Ife Journal of Agriculture, 2023, Volume 35, Number 2

DIETARY SUPPLEMENTATION WITH BOILED FLAMBOYANT (*Delonix regia*) SEED MEAL ENHANCED GROWTH PERFORMANCE, FEED UTILIZATION AND SURVIVAL OF *Clarias gariepinus* JUVENILES

ADESINA* S. A. AND ADETORO B. O.

Department of Fisheries and Aquaculture Technology, School of Agriculture, Food and Natural Resources, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria
**Corresponding Author: simonadesina3@gmail.com; (+234)08028574784*

ABSTRACT

Scarcity and escalating costs of conventional fish feed ingredients have continued to necessitate consideration of cheaper and accessible alternatives. An eight-week feeding trial was conducted to evaluate the effect of substituting boiled flamboyant (Delonix regia) seed meal (BFSM) for groundnut cake in the diet of Clarias gariepinus juveniles. A total of 360 C. gariepinus juveniles (mean weight; 6.5±0.32 g) were randomly stocked in 18 plastic aquaria (50 × 40 × 40 cm). BFSM replaced groundnut cake at 0 (control), 20, 40, 60, 80 and 100% (designated diets 1, 2, 3, 4, 5 and 6 respectively). Diets and whole-fish carcasses were proximately analyzed using standard procedures. Mean Weight Gain (MWG), Specific Growth Rate (SGR), Feed Intake (FI), Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER), Nitrogen metabolism (NM) and Percentage Survival (PS) were assessed. Data obtained were analyzed by means of descriptive statistics and ANOVA at P≤0.05. Final carcass crude protein (60.2 –62.4%) significantly (p < 0.05) exceeded 57.41% in the pre-experimental fish. Fish placed on Diet 3(40% BFSM supplementation) had the best values (p < 0.05) of MWG (54.75 g), SGR (4.01%/day), FI (71.92 g), FCR (1.31), and NM (1041.45). Growth and feed utilization indices improved up to 40% BFSM supplementation while higher BFSM supplementation (60 – 100%) caused a progressively diminishing trend in the growth and feed utilization indices. This study has demonstrated that a 40% substitution level of boiled flamboyant seed meal for groundnut cake yielded the best growth and feed utilization in C. gariepinus juveniles.

Keywords: ***Flamboyant seed meal, Clarias gariepinus, Groundnut cake, Growth response, Anti-nutrients***

INTRODUCTION

There has been a remarkable development in the aquaculture feed industry in the past few years. This is partly due to the intensification of aquaculture as the fastest-growing sector of the global animal production industry, with an average annual rate of about 10.3% since 2010 and has produced 89% of the total global volume of animal production within the last 20 years (FAO, 2020). A steady supply and the cost of procuring feed are major concerns in the aquaculture business (Pati *et al*., 2016; Dawood, 2021). The cost of feed supply is a critical factor as it usually constitutes about 40 – 70% of the total operational cost of sustainable fish farming for all species and thereby largely influences profitability in aquaculture investments (Muzinic *et al*., 2006; Danial, 2018; Dossou *et al*., 2021). This has necessitated research into alternative protein sources that can lessen the perennial over-dependence on conventional protein sources such as fish meal, soybean cake and groundnut cake, whose escalating costs are gradually getting beyond the reach of many small-scale fish farmers. The vast availability of plant-based protein sources and their relatively affordable costs have made them more viable alternative ingredients (Zulhisyam *et al*., 2020). The identification and development of alternative plant protein ingredients have received growing interest in the expanding global aquaculture sector (Azarm and Lee, 2014; Goda *et al*., 2014; Mzengereza *et al*., 2021).

According to Sinyangwe *et al*. (2017), formulated diets administered to the African catfish, *Clarias gariepinus*, are sometimes inadequate due to a shortage of nutrients in the recommended quantity and quality. In an attempt to achieve large-scale catfish farming profitability, concerted efforts must be made to ensure that the African catfish is farmed in sufficient quantities and produced in acceptable quality. This becomes imperative since poor fish farming systems and inadequate fish feed quality are presently among the major challenges facing African catfish farming. To surmount these challenges, fish nutritionists are currently considering alternative approaches to feed manufacture and administration such as incorporating alternative protein sources from plants and animals in the compounded diets. Flamboyant (*Delonix regia*) seed has been identified as a promising unconventional plant protein ingredient that, when properly processed, has a considerable inherent nutritional potential for use in feeds for aquaculture species. Proximate analysis of flamboyant seed has shown that it contains 25.11 - 29.58% crude protein, 7.31 – 15.16% crude lipid, 4.14 – 6.48% crude ash, 9.83 – 14.6% crude fibre, 23.33 – 48.34% nitrogen-free extract (carbohydrate) and 5.78 – 10.12% moisture (Bake *et al*., 2014; Bake *et al*., 2016a; Oyedeji *et al*., 2017; Abulude *et al*., 2018).

Past studies conducted on the utilization of flamboyant seeds in fish nutrition included boiled flamboyant seed meal for Nile tilapia (*Oreochromis niloticus*) fingerlings (Balogun *et al*., 2004), toasted and cooked flamboyant seed meal for *O. niloticus* fingerlings (Bake *et al*., 2013; 2014), raw, fermented and cooked flamboyant seed meal for *Heterobranchus bidorsalis* fingerlings (Oyegbile *et al*., 2017) as well as toasted flamboyant seed meal for *C. gariepinus* fingerlings (Bake *et al*., 2016a). From the foregoing, it is evident that, despite available literature on the nutrient composition and nutritional potential of flamboyant seed meal, information concerning its incorporation as a protein ingredient in the formulated diets for *C. gariepinus* juveniles still remains scanty. Therefore, this study was carried out to appraise the suitability and effect of incorporating graded levels of boiled flamboyant seed meal in the diet on growth performance, feed utilization and survival of *C. gariepinus* juveniles.

MATERIALS AND METHODS

Study location

This eight-week feeding trial was carried out between January and March 2022 in the Fish Nutrition Research Laboratory of the Department of Fisheries and Aquaculture Technology, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria.

Procurement and processing of flamboyant seeds

Six kilograms (6kg) of flamboyant seeds used for this study were manually extracted from mature and dry flamboyant pods. The seeds were boiled at 100^{o}C for 80 minutes (Bake *et al*., 2014), drained, sundried for two days and then pulverized in a locally fabricated grinding machine into a homogenous powder which was stored in an air-tight container at room temperature pending its incorporation in the diets.

Formulation and preparation of experimental diets

Other ingredients were bought from a reputable feed mill and ground separately into a powdery form. Six iso-nitrogenous (40% crude protein) experimental diets were formulated from various ingredients as shown in Table 1. Boiled flamboyant seed meal (BFSM) was substituted for groundnut cake at graded levels of 0 (control diet without BFSM), 20, 40, 60, 80 and 100% in the diets which were respectively labelled as Diet 1, Diet 2, Diet 3, Diet 4, Diet 5 and Diet 6. The diets were individually prepared by thoroughly mixing the dry ingredients inside a mixer (Hobart A-2007 Model, Hobart Ltd, London, UK) after which palm oil and warm water were added to homogenize the dry mixture into a uniform paste. Each of the diet pastes was steam-pelleted via a 2-mm die Hobart pelletizer (A-2007 Model, Hobart Ltd, London, UK). The pellets were sufficiently sundried for three days, cooled to room temperature and kept in separate air-tight containers prior to use.

Experimental fish

A total of 400 *C. gariepinus* juveniles were procured from a reputable commercial hatchery in Okitipupa, Ondo State. The juveniles were acclimated to the experimental conditions in four fibreglass tanks (1 m × 1 m× 0.5 m) for 7 days and fed twice daily with 2 mm commercial (@ Coppens) feed to visual satiation.

Experimental design and fish handling procedure

This study adopted a completely randomized design in which six dietary treatments were randomly allotted in three replicates each. At the commencement, 360 uniform-sized fish (initial mean weight: 6.5±0.32 g) were weighed in batches on a high-precision weighing balance (OHAUS LS, Model 2000) and randomly distributed into 18 plastic aquaria (50 × 40 × 40 cm^3) at twenty fish per aquarium holding 20 litres of water each. Diets were administered manually to fish twice daily (07:00 - 08:00 and 17:00 - 08:00 hrs) at 5% body weight in two equal rations with continuous aeration in each aquarium through an air-stone connected to a central air pump (HD202 New 4W-2 Outlets, UPETTOOLS Company, Amazon, USA). The temperature of the aquaria water was measured via a mercury-in-glass thermometer, dissolved oxygen values were measured through the Hydrolab Model “Multi 340I/SET” while pH values were read using a pH meter (Jenway 3015 pH meter). Juveniles in each aquarium were batch-weighed weekly and weight changes were recorded.

Proximate analysis of experimental diets and fish carcass composition

Eight grams (8 g) of each diet sample, 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 carcasses. The proximate parameters analyzed were crude protein, crude lipid, crude fibre, total ash, moisture content and nitrogen-free extract (AOAC, 2011).

Table 1: Gross ingredient composition (g/100g diet) of experimental diets

Dietary ingredients	0%BFSM Diet1	20% BFSM Diet 2	40% BFSM Diet 3	60% BFSM Diet 4	80% BFSM Diet 5	100% BFSM Diet 6
Flamboyant seed meal	0.00	8.16	16.32	24.48	32.64	40.80
Groundnut cake	40.80	32.64	24.48	16.32	8.16	0.00
Fishmeal	20.40	20.40	20.40	20.40	20.40	20.40
Soybean meal	20.40	20.40	20.40	20.40	20.40	20.40
Yellow maize	10.40	10.40	10.40	10.40	10.40	10.40
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
Salt	1.00	1.00	1.00	1.00	1.00	1.00
Vegetable oil	1.00	1.00	1.00	1.00	1.00	1.00
Cassava 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

BFSM = Boiled flamboyant seed meal

Vitamin/mineral premix: 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. K3: 15mg; 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.

Biological Evaluation of Feed Utilization and Fish Growth Performance

The following growth and feed utilization parameters were evaluated according to Adesina and Agbatan (2021):

$$Mean\ weight\ gain\ (MWG) = (W_2 - W_1)\ g$$

where: W_1 = initial mean weight (g); W_2 = final mean weight (g)

$$Percentage\ weight\ gain (\%) = \frac{Mean\ weight\ gain (g) \times 100}{Initial\ mean\ weight (g)}$$

$$Feed\ intake\ (g) = WFI_1 + WFI_2 + WFI_3 + WFI_4 + \ldots\ldots WFI_n$$

where: WFI= weekly feed intake of fish per treatment (g); 1, 2, 3, 4,……..n= first week to the last week of the experimental duration

$$Feed\ conversion\ ratio (FCR) = \frac{Mean\ feedintake (g)}{Mean\ weightgain (g)}$$

$$Specific\ growth\ rate (\%/\text{day}) = \frac{(\text{Ln Wf} - \text{Ln Wi}) \times 100}{t\ (days)}$$

where: Ln W_f = natural logarithm of the fish final weight; Ln W_i= natural logarithm of the fish initial weight; t= experimental duration in days.

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

$$Protein\ efficiency\ ratio\ (PER) = \frac{Mean\ weight\ gain}{Mean\ protein\ intake\ (g\ of\ protein\ in\ 100\ g\ of\ diet/fish)}$$

$$Nitrogen\ metabolism\ (NM) = \frac{0.549 \times (Wi + Wf)\ t}{2}$$

where: W_i= initial mean weight of fish; W_f= final mean weight of fish; t= experimental period in days; 0.549 = metabolism factor

$$Percentage\ survival,\ PS(\%) = \frac{Final\ number\ of\ fish\ harvested \times 100}{Initial\ number\ of\ fish\ stocked}$$

Statistical Analysis

The data obtained on proximate indices, feed utilization, growth and carcass composition of *C. gariepinus* juveniles were analyzed by means of one-way analysis of variance (ANOVA) using the SPSS Statistics 22.0 version (IBM, USA). The differences among treatment groups were determined using Tukey's multiple range tests and were considered as being statistically significant at $p < 0.05$ (Zar, 1996). All the data presented in this study were expressed as means of triplicate values ± standard deviation.

RESULTS AND DISCUSSION

Table 2 shows the proximate composition of raw and boiled flamboyant seed meals used in this study. The values observed were similar to most of the values previously reported by other authors with slight variations (Bake *et al*., 2014; Bake *et al*., 2016a; Abulude *et al*., 2018). Such variations may be attributed to differences in environmental conditions and the processing methods used. Besides, the increase in the crude protein and lipid contents of the boiled flamboyant seed meal could be associated with the processing method used. This observation agrees with the assertion that thermal treatment of plant-based protein ingredients improves their proximate composition, especially protein and lipid, as previously reported (Francis *et al*., 2001; Fagbenro and Davis, 2003; Solomon *et al*., 2007; Fapohunda, 2012).

Table 2: Proximate composition of raw and boiled flamboyant seed meal used in this study

Proximate Parameters	Raw FSM in this study	Boiled FSM used in this study	*Raw FSM used in previous studies	*Processed FSM used in previous studies
Crude protein	24.05	27.25	22.45 – 23.42	25.11 – 35.97
Crude lipid	4.52	6.53	4.6 – 5.68	7.3 – 9.77
Crude fibre	6.34	8.69	-----------	9.83
Ash	7.73	6.64	6.35 – 8.79	4.14 – 6.48
Nitrogen-free extract	27.68	29.36	-----------	23.33
Moisture	6.73	8.56	3.74 – 4.02	3.24 – 8.4

*** Bake *et al*., 2014; Bake *et al*., 2016a; Abulude *et al*., 2018; FSM - Flamboyant Seed meal**

Table 3 shows the proximate composition of the experimental diets used in this study. Values of crude protein, crude lipid and nitrogen-free extract indicated significant difference ($p < 0.05$) while crude fibre, ash and moisture content values were not significantly different ($p > 0.05$). These values were observed to fall within the expected range that is suitable to enhance ideal fish growth (Li *et al*., 2014). Crude protein values (38.44 – 41.63%) conformed to the acceptable range (28-39%) for ideal catfish growth (Borgstorm, 1992) and also corroborated the range of values (31.75 – 41.57%) previously reported by other authors on differently processed seed meal-supplemented diets (Bake *et al*., 2016a, 2016b; Bake *et al*., 2020; Michael and Mathias, 2020; Zulhisyam *et al*., 2021; Michael *et al*., 2021). However, the variations in crude protein values showed an irregular pattern that did not directly correspond to the observed trend of growth and feed utilization indices in the experimental fish. Crude lipid values (6.58 – 8.13%) were slightly below 10 - 20% lipid in formulated fish diets which usually supports optimal growth rate without resulting in an excessively fatty carcass (Tibbetts and Lall, 2013).

The non-significant disparities in the values of crude fibre, ash and moisture components implied the absence of bias while formulating the experimental diets. The observed values of crude fibre (12.31 – 13.24%) and ash components (11.36 – 12.01%) respectively exceeded 4.52 - 6.93% and 5.72 - 10.83% earlier recorded by other workers (Bake *et al*., 2014; Bake *et al*., 2016b; Bake *et al*., 2020; Zulhisyam *et al*., 2021; Michael *et al*., 2021). Besides, the current values of crude fibre and ash closely conformed to the 8-12% recommended for optimal fish growth (Condey, 2002), since higher crude fibre and ash contents normally reduce the digestibility of other ingredients in the diet and thereby result in high waste production which may cause water pollution and poor growth.

Values of nitrogen-free extract (NFE) (17.59 – 21.17%) almost corresponded to 13.16 – 28.73% obtained by Michael and Mathias (2020) as well as Michael *et al*. (2021) but fell below 40.29 - 45.72% found in soybean pulp-supplemented diets (Zulhisyam *et al*., 2021). The observed disparities in the values of dietary proximate parameters in this study and previous related studies could be attributed to the effect of environmental factors on the seeds (Akajiaku *et al*., 2014), morphological differences in plant species, different processing methods used and variations in ingredient combinations.

Table 4 shows the chemical composition of post-experimental fish carcass whose values followed an irregular trend and manifested significant ($p < 0.05$) variations in crude protein, ash, nitrogen-free extract and moisture content while crude lipid values were not significantly different ($p > 0.05$). The significant increase in the final carcass protein content of post-experimental *C. gariepinus* juveniles evidently indicated improved protein synthesis and new tissue formation as previously reported by Fountoulaki *et al*. (2003) and Yusuf *et al*. (2016) for gilthead bream (*Sparus aurata*) fingerlings and *C. gariepinus* juveniles respectively. Similar trends of enhanced carcass crude protein have been documented for *C. gariepinus* fingerlings and juveniles fed diets supplemented with meals produced from variously processed flamboyant, soybean pulp, lablab bean, lima bean, calabash, sickle-pod, African mesquite, locust bean and sword bean seeds (Bake *et al*., 2014, 2016a, 2016b, 2020; Aliu and Osaro, 2018; Michael and Mathias, 2020; Jibrin *et al*., 2018; Michael *et al*., 2021; Zulhisyam *et al*., 2021). Final carcass crude lipid values (8.27 – 9.83%) followed an irregular pattern as they increased progressively in the fish fed Diets 1 to 3 and then gradually diminished in those fed Diets 4 to 6. The values also exhibited non-significant variations which plausibly suggested that increasing inclusion levels of boiled flamboyant seed meal in the diets did not result in corresponding increase in fat deposition in the fish across the six treatments. This finding, however, disagreed with the progressively increasing fat deposition observed in *C. gariepinus* fingerlings fed toasted flamboyant seed meal-supplemented diets (Bake *et al*., 2016a). These values surpassed 1.5 – 6.68% recorded by other authors (Bake *et al*., 2014, 2016a, 2016b, 2020; Jibrin *et al.*, 2018) but were lower than 13.47 – 15.12% found in *C. gariepinus* fingerlings fed toasted lablab bean meal (Aliu and Osaro, 2018). The observed differences in fish carcass composition between this study and previous related studies could be attributed to interspecies' genetic variations, different plant-based ingredients used, processing methods employed and influence of environmental factors or culture conditions.

Table 3: Proximate composition of graded levels of boiled flamboyant seed meal-supplemented diets fed to *C. gariepinus* juveniles

Proximate indices	Diet 1 Control	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Crude protein	40.91 ± 1.09^{bc}	38.44 ± 0.6^{a}	40.71 ± 0.59^{bc}	41.03 ± 0.46^{bc}	40.05 ± 0.07^{b}	41.63 ± 1.07^{c}
Crude lipid	6.58 ± 0.43^{a}	7.92 ± 0.18^{b}	8.13 ± 0.12^{b}	7.92 ± 0.2^{b}	8.01 ± 0.06^{b}	8.09 ± 0.92^{b}
Crude fibre	13.06 ± 0.15^{a}	12.79 ± 0.94^{a}	12.91 ± 1.05^{a}	13.24 ± 0.67^{a}	12.31 ± 0.53^{a}	12.32 ± 0.53^{a}
Ash	12.34 ± 0.78^{a}	11.92 ± 0.83^{a}	12.01 ± 0.28^{a}	11.49 ± 0.57^{a}	11.46 ± 0.69^{a}	11.36 ± 0.65^{a}
Nitrogen-free extract	18.69 ± 1.03^{ab}	21.17 ± 0.75^{c}	17.59 ± 0.5^{a}	18.86 ± 1.29^{ab}	19.38 ± 1.01^{b}	18.29 ± 0.44^{ab}
Moisture	8.41 ± 1.03^{a}	7.76 ± 0.87^{a}	7.99 ± 0.95^{a}	7.57 ± 0.89^{a}	8.78 ± 0.86^{a}	8.32 ± 0.76^{a}

Mean values with different superscripts a,b, c, etc. along the same row are significantly different ($p < 0.05$).

BFSM = Boiled Flamboyant Seed Meal

Table 4: Carcass proximate composition of *C. gariepinus* juveniles fed graded levels of boiled flamboyant seed meal-supplemented diets

Proximate indices	Initial carcass values	Diet 1 Control	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Crude protein	57.41 ± 1.21^{a}	61.26 ± 0.76^{bc}	60.53 ± 0.97^{bc}	60.50 ± 0.8^{bc}	61.56 ± 1.06^{bc}	62.40 ± 1.9^{c}	60.20 ± 0.6^{b}
Crude lipid	8.27 ± 0.43^{a}	8.51 ± 0.61^{a}	9.66 ± 0.96^{a}	9.83 ± 0.93^{a}	9.57 ± 0.73^{a}	8.27 ± 1.23^{a}	9.12 ± 0.38^{a}
Ash	11.45 ± 1.45^{ab}	10.63 ± 0.57^{a}	11.68 ± 0.98^{ab}	13.54 ± 0.84^{c}	11.83 ± 0.67^{ab}	10.58 ± 0.72^{a}	12.90 ± 0.6^{bc}
Nitrogen-free extract	10.24 ± 1.26^{d}	10.04 ± 1.54^{cd}	8.55 ± 0.15^{bcd}	6.53 ± 1.27^{a}	7.99 ± 0.31^{ab}	9.07 ± 1.13^{bcd}	8.25 ± 0.35^{abc}
Moisture	12.70 ± 1.4^{b}	9.61 ± 0.89^{a}	9.62 ± 1.12^{a}	9.59 ± 0.99^{a}	9.03 ± 0.28^{a}	9.71 ± 0.21^{a}	9.75 ± 0.95^{a}

Mean values with different superscripts a,b,c, etc. along the same row are significantly different ($p < 0.05$).

BFSM = Boiled Flamboyant Seed Meal

Table 5 shows that the values of the water quality parameters monitored in the culture aquaria throughout the experimental period were not significantly different ($p > 0.05$) among the six treatments. Dissolved oxygen ranged from 5.42 to 6.4 mg/L, pH from 7.37 to 7.64 and temperature from 26.5 to 27.62°C. The values of the water quality parameters monitored in this study fell within the normal range of values recommended for profitable culture of warm-water fish species such as *C. gariepinus*. The observed values aligned with those of Okechi (2004) who reported 25 - 30°C as optimal temperature range for the culture of *C. gariepinus*. Furthermore, the present values also supported those previously reported by Musa *et al.* (2013) and Samkelisiwe and

Ngonidzashe (2014) in similar studies involving *C. gariepinus* fingerlings in which different plant parts were used as dietary supplements. Water pH, dissolved oxygen and temperature are among important factors in fish culture which significantly affect diet intake and inherent nutrients' utilization as well as growth either positively or negatively. The current results suggested that boiled flamboyant seed meal can be profitably incorporated in aquaculture feed without impairing the ideal water quality conditions of the culture medium.

Table 5: Water quality parameters of fish culture aquaria

Dietary treatments	Dissolved oxygen (mg/L)	pH	Temperature (°C)
Initial values	6.40±0.2[a]	7.52±0.26[a]	26.50±0.41[a]
Diet 1	5.54±0.52[a]	7.46±0.43[a]	27.36±0.06[a]
Diet 2	6.20±0.41[a]	7.58±0.42[a]	26.53±0.51[a]
Diet 3	5.42±0.26[a]	7.37±0.56[a]	27.48±0.42[a]
Diet 4	6.25±0.37[a]	7.64±0.32[a]	27.24±0.06[a]
Diet 5	6.08±0.62[a]	7.51±0.52[a]	27.39±0.37[a]
Diet 6	5.46±0.53[a]	7.61±0.15[a]	27.62±0.28[a]

Mean values with different superscripts a,b,c, etc. along the same row are significantly different ($p < 0.05$). BFSM = Boiled Flamboyant Seed Meal

Table 6 shows the growth response and feed utilization parameters which revealed significant ($p < 0.05$) variations in mean values for *C. gariepinus* juveniles. Acceptance of the experimental diets vis-à-vis corresponding weight gain significantly ($p < 0.05$) increased in the fish fed Diets 1 to 3 (0% - 40% BFSM) beyond which it then manifested an irregularly declining trend with increase in the substitution level of boiled flamboyant seed meal. Values of Mean weight gain (MWG) and specific growth rate (SGR) were highest (54.75 g and 4.01% day^{-1} respectively) in fish fed Diet 3 and least (41.89 g and 3.58% day^{-1} respectively) in those fed Diet 6. MWG and SGR significantly ($p < 0.05$) increased in fish fed Diets 1 to 3 and thereafter followed a diminishing trend in those fed Diets 4 to 6 (60% -100% BFSM).

Supplementation of boiled flamboyant seed meal in the diets of *C. gariepinus* juveniles in this study led to appreciable improvement in growth and feed utilization. Similar findings have been reported on *C. gariepinus*, *O. niloticus* and *Heterobranchus bidorsalis* fingerlings fed with differently processed flamboyant seed meal-supplemented diets (Balogun *et al*., 2004; Bake *et al*., 2013, 2014, 2016a; Oyegbile *et al*., 2017). Fish fed with Diet 3 (40% BFSM supplementation) had the best growth and feed utilization indices which evidently indicated optimal diet utilization that nevertheless was not achievable at higher substitution levels as growth steadily declined with increasing substitution levels. The significantly superior values of mean weight gain (MWG) and specific growth rate (SGR) attained by juveniles fed Diet 3 obviously suggested their superlative conversion of dietary nutrients to flesh when compared with those fed with the other diets.

The significantly lower growth response exhibited by juveniles fed with Diets 4 to 6 (60 - 100% BFSM supplementation) could be attributed to diminishing palatability of the diets which possibly resulted from low feed intake. Likewise, the least weight gain achieved by fish fed Diet 6 could be linked with the presence of anti-nutrients in the experimental diets which possibly increased vis-à-vis increase in BFSM supplementation level. This observation concurs with Bake *et al.* (2013, 2014 and 2016a) who found significantly lower levels of phytic acid, tannin, oxalate, cyanide and trypsin-inhibitor activity (TIA) in the toasted and boiled flamboyant seed meals than in the raw meal. The present finding also agrees with the report of Akande and Fabiyi (2010) that most anti-nutrients inactivate some major dietary nutrients by inhibiting the digestive process or metabolic utilization of feed which in turn impairs optimum nutrition. Similar patterns of diminishing growth response were observed beyond 40% supplementation levels in *C. gariepinus* fingerlings fed sundried pawpaw and flamboyant leaf meal as well as toasted flamboyant seed meal-supplemented diets (Bake *et al*., 2016a; Adesina and Ikuyeju, 2019; Adesina and Agbatan, 2021). Besides, the higher SGR values (3.58 – 4.01%day^{-1}) obtained in this study closely harmonized with 3.11 – 4.88%day^{-1} observed in *C. gariepinus*, *O. niloticus* and *Heteroclarias* fingerlings (Bake *et al*., 2014, 2016a, 2016b, 2020) while they suggested better growth performance when compared with 0.27 – 1.9%day^{-1} previously reported on *C. gariepinus* and *Heteroclarias* fingerlings fed differently processed seed meal-supplemented diets (Aliu and Osaro, 2018; Michael and Mathias, 2020; Michael *et al*., 2021; Jibrin *et al*., 2021; Zulhisyam *et al*., 2021).

The range of values (1.31 - 1.51) documented for feed conversion ratio (FCR) revealed significant ($p < 0.05$) variations across the six treatments, with fish fed Diet 3 manifesting the most efficient feed utilization. Similarly, values obtained for protein intake (PI), protein efficiency ratio (PER), nitrogen metabolism (NM) and percentage survival (PS) showed significant ($p < 0.05$) variations across the treatments. The low feed conversion ratio (FCR) values (1.31 – 1.51) recorded in this study signified enhanced diet utilization by the fish. According to DeSilva (2001), the ideal FCR values range between 1.2 and 1.8 for fish fed adequately prepared diets. FCR as a measure of feed utilization has been known to be affected by body weight/size, ration and temperature (Keremah and Beregha, 2014). Lower FCR signifies higher protein conversion efficiency and is inversely correlated with better feed utilization by fish which results in better growth (Adikwu, 2003; Olele *et al*., 2013). The least FCR value (1.31) recorded by fish fed Diet 3 suggested that they efficiently metabolized dietary protein and converted it to more flesh at 40% BFSM supplementation level. Comparable values (0.97 – 2.19) have been documented for *C. gariepinus* fingerlings reared on variously processed seed meal-supplemented diets (Michael *et al*., 2021; Zulhisyam *et al*., 2021). In addition, the present FCR values connoted superior feed absorption and utilization when compared with the higher values (3.1 – 15.73) reported by other authors on *C. gariepinus* and *Heteroclarias* fingerlings (Aliu and Osaro, 2018; Michael and Mathias, 2020; Jibrin *et al*., 2018; Nwose *et al*., 2021).

The capability of an organism to efficiently absorb and metabolize dietary nutrients, particularly protein, will substantially boost its growth performance. This assertion was justified by the best protein intake, nitrogen metabolism and growth performance indices recorded for fish raised on Diet 3. The values of protein intake (24.44 – 29.76 g per 100g diet/fish) similarly indicated better dietary protein assimilation in comparison with 0.18 – 0.29 and 0.84 - 1.33 g per 100g diet/fish respectively observed in *Heteroclarias* and *C. gariepinus* fingerlings in related studies (Adesina and Ikuyeju, 2019). The protein efficiency ratio (PER) values (1.71 – 1.85) closely harmonized with 1.63 – 2.58 attained by *C. gariepinus* fingerlings in related studies (Babale, 2016; Oyelere *et al*., 2016; Bake *et al*., 2016a, 2016b, 2020; Jibrin *et al*., 2018) and evidently signified better dietary protein utilization than 0.1 – 0.38 found in *C. gariepinus* fingerlings fed locust bean seed meal-supplemented diets (Michael and Mathias, 2020). PER has been described as an indicator of how effectively the protein sources in a particular diet can release the required essential amino acids in the fish reared on such a diet (Davis, 2004).

The observed percentage fish survival (62.5 – 92.5%) in the current study closely matched 54.03 – 97.33% already documented for *C. gariepinus* fingerlings (Bake *et al*., 2014; Aliu and Osaro, 2018; Nwose *et al*., 2021) while it signified better survival when juxtaposed with 48.0 - 86.0% attained by *C. gariepinus* fingerlings (Anyanwu *et al*., 2015). Such an appreciable level of survival suggested that supplementing *C. gariepinus* fingerlings' diets with boiled flamboyant seed meal did not result in severe fish mortality. Moreover, it reflected sufficient acceptability of the experimental diets by fish which could be attributed to proper handling, adequate water quality management, appropriate feed processing, suitability as well as non-toxicity of boiled flamboyant seed meal supplementation in *C. gariepinus* diet. However, comparatively higher survival rates (90 - 100%) have been previously attained by *C. gariepinus* fingerlings in closely related studies (Dienye and Olumuji, 2014; Bake *et al*., 2016b; Oyelere *et al*. 2016; Michael *et al*., 2021; Zulhisyam *et al*., 2021).

CONCLUSION

The results from this study have demonstrated that boiled flamboyant seed meal (BFSM) can be used to partially replace groundnut cake in diet formulation for *C. gariepinus* juveniles. It was observed that 40% BFSM supplementation level (Diet 3) produced the best indices of growth performance, feed intake and utilization. The observed high level of survival suggested that supplementing *C. gariepinus* fingerlings' diets with boiled flamboyant seed meal did not cause severe fish mortality. However, Incorporation of BFSM above 40% level caused poor feed utilization, growth response and body composition. Other processing methods should be explored with a view to expanding the spectrum of utilization of the growth-enhancing potential of flamboyant seed meal in aquaculture feed production for *C. gariepinus* and other cultivable species.

ACKNOWLEDGEMENT

The authors thankfully acknowledge the effort of Mr. A. J. Adebayo (Assistant Chief Technologist) and his colleagues in the Department of Chemical Sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria for technical assistance during chemical analyses of experimental diet and fish samples.

Table 6: Growth performance and feed utilization indices of *C. gariepinus* juveniles fed graded levels of boiled flamboyant seed meal-supplemented diets

Growth and feed utilization parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Initial mean weight (g)	6.50 ± 0.4^{a}	6.50 ± 0.3^{a}	6.50 ± 0.4^{a}	6.50 ± 0.1^{a}	6.50 ± 0.3^{a}	6.50 ± 0.4^{a}
Final mean weight (g)	53.53 ± 3.16^{bc}	50.85 ± 1.45^{ab}	61.25 ± 0.85^{d}	48.53 ± 0.57^{a}	56.20 ± 2.0^{c}	48.39 ± 1.66^{a}
Mean weight gain (g)	47.05 ± 1.05^{bc}	44.35 ± 1.85^{ab}	54.75 ± 1.37^{d}	42.03 ± 1.93^{a}	49.70 ± 2.5^{c}	41.89 ± 1.09^{a}
Percentage weight gain (%)	723.83 ± 5.19^{c}	682.31 ± 1.81^{b}	842.31 ± 2.26^{e}	646.62 ± 3.88^{a}	764.62 ± 4.52^{d}	644.46 ± 5.64^{a}
Specific growth rate (%day)	3.77 ± 0.03^{ab}	3.67 ± 0.02^{ab}.	4.01 ± 0.02^{b}	3.59 ± 0.09^{a}	3.85 ± 0.05^{ab}	3.58 ± 0.44^{a}
Mean feed intake (g)	65.46 ± 1.96^{bc}	63.68 ± 0.52^{bc}	71.92 ± 1.12^{d}	63.48 ± 2.02^{b}	67.00 ± 2.7^{c}	58.71 ± 1.81^{a}
Feed conversion ratio	1.39 ± 0.04^{bc}	1.44 ± 0.04^{c}	1.31 ± 0.02^{a}	1.51 ± 0.01^{d}	1.35 ± 0.04^{ab}	1.40 ± 0.05^{bc}
Protein intake	26.78 ± 0.04^{b}	24.48 ± 0.62^{b}	29.76 ± 0.44^{c}	26.05 ± 1.45^{b}	26.83 ± 0.77^{b}	24.44 ± 0.94^{a}
Protein efficiency ratio	1.76 ± 0.04^{b}	1.81 ± 0.05^{b}	1.84 ± 0.05^{b}	1.61 ± 0.14^{a}	1.85 ± 0.07^{b}	1.71 ± 0.03^{ab}
Nitrogen metabolism	923.09 ± 6.96^{c}	881.58 ± 10.92^{b}	1041.45 ± 6.85^{e}	845.92 ± 5.13^{a}	963.82 ± 3.12^{d}	843.77 ± 2.97^{a}
Percentage survival (%)	85.00 ± 2.3^{c}	62.5 ± 1.0^{a}	82.5 ± 2.5^{bc}	80.00 ± 2.0^{b}	92.50 ± 2.5^{d}	90.00 ± 1.0^{d}

Mean values with different superscripts a,b,c, etc. along the same row are significantly different ($p < 0.05$). BFSM = Boiled Flamboyant Seed Meal

REFERENCES

Abulude, F.O., Makinde, O.E. and Adejayan, A.W. (2018). Biochemical profile of flamboyant (*Delonix regia*) seeds obtained in Akure, Nigeria. *Continental Journal of Applied Sciences*, 13 (2): 29 – 43.

Adesina, S.A. and Agbatan, O.D. (2021). Growth response and feed utilization in *Clarias gariepinus* fingerlings fed diets supplemented with processed flamboyant (*Delonix regia*) leaf meal. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*, 20 (1): 38 – 45.

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*, 1 (1): 130–142.

Adikwu, I.A. (2003). A review of aquaculture nutrition in aquaculture development in Nigeria. In: Proceeding of the Joint Fisheries Society of Nigeria, National Institute for Freshwater Fisheries Research, FAO-National Special Programme for Food Security and National Workshop on Fish Feed Development and Feeding Practices in Aquaculture held at National Institute for Freshwater Fisheries Research, New-Bussa. (Eyo A.A. Ed.), 34 - 42.

Akajiaku, L.O., Nwosu, J.N., Onuegbu, N.C., Njoku, N.E. and Egbeneke, C.O. (2014). Proximate, mineral and anti-nutrient composition of processed (soaked and roasted) tamarind (*Tamarindus indica*) seed nut. *Current Research Journal of Nutrition and Food Science*, 2 (3): 136 - 145.

Akande, K.E. and Fabiyi, E.F. (2010). Effect of processing methods on some anti-nutritional factors in legume seeds for poultry feeding. *International Journal of Poultry Science*, 9 (10): 996-1001.

Aliu, B.S. and Osaro, G.E. (2018). Replacement of soybean meal with dietary lablab bean (*Lablab purpureus*) meal in the diet of Clariid catfish (*Clarias gariepinus*) fingerlings. *International Journal of Fisheries and Aquatic Studies*, 6 (5): 206-209.

Anyanwu, D.C., Offor, J.I. and Nkulo, U.U. (2015). Product quality assessment of *Clarias gariepinus* fed on varying dietary levels of *Azadirachta indica* leaf meal. *American Journal of Experimental Agriculture*, 9 (6): 1-6.

AOAC (2011). Association of Official Analytical Chemists. Official Methods of Analysis (18th edition), Arlington, Virginia. pp. 541-543.

Azarm, H.M. and Lee, S.M. (2014). Effects of partial substitution of dietary fish meal by fermented soybean meal on growth performance, amino acid and biochemical parameters of juvenile black sea bream, *Acanthopagrus schlegeli*. *Aquaculture Research*, 45: 994–1003.

Babale, M. Y. (2016). Growth performance of *Clarias gariepinus* (Burchell, 1822) juveniles fed with watermelon (*Citrullus lanatus*) seed cake diets as a replacement of soybean meal. *FUW Trends in Science and Technology Journal*, 1 (2): 554–557.

Bake, G.G., Adejumo, T.M. and Sadiku, S.O.E. (2013). Growth performance and nutrient utilization of Nile Tilapia (*Oreochromis niloticus*) fed toasted flamboyant (*Delonix regia*) seed meal. *Continental Journal of Agricultural Science*, 7(1): 1-10.

Bake, G.G., Atoyebi, O.A., Abdulkarim, I.A., Adam, A. and Sadiku, S.O.E. (2016b). Evaluation of varying inclusion levels of toasted sickle pod (*Senna obtusifolia*) seed meal in the practical diet of catfish (*Clarias gariepinus*) fingerlings in concrete tanks. *International Journal of Fisheries and Aquatic Studies*, 4 (3): 458 - 463.

Bake, G.G., Martins, E.I. and Sadiku, S.O.E. (2014). Nutritional evaluation of varying levels of cooked flamboyant (*Delonix regia*) seed meal on the growth performance and body composition of Nile Tilapia

(*Oreochromis niloticus*) fingerlings. *Agriculture, Forestry and Fisheries*, 3 (4): 233-239.

Bake, G.G., Olabisi, H., Abdullahi, A., Nwangwu, D.C., Ricketts, A.O., Samaila, J. and Gana, A.B. (2020). Growth performance, nutrient utilization and haematological indices of hybrid catfish fingerlings fed varying inclusion levels of toasted sword beans (*Canavalia gladiata*) seed meal in concrete tanks. *International Journal of Fisheries and Aquatic Studies*, 8 (1): 271-278.

Bake, G.G., Yusuf, I. and Sadiku, S.O.E. (2016a). Evaluation and nutrient quality of toasted flamboyant seed meal in the diet of *Clarias gariepinus* fingerlings. *Journal of Agriculture and Ecology Research International*, 5 (2): 1-9.

Balogun, J.K., Abdullahi, S.A., Auta, J. and Ogunlade, I. (2004). Feed conversion, protein efficiency, digestibility and growth performance of *Oreochromis niloticus* fed *Delonix regia* meal. Proceedings of the 19th Annual Conference of the Fisheries Society of Nigeria (FISON). Pp 823-831.

Borgstorm, G. (1992). *Fish as Food / Feed.*New York Academic Press, Vol.1, 477 pp.

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

Danial, N. (2018). A review on replacing fish meal in aqua feeds using plant protein sources. *International Journal of Fisheries and Aquatic Studies*, 6: 164–179.

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.

Dawood, M.A. (2021). Nutritional immunity of fish intestines: important insights for sustainable aquaculture. *Rev. Aquac*., 13 (1): 642–663.

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.

Dienye, H.E. and Olumuji, O.K. (2014). Growth performance and haematological responses of African mud catfish *Clarias gariepinus* fed dietary levels of *Moringa oleifera* leaf meal. *Net Journal of Agricultural Science*, 2 (2): 79–88.

Dossou, S., Dawood, M.A., Zaineldin, A.I., Abouelsaad, I.A., Mzengereza, K., Shadrack, R. S., Zhang, Y., El-Sharnouby, M., Ahmed, H.A. and El Basuini, M.F. (2021). Dynamical hybrid system for optimizing and controlling efficacy of plant-based protein in aquafeeds. Pages i – xx.

Fagbenro, O. A. and Davis, S. J. (2003). Use of high percentages soybean protein concentrate as fishmeal substitute in practical diets for African catfish, *C. gariepinus* (Burchell 1822): growth, feed utilization and digestibility. *Journal of Applied Aquaculture*, 16: 1.

FAO (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in Action. Rome. Pages i – xx.

Fapohunda, O. O. (2012). Evaluation of processed soybean meal in the feeding of *Clarias gariepinus* fingerlings. *J. Anim. Sci. Adv.*, 2 (2): 244 - 249.

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.

Francis, G., Makkar, H. P. S. and Becker, K. (2001). Anti-nutritional factors present in plant- derived alternate fish feed ingredients and their effects in fish. *Aquaculture*, 199: 197- 227.

Goda, A.M.A.S., Saad, A., Wafa, M. and Sharawy, Z. (2014). Complete substitution of dietary wheat bran with duckweed Lemna species supplemented with exogenous digestive enzymes for freshwater prawn, *Macrobrachium rosenbergii* (De Man1879) post-larvae. The International Conference and Exposition of Aquaculture Europe 2014.Kursaal in San Sebastian, Spain. Pages i – xx.

Iheanacho, S.C., Ogunji, J.O. and Ogueji, E.O.(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.

Jibrin, H., Chidume, I., Eze, N.C. and Nwadu, I.I. (2018). Effect of substituting calabash (*Lagenaria vulgaris*) seed meal for groundnut cake in the diet of catfish (*Clarias* x *Heterobranchus longifilis*) hybrid fingerlings. *International Journal of Fisheries and Aquatic Studies*, 6 (3): 134-138.

Keremah, R.I. and Beregha, O. (2014). Effect of varying dietary protein levels on growth and nutrient utilization of African catfish *Clarias gariepinus* fingerlings. *Journal of Experimental Biology and Agricultural Sciences*, 2 (1): 13-18.

Li, X.F., Wang, Y., Liu, W.B., Jiang, G.Z. and Zhu, J. (2014). Effects of dietary carbohydrate/lipid ratios on growth performance, body composition and glucose metabolism of fingerling blunt-snout bream (*Megalobrama amblycephala*). *Aquaculture Nutrition*, 2: 1-12.

Michael, K.G. and Mathias, A.I. (2020). Growth performance of *Clarias gariepinus* fed locust bean (*Parkia biglobosa*) meal-supplemented diets. *International Journal of Fisheries and Aquatic Studies*, 8 (1): 266-270.

Michael, K.G., Amos, N. and Solomon, K. (2021). Growth performance of *Clarias gariepinus* fingerlings fed varying inclusion levels of toasted African mesquite (*Prosopis africana*) seed meal. *International Journal of Fisheries and Aquatic Studies*, 9 (6): 320-327.

Musa, S. M., Aura, C. M., Ogello, E. O., Omondi, R., Charo-Karisa, H. and Munguti, J. M. (2013). Haematological response of African catfish (*Clarias gariepinus* Burchell 1822) fingerlings exposed to different concentrations of tobacco (*Nicotiana tobaccum*) leaf dust. *ISRN Zoology*, 2013: 1 - 7.

Muzinic, L.A., Thompson, K.R., Metts, L.S., Dasgupta, S. and Webster, C.D. (2006). Use of turkey meal as partial and total replacement of fish meal in practical diets for sunshine bass (*Morone chrysops* × *Morone saxatilis*) grown in tanks. *Aquaculture Nutrition*, 12: 71–81.

Mzengereza, K., Ishikawa, M., Koshio, S., Yokoyama, S., Yukun, Z., Shadrack, R.S., Seo, S., DuyKhoa, T.N., Moss, A., Dossou, S. and Basuini, M.F.E. (2021). Effect of substituting fish oil with Camelina oil on growth performance, fatty acid profile, digestibility, liver histology and antioxidative status of red seabream (*Pagrus major*). *Animals*, 11 (7): 1990.

Nwanna, L.C. (2003). Replacement of fish meal with chemically preserved shrimp head meal in the diets of African catfish. *Pakistan Journal of Nutrition*, 2: 339-345.

Nwose, F.O., Aliu, B.S. and Nwakaji, S. (2021). Effect of dietary replacement of soyabean meal with toasted lima bean meal on the growth and nutrient utilization of heteroclarias juveniles. *International Journal of Fisheries and Aquatic Studies*, 9 (5): 52-55.

Okechi, J.K. (2004). Profitability assessment: A case study of African catfish (*Clarias gariepinus*) farming in the Lake Victoria Basin, Kenya. Kenya Marine and Fisheries Research Institute (KMFRI), Kisumu Research Centre, Final Project. pp. 1 - 56.

Olele, N.F., Onyema, M.I. and Odiko, A.E. (2013). Growth performance, survival rate and nutrient profile of *Clarias gariepinus* fingerlings fed rations of soybean as alternative protein source. *Academic Journal of Interdisciplinary Studies*, 2 (10): 58-66.

Oyedeji, O.A., Azeez, L.A. and Osifade, B.G. (2017). Chemical and nutritional compositions of flame of the forest (*Delonix regia)* seeds and seed oil. *South African Journal of Chemistry*, 70:16 – 20.

Oyegbile, B., Abdullahi, B.A. and Yola, I.A. (2017). Haematological profile of *Heterobranchus bidorsalis* fingerlings fed processed *Delonix regia* seeds at different inclusion levels of diets. *International Journal of Fisheries and Aquaculture*, 9 (8): 81 – 85.

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.

Pati, S., Sumedha, C., Chatterji, A. and Dash, B.P. (2016). A novel food formulation for the juveniles of *Penaeus monodon* (*Fabricius*). *Turkish Journal of Fisheries and Aquatic Science*, 16: 481–488.

Samkelisiwe, N.H. and Ngonidzashe, A.M. (2014). Replacing fishmeal with kikuyu grass and moringa leaves: effects on growth, protein digestibility, histological and haematological parameters in *Clarias gariepinus. Turkish Journal of Fisheries and Aquatic Sciences*, 14: 795-806.

Sinyangwe, B.G., Chirwa, E.R., Mzengereza, K., Kapute, F. and Singini, W. (2017). Effect of varying dietary protein levels and stocking density on growth performance, survival and feed utilization of African catfish (*Clarias gariepinus* Burchell, 1822). *Insights Aquac. Cult. Biotechnol*. 1: 1–6.

Solomon, S. G., Tiamiyu, L. O. and Agaba, U. J. (2007). Effect of feeding different grain sources on the growth performance and body composition of tilapia (*Oreochromis niloticus*) fingerlings fed in outdoor hapas. *Pakistan Journal of Nutrition*, 6 (3): 271 - 279.

Tibbetts, S.M. and Lall, S.P. (2013). Effect of dietary inclusion of Atlantic snow crab, *Chionoecetes opilio* and Northern pink shrimp (*Pandalis borealis*) processing by-products on nutrient digestibility by juvenile haddock (*Melanogrammus aeglefinus*). *Animal Feed Science and Technology*, 182 (1- 4): 126-130.

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.

Zulhisyam, A. K., Kabir, M. A., Mat, K., Rusli, N. D., Abdul Razab, M.K.A., Ariff, N.S.N.A., Edinur, H.A., Abdul Rahim, M. Z., Pati, S., Dawood, M. A. O. and Wei, L.S. (2021). The possibility of replacing fish meal with fermented soy pulp on the growth performance, blood biochemistry, liver and intestinal morphology of African catfish (*Clarias gariepinus*). *Aquaculture Reports*, 21 (100815): 1-10.

Zulhisyam, A.K., Kabir, M. A., Razab, M.K.A., Abdul, M.M.B. and Wei, L.S. (2020). A replacement of plant and animal protein sources as an alternative for fish meal ingredient for African catfish, *Clarias gariepinus*: a review. *J. Trop. Resour. Sustain. Sci*., 8: 47–59.