilization. Values recorded for the protein intake (PI), protein efficiency ratio (PER) and percentage survival (PS) showed significant ($p < 0.05$) variations across treatments and fish fed with diet 3 had the highest values of these indices.

DISCUSSION

Result of proximate analysis showed that flamboyant leaf meal had high levels of crude protein (24.72%) and nitrogen-free extract (40.86%). According to Auta and Anwa (2007), a criterion for a feedstuff to be regarded as a potential protein source is that its crude protein level must exceed 20%. This implies that flamboyant leaf meal has a considerable potential as a good source of protein for fish. The proximate composition of the experimental diets administered to *C. gariepinus* fingerlings in this study fell within the range expected to support ideal fish growth (Li *et al*., 2014). The lack of significant variations in the crude protein values indicated absence of bias while compounding the experimental diets. The values agreed with the acceptable range (28-39%) for ideal catfish growth (Borgstorm, 1992) and also supported 39.98 to 40.01% reported by Adegbesan *et al*. (2018) for *Aloe barbadensis* leaf meal-based diets. Crude lipid values agreed with 10-20% lipid in fish diets which generally supports optimal growth rate without producing an excessively fatty carcass (Tibbetts and Lall, 2013). The values, however, exceeded 4.15-5.05% documented by Dienye and Olumuji (2014) for *Moringa oleifera* leaf meal-based diets. Values of ash content were closely similar to 11.50-13.70% documented by Anyanwu *et al*. (2008) for *Alchornia cordifolia* leaf meal-based diets. The highest value of ash obtained in diet 6 could be attributed to its highest inclusion of sundried flamboyant leaf meal. The values of ash and crude fibre contents obtained in this study favourably aligned with 8-12% recommended for optimal fish growth (Condey, 2002), since higher ash and crude fiber contents generally reduce the digestibility of other feed ingredients in the diet and result in high waste output which may cause water pollution and poor growth. Values of moisture content observed in the experimental diets nearly corresponded to 7.31-9.81% obtained by Dienye and Olumuji (2014) for *M. oleifera* leaf meal-based diets while the values recorded for nitrogen-free extract, however, were lower than 34.83-36.61% obtained by Dienye and Olumuji (2014). The variations between the observed proximate values in this study and other related studies could be due to the influence of environmental factors on the seeds (Akajiaku *et al*., 2014), morphological differences in plant species, processing methods and variations in ingredient combinations.

The fact that all experimental diets significantly increased the protein content of *C. gariepinus* fingerlings implied that there was enhanced protein synthesis and tissue formation as reported by Fountoulaki *et al*. (2003) and Yusuf *et al*. (2016) for gilthead bream (*Sparus aurata*) fingerlings and *C. gariepinus* juveniles respectively. Comparable trends of improved carcass crude protein were documented for *C. gariepinus* fingerlings fed *M. oleifera* leaf meal-based diets (60.03-62.47%) (Dienye and Olumuji 2014) and *Azadirachta indica*

Table 6: Growth response and feed utilization of *C. gariepinus* fingerlings fed graded levels of sundried flamboyant leaf meal-based diets

Growth Parameters	Diet 1 (control)	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Initial mean weight (g)	5.12±0.10^{a}	5.11±0.21^{a}	5.11±0.18^{a}	5.10±0.30^{a}	5.10±0.14^{a}	5.12±0.05^{a}
Final mean weight (g)	14.54±0.20^{b}	14.62±0.11^{b}	16.84±0.17^{a}	14.60±0.31^{b}	14.48±0.24^{bc}	14.18±0.41^{c}
Mean weight gain (g)	9.42±0.21^{b}	9.51±0.32^{b}	11.73±0.02^{a}	9.50±0.41^{b}	9.38±0.33^{b}	9.06±0.14^{b}
Percentage weight gain (%)	183.98±0.12^{c}	186.11±0.21^{b}	229.55±0.13^{a}	185.91±0.06^{b}	183.56±0.12^{c}	176.95±0.03^{d}
Specific growth rate (%/day)	1.86±0.11^{b}	1.88±0.04^{b}	2.13±0.23^{a}	1.88±0.21^{b}	1.86±0.10^{b}	1.82±0.12^{c}
Total feed intake (g)	189.58±1.23^{b}	190.35±0.54^{b}	211.66±0.61^{a}	190.26±0.45^{b}	189.01±0.58^{b}	186.13±0.60^{c}
Mean feed intake (g)	4.74±0.01^{b}	4.76±0.13^{b}	5.29±0.31^{a}	4.76±0.21^{b}	4.73±0.01^{b}	4.65±0.12^{c}
Feed conversion ratio	0.503±0.10^{b}	0.500±0.21^{b}	0.451±0.11^{c}	0.501±0.12^{b}	0.504±0.12^{b}	0.514±0.03^{a}
Protein intake	1.89±0.03^{b}	1.90±0.20^{b}	2.11±0.21^{a}	1.91±0.22^{b}	1.91±0.14^{b}	1.86±0.31^{b}
Protein efficiency ratio	4.96±0.43^{b}	5.00±0.32^{b}	5.57±0.15^{a}	4.96±0.51^{b}	4.91±0.18^{b}	4.88±0.41^{b}
Nitrogen metabolism	302.21±0.58^{b}	303.29±1.15^{b}	337.42±0.65^{a}	303.14±1.25^{b}	301.29±1.43^{b}	296.68±1.06^{c}
Percentage survival (%)	75.00±1.01^{b}	77.50±0.61^{b}	82.50±0.54^{a}	77.50±1.23^{b}	75.00±1.02^{b}	72.50±0.51^{c}

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

leaf meal-based diets (66.12-67.86%) (Anyanwu *et al*., 2015). Crude lipid values closely harmonized with 5.84-6.31% and 4.10-7.63% reported for *C. gariepinus* fingerlings fed *M. oleifera* leaf meal-based diets (Dienye and Olumuji 2014) and *A. indica* leaf meal-based diets (Anyanwu *et al*., 2015) respectively. Ash content values were much below 16.90-18.32% reported by Afe and Omosowone (2019) for *C. gariepinus* fingerlings fed with *Acacia auriculiformis* leaf meal-based diets. Values of moisture content contradicted those obtained by Afe and Omosowone (2019) in *C. gariepinus* fingerling which showed no significant variation. Values of nitrogen-free extract harmonized with those reported by Afe and Omosowone (2019) which followed a reducing trend in *C. gariepinus* fingerlings. Variations in fish body composition between this study and other studies could be due to interspecies' genetic variations, different plant-based ingredients and processing techniques used as well as influence of environmental factors/culture conditions. The values of the physico-chemical parameters of water quality measured in the experimental units were within the ideal range of values recommended for successful culture of tropical warm-water fishes such as *C. gariepinus*. These values corroborated those reported by Idowu *et al*. (2020) on juvenile *O. niloticus* treated with graded *Kigelia africana* stem bark aqueous extract. Similar findings were documented by Tolan and Sherif (2007), Musa *et al*. (2013) and Samkelisiwe and Ngonidzashe (2014) in related laboratory-based fish nutritional studies using different plant parts as dietary supplements. Water temperature, dissolved oxygen and pH are among important parameters in fish culture which significantly affect feed and/or protein intake and growth either positively or negatively. The result also harmonized with that of Okechi (2004) who reported 25-30ºC as optimum temperature for warm-water fish culture. These results indicated that processed flamboyant leaves can be profitably used in aquaculture as they did not impair the ideal water quality conditions.

Incorporation of sundried flamboyant leaf meal in the diets of *C. gariepinus* fingerlings in this study resulted in considerable improvement in their growth and feed utilization. Similar observations have been reported on *O. niloticus* and *Heterobranchus bidorsalis* fingerlings fed with differently processed flamboyant seed meal (Balogun *et al*., 2004; Bake *et al*., 2013, 2014; Oyegbile *et al*., 2017). Fish fed with diet 3 had the best growth and feed utilization indices which obviously indicated optimal diet utilization that was not feasible at higher substitution levels as growth progressively declined with increasing substitution levels. The higher values of MWG and SGR in fish fed with diet 3 clearly suggested that they optimally converted feed to flesh when compared with those fed with the other diets. The slightly lower growth response by fish fed with diet 6 is attributed to reduced palatability of the diet which probably resulted from low feed intake. The SGR values obtained in this study suggested superior growth response compared to 0.25-0.59% day^{-1} reported by Adesina and Ikuyeju (2019) for *C. gariepinus* fingerlings fed pawpaw leaf meal-based diets and 0.44-1.81% day^{-1} observed by Anyanwu *et al*. (2008) for hybrid *Heteroclarias* (*H. bidorsalis* × *C. gariepinus*) fingerlings fed *A. cordifolia* leaf meal-based diets.

Lower feed conversion ratio (FCR) indicates better feed utilization by the fish. According to De Silva (2001), an ideal feed conversion ratio ranges between 1.2 and 1.8 for fish fed carefully prepared diets and FCR values in the present study were slightly below this range. In addition, the present FCR values suggested better feed utilization compared to 1.71-1.85 reported for *Heteroclarias* fingerlings fed cassava root meal-based diets (Abu *et al*., 2010) and 1.31-3.30 documented by Dienye and Olumuji (2014) for *C. gariepinus* fingerlings fed *M. oleifera* leaf meal-based diets. The ability of an organism to effectively absorb and utilize dietary nutrients, especially protein, will positively enhance its growth performance. This was justified by the best protein intake, protein efficiency ratio (PER) and growth performance indices recorded for fish fed with diet 3. The current protein intake values indicated better dietary protein assimilation when compared with 0.18-0.29 g 100 g^{-1} diet per fish reported by Anyanwu *et al*. (2008) for *Heteroclarias* fingerlings as well as 0.84-1.33 g 100 g^{-1} diet per fish observed by Adesina and Ikuyeju (2019) for *C. gariepinus* fingerlings. Similarly, the PER values obtained in this study suggested superior dietary protein utilization compared to 1.54-1.98 reported for *Heteroclarias* fingerlings fed cassava root meal-based diets (Abu *et al*., 2010) and 1.67-2.58 recorded by Oyelere *et al*. (2016) for *C. gariepinus* fingerlings. According to Davis (2004), protein efficiency ratio is a measure of how effectively the protein sources in a diet can supply the needed essential amino acids in the fish fed with such a diet. The observed fish survival rate in this study corresponded to 76.26-87.45% reported by Abu *et al*. (2010) for *Heteroclarias* fingerlings and also indicated better survival in comparison with 48.00% to 86.00% recorded by Anyanwu *et al*. (2015) for *C. gariepinus* fingerlings. Such high level of survival indicated that feeding *C. gariepinus* fingerlings with sundried flamboyant leaf meal did not cause serious fish mortality. Besides, it reflected adequate acceptability of the experimental diets by fish which could be attributed to good handling, adequate water quality management, proper feed processing to substantially reduce anti-nutrients and suitability of sundried flamboyant leaf meal inclusion in the diet of *C. gariepinus*. However, higher survival values (90.00-96.67% and 93.33-100.00%) have been reported for *C. gariepinus* fingerlings fed *A. lebbeck* (Oyelere *et al*. 2016) and *M. oleifera* (Dienye and Olumuji, 2014) leaf meal-based diets, respectively.

CONCLUSION

The results from this study showed that substitution of sundried flamboyant leaf meal as an alternative protein source for groundnut cake in *C. gariepinus* fingerlings' diet above 40% caused reducing growth and decreased feed utilization. The study, therefore, indicated that processed flamboyant leaf meal could efficiently replace groundnut cake up to 40% in the diets of *C. gariepinus* without obvious deleterious effects on its growth response, feed utilization and survival. The acceptance of the experimental diets in this study as reflected by the feed utilization indices has established the flexibility of *C. gariepinus* fingerlings to efficiently utilize a wide range of unconventional feed ingredients. Other processing methods are recommended with a view to increasing the utilization of flamboyant leaf meal which has a considerable potential in reducing the cost of production of fish feed and thereby maximize aquaculture profitability.

CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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