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# Dietary Effects of Sun-dried Bitter Leaf (*Vernonia amygdalina)* Meal as Additive on Feed Utilization, Growth Response, Body Composition and Survival in *Clarias gariepinus* Juveniles

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**ABSTRACT**

Insufficiency and rising costs of conventional fish feed ingredients have prompted the need to consider cheaper and locally accessible substitutes and feed additives. An eight-week feeding experiment was carried out to evaluate the dietary effect of supplementing sun-dried bitter leaf (*Vernonia amygdalina)* meal (SBLM) as a feed additive on the growth, feed utilization and survival of *Clarias gariepinus* juveniles. A total of 360 uniform-sized *C. gariepinus* juveniles (mean weight = 4.02±0.02 g) were randomly allocated to 18 plastic aquaria (50 × 40 × 40 $cm^3$). SBLM was added at six graded levels, 0 (control), 20, 40, 60, 80 and 100%, labelled as diets 1, 2, 3, 4, 5 and 6 respectively. The diets (40% crude protein) and fish carcass were proximately analyzed via standard procedures. Mean Weight Gain (MWG), Specific Growth Rate (SGR), Feed Intake (FI), Feed Conversion Ratio (FCR), Protein Intake (PI), Protein Efficiency Ratio (PER), Nitrogen Metabolism (NM) and Percentage Survival (PS) were evaluated. Data obtained were analyzed using descriptive statistics and ANOVA at $P \leq 0.05$. Final carcass crude protein (54.09 – 56.78%) significantly ($p < 0.05$) surpassed 53.08% in the pre-experimental fish. Fish placed on the Control Diet (0% SBLM supplementation) had the best values ($p < 0.05$) of MWG (24.96 g), SGR (3.52%/day), FI (28.46 g), FCR (1.14), PI (11.41 g of protein in 100g diet/fish) and NM (507.5), followed by those fed with 20% SBLM while higher SBLM supplementation (40 – 100%) caused progressively reduced growth pattern. This study revealed that higher supplementation of sun-dried bitter leaf meal suppressed growth in *C. gariepinus* juveniles.

**Keywords:**
*Clarias gariepinus, Vernonia amygdalina, Processing, Feed Additive, Growth*

## Introduction

Rapid growth in human population without a corresponding increase in animal protein production has been recognized as one of the major challenges confronting developing countries including Nigeria (Olopade *et al*., 2015). Insufficient intake of animal protein among most Nigerians has been reported (Collins, 2007). The animal protein intake is less than 10 g which is far below the Food and Agriculture Organization's recommended value of 35 g per day (FAO, 2014). This wide margin between the recommended protein intake and the average human consumption rate has prompted a continuous

demand for animal protein by the Nigerian populace. This increasing demand for the required protein production can be satisfied through fish culture (Olopade *et al*., 2015) since fish products constitute about 22% of animal protein supply in sub-Saharan Africa and 40% of animal protein consumption in Nigeria (FAO, 2003). In a bid to maximize nutritional and economic benefits, research efforts have focused on increasing the utilization of unconventional plant by-products to replace conventional feed ingredients. Integration of leaf meals in aquaculture feed production is rapidly attracting global attention owing to their enormous availability, nutrient contents and economic feasibility (Udo and John, 2015). Bitter leaf plant (*Vernonia amygdalina*) is a perennial shrub belonging to the family Asteraceae (Ijeh and Ejike, 2011). The shrub produces indigenous edible vegetable leaves which are rich sources of proteins, carbohydrates, minerals, vitamins and fibres. The leaf also contains beta-carotene, a precursor of vitamin A (Aregheore, 2012) and ascorbic acid (Ucheck, 2004). Anthraquinones, tannins, flavonoids, alkaloids, saponins, glycosides and terpenoids are phytochemicals present in the plant (Audu *et al*., 2012). The vitamins A and C and the phytochemicals present in bitter leaf are responsible for its antioxidant properties (Hamzah *et al*., 2013) while the bitter taste of parts of this shrub is due to lots of saponins present (Ijeh and Ejike, 2011). Apart from its dietary value, the leaf is also anti-parasitic (Ucheck, 2004), hepatoprotective (Farombi and Owoeye, 2011), nephroprotective (Ebong, 2011), anti-diarrhoeic (Hassan *et al.*, 2007), anti-febrile (Areghore, 2012) and aids healing (Ucheck, 2004). Chemical analysis has revealed that bitter leaf contains 24.77 – 25.25% crude protein, 5.2 - 6.28% crude lipid, 11.37 - 15.4% crude fibre, 7.23 – 15.65% ash content and 29.25 – 40.75% nitrogen-free extract (Okoli *et al*., 2003; Adetoro *et al*., 2017; Olosunde and Odeyinka, 2017).

Some previous studies on dietary utilisation of bitter leaf, its extracts and their effects have been documented which included enhancing fertility in *Heterobranchus bidorsalis* broodstock (Francis *et al*., 2013), protecting smoke-dried catfish from bacterial spoilage during storage (Abdurrazzaq *et al*., 2019), efficiently reducing infections in cockerels (Olabatoke and Oloniruha, 2009), growth and haematological profile of *C. gariepinus* broodstock (Udoh *et al*., 2017), enhancing sperm quality and reducing cholesterol level in *C. gariepinus* juveniles (Olaniyi *et al*., 2020) as well as improving serological and haematological profile of broiler finishers (Owen and Amakiri, 2011, to mention a few. However, despite several studies conducted by many researchers on this plant, there are few literature reports on the inclusion of sun-dried bitter leaf meal as a feed additive in formulating diets for *C. gariepinus*. This study was conducted to assess the effect of sun-dried bitter leaf meal on the growth, feed utilization, body composition and survival of *C. gariepinus* juveniles.

## Materials and Methods

### Study location

This eight-week feeding trial was conducted between August and November, 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.

### Collection, identification and processing of fresh bitter leaves into bitter leaf meal

Ten kilograms (10 kg) of fresh bitter leaves used for this study were harvested by cutting branches from bitter leaf shrubs in a residential garden at Ode-Ayeka in Okitipupa Local Government Area, Ondo State, Nigeria and were identified as well as authenticated by a plant taxonomist in the Herbarium Unit of the Department of Biological Sciences, Olusegun Agagu University of Science and Technology,

Okitipupa, Ondo State, Nigeria. The leaves were screened to remove bad ones, sun-dried for seven days, milled into a uniform powder inside a locally fabricated grinder and stored in air-tight containers at room temperature until required.

**Formulation and preparation of experimental diets**

Other ingredients were purchased from a reputable feed mill and ground separately into a powdery form. Six iso-nitrogenous (40% crude protein) diets were formulated as indicated in Table 1. Sun-dried bitter leaf meal (SBLM) was added as a feed additive at varied levels of 0 (control diet without SBLM), 20, 40, 60, 80 and 100% in the diets which were respectively designated 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) while 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 sun-dried 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 purchased from a reliable fish hatchery in Okitipupa, Ondo State. The juveniles were adapted to the experimental conditions in four fiberglass tanks (1 m × 1 m× 0.5 m) for 7 days and fed twice daily with 2 mm Coppens feed to visual satiation.

**Experimental design and fish handling procedure**

This study used a completely randomized design comprising six treatments with three replicates each. At the onset, 360 equal-sized fish (initial mean weight: 4.02±0.02 g) were weighed in batches on a high-precision scale (OHAUS LS, Model 2000) and randomly allocated into 18 plastic aquaria (50 × 40 × 40 $cm^3$) at twenty fish per aquarium containing 20 litres of water each. Diets were fed manually to the fish twice daily (07:00 - 08:00 and 17:00 - 18:00 hrs) at 5% body weight in two equal rations. Water temperature in the aquaria was measured with mercury-in-glass thermometer, dissolved oxygen values measured via DO meter (Hydrolab Model "Multi 340I/SET") while pH values were determined using pH meter (Jenway 3015 pH meter). Fish in each aquarium were batch-weighed weekly and weight changes recorded.

**Proximate analysis of experimental diets and fish carcass composition**

Eight grams (8 g) of each diet sample, six pre-experimental fish specimens and four post- experimental fish specimens per treatment were randomly selected and kept frozen to determine the proximate composition of experimental diets and whole-fish carcass. The proximate parameters analyzed included crude protein, crude lipid, crude fibre, total ash, moisture content and nitrogen-free extract (AOAC, 2011).

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

| Dietary ingredients | 0%SBLM Diet1 (Control) | 20%SBLM Diet 2 | 40%SBLM Diet 3 | 60%SBLM Diet 4 | 80%SBLM Diet 5 | 100%SBLM Diet 6 |
|---|---|---|---|---|---|---|
| Bitter leaf meal | 0.00 | 4.11 | 8.22 | 12.34 | 16.45 | 20.56 |
| Yellow maize | 20.56 | 16.45 | 12.34 | 8.22 | 4.11 | 0.00 |
| Fishmeal | 23.82 | 23.82 | 23.82 | 23.82 | 23.82 | 23.82 |
| Soybean meal | 23.82 | 23.82 | 23.82 | 23.82 | 23.82 | 23.82 |
| Groundnut cake | 23.82 | 23.82 | 23.82 | 23.82 | 23.82 | 23.82 |
| Shrimp meal | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vitamin/mineral premix* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Table salt | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Vegetable oil | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cassava starch | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Total (g) | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

SBLM = Sun-dried bitter leaf 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: 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.

**Biological evaluation of feed utilization and fish growth performance**

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

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

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

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

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

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

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

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

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.

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

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

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

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

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

**Data analysis**

The data generated 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). Differences among the treatments 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**

**Proximate composition of sun-dried bitter leaf meal-supplemented diets fed to *C. gariepinus* juveniles**

Table 2 shows the result of the proximate analysis of the experimental diets. There was no significant difference ($p > 0.05$) in the crude protein values of the experimental diets. However, the observed values of crude lipid, total ash, crude fibre, moisture and nitrogen-free extract contents in the experimental diets revealed significant difference ($p<0.05$).

**Table 2: Proximate composition of graded levels of sun-dried bitter leaf meal-supplemented diets fed to *C. gariepinus* juveniles**

| Dietary treatments | Moisture | Ash | Crude lipid | Crude fibre | Crude protein | Nitrogen-free extract |
|---|---|---|---|---|---|---|
| 0% SBLM | 5.28±0.00$^{b}$ | 11.43±0.00$^{b}$ | 17.67±0.00$^{b}$ | 5.56±0.00$^{b}$ | 40.09±0.02$^{a}$ | 20.01±0.01$^{a}$ |
| 20% SBLM | 5.22±0.00$^{b}$ | 10.69±0.01$^{b}$ | 20.06±0.05$^{a}$ | 6.86±0.03$^{a}$ | 39.50±0.05$^{a}$ | 17.65±0.06$^{b}$ |
| 40% SBLM | 6.00±0.00$^{a}$ | 13.50±0.00$^{a}$ | 15.51±0.01$^{c}$ | 5.23±0.01$^{b}$ | 40.28±0.01$^{a}$ | 19.47±0.18$^{a}$ |
| 60% SBLM | 6.87±0.00$^{a}$ | 10.35±0.00$^{b}$ | 19.31±0.00$^{a}$ | 6.52±0.00$^{a}$ | 40.00±0.01$^{a}$ | 16.97±0.01$^{c}$ |
| 80% SBLM | 6.84±0.00$^{a}$ | 11.05±0.00$^{b}$ | 17.40±0.00$^{b}$ | 6.59±0.00$^{a}$ | 40.02±0.02$^{a}$ | 18.25±0.15$^{b}$ |
| 100% SBLM | 4.44±0.01$^{c}$ | 11.75±0.00$^{b}$ | 17.21±0.00$^{b}$ | 6.54±0.00$^{a}$ | 40.01±0.02$^{a}$ | 20.05±0.02$^{a}$ |

Mean values with different superscripts a, b, c, etc. along the same column are significantly different ($p < 0.05$).
SBLM = Sun-dried bitter leaf meal

**Carcass proximate composition of *C. gariepinus* juveniles fed sun-dried bitter leaf meal-supplemented diets**

Chemical composition of experimental fish carcass (Table 3) followed an irregular pattern and showed significant variations ($p < 0.05$) among the treated fish, thus signifying that inclusion of sun-dried bitter leaf meal has affected their body composition. Crude protein values in the post-experimental fish carcasses were significantly higher ($p<0.05$) than the value in the pre-treatment fish carcass. Similarly, the values of the crude lipid, total ash, nitrogen-free extract and moisture contents observed in the experimental fish carcass showed significant difference ($p<0.05$).

**Table 3: Carcass proximate composition of *C. gariepinus* juveniles fed graded levels of sun-dried bitter leaf meal-supplemented diets**

| Dietary treatments | Moisture | Ash | Crude Lipid | Crude Protein | Nitrogen-free extract |
|---|---|---|---|---|---|
| Initial | 7.08±0.00$^{b}$ | 17.72±0.00$^{a}$ | 5.49±0.00$^{d}$ | 53.08±0.03$^{b}$ | 16.63±0.04$^{a}$ |
| 0% SBLM | 8.23±0.00$^{a}$ | 13.51±0.00$^{b}$ | 14.55±0.01$^{c}$ | 55.08±0.02$^{a}$ | 8.63±0.01$^{b}$ |
| 20% SBLM | 6.51±0.01$^{b}$ | 11.49±0.01$^{c}$ | 17.23±0.01$^{b}$ | 56.78±0.01$^{a}$ | 7.99±0.00$^{b}$ |
| 40% SBLM | 8.51±0.01$^{a}$ | 10.59±0.01$^{c}$ | 17.90±0.01$^{b}$ | 54.33±0.03$^{a}$ | 8.68±0.02$^{b}$ |
| 60% SBLM | 6.14±0.00$^{b}$ | 14.07±0.07$^{b}$ | 19.06±0.01$^{a}$ | 54.09±0.07$^{a}$ | 6.64±0.11$^{c}$ |
| 80% SBLM | 7.87±0.07$^{ab}$ | 14.30±0.01$^{b}$ | 17.27±0.07$^{b}$ | 55.23±0.02$^{a}$ | 5.31±0.00$^{d}$ |
| 100% SBLM | 6.85±0.01$^{b}$ | 13.57±0.05$^{b}$ | 19.08±0.07$^{a}$ | 54.23±0.07$^{a}$ | 6.27±0.20$^{c}$ |

Mean values with different superscripts a, b, c, etc. along the same column are significantly different ($p < 0.05$).
SBLM = Sun-dried bitter leaf meal

**Growth and feed utilization of *C. gariepinus* juveniles fed graded levels of sun-dried bitter leaf meal-supplemented diets**

Table 4 shows the growth and feed utilization indices which revealed significant variations ($p < 0.05$) in the fish groups exposed to the various diets. Acceptability of the diets progressively significantly

reduced ($p < 0.05$) from the fish fed Diets 1 to 6 and was inversely proportional to increase in the inclusion level of sun-dried bitter leaf meal. Values of growth and feed utilization indices assumed a declining trend in those fed Diets 1 to 6. Mean weight gain (MWG) and specific growth rate (SGR) were highest (24.96 g and 3.52%/day) in the fish fed Diet 1 (Control), closely followed by those fed Diet 2 (22.72 g and 3.38%/day) and lowest (18.01 g and 3.04%/day) in those fed Diet 6 respectively. Values (1.14 – 1.31) recorded for feed conversion ratio (FCR) in the fish fed Diets 1 to 3 indicated efficient feed utilization and showed significant ($p < 0.05$) variations from the values (1.36 – 1.41) observed in the fish fed Diets 4 to 6. Similarly, the values of protein intake (PI) (11.3 – 11.84) and protein efficiency ratio (PER) (1.9 – 2.19) in the fish fed Diets 1 to 3 were significantly higher ($p < 0.05$) than 10.16 – 10.66 and 1.77 – 1.84 found in the fish fed Diets 4 to 6 respectively. Percentage survival (PS) showed significant ($p < 0.05$) variations across all the treatments and the fish fed with Diet 1 had the highest survival rate.

**Table 4: Growth performance and feed utilization indices of *C. gariepinus* juveniles fed graded levels of sun-dried bitter leaf meal-supplemented diets**

| Parameters | 0% SBLM Control | 20% SBLM | 40% SBLM | 60% SBLM | 80% SBLM | 100% SBLM |
|---|---|---|---|---|---|---|
| Initial mean weight (g) | 4.03±0.02$^{a}$ | 4.02±0.02$^{a}$ | 4.01±0.01$^{a}$ | 4.02±0.02$^{a}$ | 4.03±0.02$^{a}$ | 4.02±0.02$^{a}$ |
| Final mean weight (g) | 28.99±0.99$^{a}$ | 26.74±2.02$^{b}$ | 26.51±1.66$^{b}$ | 23.60±1.35$^{c}$ | 22.73±1.54$^{c}$ | 22.03±0.01$^{d}$ |
| Mean weight gain (g) | 24.96±1.01$^{a}$ | 22.72±2.01$^{b}$ | 22.50±1.65$^{b}$ | 19.58±1.33$^{c}$ | 18.70±1.56$^{d}$ | 18.01±0.01$^{d}$ |
| Percentage weight gain (%) | 619.36±28.22$^{a}$ | 565.17±48.25$^{b}$ | 561.10±40.73$^{b}$ | 487.07±37.50$^{c}$ | 464.02±40.37$^{c}$ | 448.01±2.14$^{d}$ |
| Specific growth rate (%day) | 3.52±0.07$^{a}$ | 3.38±0.13$^{b}$ | 3.37±0.11$^{b}$ | 3.16±0.10$^{c}$ | 3.09±0.13$^{c}$ | 3.04±0.01$^{d}$ |
| Mean feed intake (g) | 28.46±0.48$^{a}$ | 28.61±1.08$^{a}$ | 29.39±0.70$^{a}$ | 26.65±0.68$^{b}$ | 25.79±1.9$^{b}$ | 25.39±1.41$^{b}$ |
| Feed conversion ratio | 1.14±0.04$^{a}$ | 1.26±0.14$^{a}$ | 1.31±0.10$^{a}$ | 1.36±0.05$^{b}$ | 1.38±0.17$^{b}$ | 1.41±0.08$^{b}$ |
| Protein intake | 11.41±0.26$^{a}$ | 11.3±0.65$^{a}$ | 11.84±0.39$^{a}$ | 10.66±0.36$^{b}$ | 10.32±1.04$^{b}$ | 10.16±0.64$^{b}$ |
| Nitrogen metabolism | 507.59±14.80$^{a}$ | 472.78±31.25$^{b}$ | 469.20±25.50$^{b}$ | 424.60±21.02$^{c}$ | 411.21±23.52$^{d}$ | 400.21±0.41$^{d}$ |
| Protein efficiency ratio | 2.19±0.06$^{a}$ | 2.01±0.23$^{a}$ | 1.90±0.20$^{a}$ | 1.84±0.07$^{b}$ | 1.81±0.29$^{b}$ | 1.77±0.17$^{b}$ |
| Percentage survival | 90.33±2.89$^{a}$ | 86.33±10.41$^{c}$ | 83.33±7.64$^{d}$ | 88.67±2.89$^{b}$ | 86.33±5.77$^{c}$ | 86.00±0.00$^{c}$ |

Mean values with different superscripts a, b, c, etc. along the same row are significantly different ($p < 0.05$).
SBLM = Sun-dried bitter leaf meal

## Discussion

The values of the proximate composition of the experimental diets administered to *C. gariepinus* juveniles in this study were within the range recommended to support ideal fish growth (Li *et al*., 2014). The absence of significant variations in the crude protein values suggested absence of bias while compounding the experimental diets. The present values agreed with the acceptable range (28 – 39%) for ideal catfish growth (Borgstorm, 1992) and also concurred with 39.92 - 40.08% reported for bitter leaf meal-supplemented diets (Francis *et al.*, 2013) and 39.98 - 40.01% documented for *Aloe barbadensis* leaf meal-based diets (Adegbesan *et al*., 2018) respectively. Crude lipid values aligned with 10 – 20% lipid in fish diets which normally supports ideal growth rate without producing an extremely fatty carcass (Tibbetts and Lall, 2013). The values correlated with 10.42 – 11.12% reported by Francis *et al.* (2013) but surpassed 4.15 - 5.05% obtained by Dienye and Olumuji (2014) for *Moringa oleifera* leaf meal-based diets. Values of ash content also harmonized with 11.50 - 13.70% reported by Anyanwu *et al*. (2008) for *Alchornia cordifolia* leaf meal-based diets and slightly exceeded 8.76 - 10.12% obtained by Francis *et al.* (2013). Values of crude fibre were slightly below 7.06 - 8.1% observed by Francis *et al.* (2013). The current values of ash and crude fibre contents closely coincided with 8 – 12% recommended for optimal fish growth (Condey, 2002), since higher ash and crude fiber contents usually reduce the digestibility of other ingredients in the diet and result in high waste output which may cause water pollution and poor growth. Values of nitrogen-free extract were slightly below 20.79 - 23.22% documented by Francis *et al.* (2013) and much lower than 34.83 - 36.61% obtained by Dienye and Olumuji (2014). The variations in the observed proximate values and values in previous related studies could be due to the impact of environmental factors on the leaves (Akajiaku *et al*., 2014), seasonal variations, morphological variations in plant species, types of processing methods adopted and variations in ingredient combinations.

The significant increase in the protein content of the post-experimental fish due to the various diets indicated that there was enhanced protein synthesis and new tissue formation as reported by Yusuf *et al*. (2016) for *C. gariepinus* juveniles. Similar trends of enhanced 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* leaf meal-based diets (66.12 – 67.86%) (Anyanwu *et al*., 2015).

Crude lipid values were higher than 5.84 - 6.31% and 4.10 – 7.63% respectively reported for *C. gariepinus* fingerlings fed *M. oleifera* and *A. indica* leaf meal-based diets (Dienye and Olumuji 2014; Anyanwu *et al*., 2015). Ash content values concurred with 16.90 – 18.32% reported by Afe and Omosowone (2019) for *C. gariepinus* fingerlings fed with *Acacia auriculiformis* leaf meal-based diets. The disparities in fish carcass composition between this study and other studies could be attributed to interspecies' genetic variations, different plant-based ingredients and processing techniques used as well as effect of culture conditions.
Inclusion of sun-dried bitter leaf meal in the diets of *C. gariepinus* juveniles in this study was observed to cause reduced growth and feed utilization which progressively diminished with increasing inclusion levels of bitter leaf meal in the diets. Similar trends of diminishing feed utilization and growth were observed in *C. gariepinus* juveniles and broodstock fed diets containing processed bitter leaf meals (Udoh *et al*., 2017; Olaniyi *et al*., 2020). Apart from the fish placed on Diet 1 (Control diet) which exhibited the best growth,

those fed Diets 2 and 3 also showed appreciable growth and feed utilization indices which evidently indicated optimal diet utilization that was not achievable at higher inclusion levels. The significantly higher values of MWG and SGR in the fish fed Diets 1 to 3 visibly suggested that they optimally converted feed to flesh when compared with those fed Diets 4 to 6. The lower growth response exhibited by fish fed Diets 4 to 6 could be ascribed to reduced palatability of the diet which probably resulted from low feed intake and the presence of anti-nutrients in the sun-dried bitter leaf meal. The SGR values recorded in this study connoted superior growth rate when compared with 0.11 - 0.65 %/day found in *C. gariepinus* juveniles and broodstock fed similar diets (Udoh *et al*., 2017; Olaniyi *et al*., 2020), 0.25 – 0.59 %/day reported by Adesina and Ikuyeju (2019) for *C. gariepinus* fingerlings fed pawpaw leaf meal-based diets and 0.44 - 1.81%/day observed by Anyanwu *et al*. (2008) for hybrid *Heteroclarias* (*H. bidorsalis* x *C. gariepinus*) fingerlings fed *A. cordifolia* leaf meal-based diets.

Lower feed conversion ratio (FCR) signifies better feed utilization by fish. According to DeSilva (2001), ideal FCR values range between 1.2 and 1.8 for fish fed carefully prepared diets and FCR values (1.14 - 1.41) obtained in this study closely agreed with this range. In addition, the present FCR values supported 1.31 - 1.66 found in *C. gariepinus* juveniles fed similar diets (Olaniyi *et al*., 2020) but suggested better feed utilization when compared with 1.31 – 3.30 documented by Dienye and Olumuji (2014) for *C. gariepinus* fingerlings fed *M. oleifera* leaf meal-based diets. The capacity of an organism to effectively absorb and assimilate dietary nutrients, especially protein, will positively boost its growth performance. This was justified by the best protein intake, protein efficiency ratio (PER) and growth performance indices recorded for the fish fed Diets 1 to 3. The current protein intake values suggested better dietary protein assimilation when compared with 0.18 – 0.29 g/100g diet/fish previously reported by Anyanwu *et al*. (2008) for *Heteroclarias* fingerlings as well as 0.84 – 1.33 g/100g diet/fish observed by Adesina and Ikuyeju (2019) for *C. gariepinus* fingerlings. Moreover, the PER values obtained in this study closely harmonized with 1.67 – 2.58 recorded by Oyelere *et al*. (2016) for *C. gariepinus* fingerlings fed *Albizia lebbeck* leaf meal-supplemented diets. According to Davis (2004), protein efficiency ratio indicates 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 surpassed 76.26 – 87.45% reported by Abu *et al*. (2010) for *Heteroclarias* fingerlings and also implied better survival in comparison with 48.0 - 86.0% recorded by Anyanwu *et al*. (2015) for *C. gariepinus* fingerlings. Such high level of survival indicated that feeding *C. gariepinus* fingerlings with sun-dried bitter leaf meal did not cause serious fish mortality. Besides, it signified appreciable acceptability of the experimental diets by fish which could be attributed to proper handling, proper feed processing and, to some extent, suitability of sun-dried bitter 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* and *M. oleifera* leaf meal-based diets respectively (Dienye and Olumuji, 2014; Oyelere *et al*. 2016).

**Conclusion**

The results from this study showed that Diet 1 (control diet without sun-dried bitter leaf meal) produced the best growth and feed utilization and was closely followed by Diets 2 and 3 containing 20% and 40% inclusions of sun-dried bitter leaf meal respectively. It was observed that inclusion of sun-dried bitter leaf

meal as a feed additive in *C. gariepinus* juveniles' diet above 40% caused progressively reduced growth and feed utilization. The study, therefore, indicated that higher inclusion levels of sun-dried bitter leaf meal suppressed growth and feed utilization in *C. gariepinus.* Other processing methods are recommended in order to increase the utilization of bitter leaf meal which has an appreciable potential in reducing the cost of fish feed production and thereby maximize aquaculture profitability.

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