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# Growth Performance of the African Catfish, *Clarias gariepinus* (Burchell), Fed Varying Inclusion Levels of Castor Seed (*Ricinus communis* L.)

**Agboola EO[1,2*], Owoeye OA[1], Balogun JK[2], Auta J[2] and Abdullahi SA[2]**

[1]*Department of Fisheries and Aquaculture, Ekiti State University, Ado-Ekiti, Nigeria*
[2]*Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria*

## Abstract

An 84 day feeding trial was conducted to evaluate raw and boiled castor seed (*Ricinus communis* L.) in the diet of *Clarias gariepinus* (Burchell, 1822) fingerlings with average body weight of 9.55 g ± 0.24 g. The fish were assigned to five treatments. The fish in five treatments, each replicated thrice, were fed with 37% crude protein experimental diets containing raw castor seed meal, (D1) and boiled seed diets subjected to boiling at 100ºC for 20 (D2), 35 (D3), 50 (D4) and 65 (D5) minutes respectively. Diet1 (D1) served as control and was fed to the fish in the first treatment. Castor seeds served as an isonitrogenous source of protein in the experimental diets. There were no significant differences (p>0.05) in the Mean Weight Gain (MWG), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER) of the experimental fish fed diets D2, D3, D4 and D5. Highest percentage weight gain, SGR, FCR, PER, Net Protein Utilization (NPU) and digestibility rate were recorded in diet D4 containing castor seed boiled for 50 minutes at 100ºC. Hence, boiling of castor seeds for 50 minutes at 100ºC is considered the best approach for processing castor seeds through boiling.

**Keywords:** Boiling; Castor seed; *R. communis* seeds; *C. gariepinus*; Specific growth rate; Feed conversion ratio

## Introduction

The human population explosion in the recent time is being on a geometric ratio. The food quantity and quality, particularly those of protein sources, meant for consumption to meet the demand of this large number had not been commensurate with the population size [1,2]. Fish has continued to be the most easily affordable source of animal protein to humans [3].

Research into the utilization of unconventional feedstuffs are gaining priority today due to the extent at which protein feed ingredients are more expensive than the other feedstuffs [4,5]. This effort by the fish nutritionists had been yielding encouraging result in ameliorating the aforementioned challenge being faced by the fish farmers and consumers across the globe [6]. Nonetheless, the satisfaction limit has not been attained; hence further exploration of the environment by the fish nutritionists is necessary. The castor oil plant, *R. communis* belongs to Euphorbiaceae family and is an annual and perennial plant found in all the tropical and semi-tropical regions of the world such as Southern Mediterranean Basin, Eastern Africa and India. It is a fast-growing, suckering perennial shrub which can reach the size of a small tree, around 12 metres or 39 feet [7,8].

Castor oil seeds (*R. communis* L.) have crude protein content that is above 20% [7,9,10]. Nsa et al. [11] reported 30.82% for crude protein, 11.42% crude fibre, 20.72% ether extract, 5.54% ash and 31.16% nitrogen free extract. Ishiwu et al. [12] also reported crude protein 23.00%, crude fibre 6.85%, carbohydrate 27.50%, fat 22.67%, moisture 17% and ash 2.98%. The seeds are available during the fruiting season all over the places in Nigeria but the seeds are mostly wasted and investigation on its inclusion in fish diet is scanty. These factors qualify it to serve as protein source in fish feeds. However, a major limitation of the seeds in fish diets is the presence of ricin, which is a toxic anti-nutritional factor. *C. gariepinus* is found nearly in all fresh water bodies in Nigeria and other tropical countries across the globe; it is hardy, disease-resistant and a good converter of feeds [13,14], hence its choice for this investigation.

### Aim of the Study

This study is aimed at testing the possibility of inactivating ricin in *R. communis* L. seeds by subjecting the seeds to various levels of boiling and evaluating the boiled seeds in the diet of African catfish, *C. gariepinus* (Burchell).

## Materials and Methods

### Study location

The study was conducted at the Department of Biological Sciences, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

### Experimental procedure

Fingerlings of *C. gariepinus* (Burchell, 1822) were obtained from Kagoro fish farm in Kaduna state, Nigeria. The fish were brought to the wet laboratory (of the Department of Biological Sciences, Ahmadu Bello University, Zaria) immediately and kept in two large water baths where they were acclimatized for two weeks. Control diet (commercial open feed) was used to feed the fish during the period of acclimatization. Water temperature, pH and Dissolved Oxygen (DO) in the water baths were monitored.

Healthy fish with average body weight 9.55 ± 0.24 g were randomly stocked into fifteen glass aquaria measuring 45×30×30 cm containing 25 L of de-chlorinated water at a loading rate of 10 fish per tank. The aquaria were divided into five treatments. Each treatment was made up

***Corresponding author:** Agboola EO, Department of Fisheries and Aquaculture, Ekiti State University, Ado-Ekiti, Nigeria, Tel: +233302 775351; E-mail: eliasgbola@gmail.com

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of three replicates. The faecal matters from fish in each of the aquaria were siphoned daily in the morning by the use of rubber tube. The water in each aquarium was changed every other day.

## Sample collection, identification and processing

Castor seeds from dehiscenced mature capsules of the plants were fetched within Zaria metropolis and used for this research. The plant capsule and seed samples were identified at the Herbarium of the Department of Biological Sciences Ahmadu Bello, University, Zaria. Two hundred grams (200 g) of raw castor seeds were washed, decorticated, sundried, ground and used for proximate analysis. Four processing methods were carried out using kerosene stove to boil water to the boiling point, 100°C in accordance to the method used by Vadivel et al. [15]. 2 kg of castor seed samples were boiled at 100°C using tap water at the ratio of 1 kg to 10 L of water in a 15 L metal cooking pot for duration of 65 minutes. A portion (500 g) of the original seed samples was removed from the boiling water with a sieve at 20, 35, 50 and 65 minutes intervals respectively using a stopwatch while the boiling continues. Samples were sun-dried separately for 5 days [11], ground and packed in air tight polythene bags against the subsequent analysis.

## Sources of ingredients and diets preparation

Table 1 shows composition of diet fed *C. gariepinus*. Pearson square method was adopted in formulating the feeds. Five 37% crude protein experimental treatment diets containing raw castor seed meal and castor seed meals obtained by subjecting the seeds to boiling for 20, 35, 50 and 65 minutes respectively were fed to the fish in five treatments respectively. The diets were designated as: D1 (containing raw castor seed meal), D2 (containing castor seed meal boiled for 20 minutes), D3 (containing castor seed meal boiled for 35 minutes), D4 (containing castor seed meal boiled for 50 minutes) and D5 (containing castor seed meal boiled for 60 minutes) respectively. Castor seed (*R. communis*) was used as the main source of plant protein. Other ingredients include: cassava flour and maize, which served as the source of energy as well as the coagulant (binder) and palm oil which was the essential source of fatty acid. Blood meal (of cattle) and fish meal were included to supplement the plant protein source.

Grower vitamins and mineral premixes were used as sources of vitamins and minerals. 0.5 gm of chromic oxide ($Cr_2O_3$) was added and thoroughly mixed with the experimental and control diets to serve as an indicator for digestibility evaluation. In preparing the diets, dry ingredients were ground to a powdery form in a Wiley mill to enhance optimum utilization and digestibility. Diets were thoroughly mixed with red oil and pelleted using Hobart a 200 pelleting machine with a 2.0 mm die. Diets were sun dried and packed in labelled air tight containers and kept in a cool place prior to use. Before and after the experiments, samples of the prepared diets were collected and ground into powder. Each sample (2 g) was weighed with the Sauter analytical balance and was put in a Petri dish. The petri dish, with its content, was put in Gallenkamp hotbox oven at a constant temperature of 105°C. The sample was left to dry in the oven for 24 hours. Thereafter, the sample was removed, allowed to cool in a desiccator and then weighed. The drying continued until a constant weight was ensured.

| Boiling period | D1 (0 minute)% | D2 (20 minutes)% | D3 (35 minutes)% | D4 (50 minutes)% | D5 (65 minutes)% |
|---|---|---|---|---|---|
| Castor Seed (C.S) | 28.9 | 28.9 | 28.9 | 28.9 | 28.9 |
| Blood meal (cow) | 12.3 | 12.3 | 12.3 | 12.3 | 12.3 |
| Fish meal | 12.3 | 12.3 | 12.3 | 12.3 | 12.3 |
| Cassava flour | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 |
| Maize flour | 20.7 | 20.7 | 20.7 | 20.7 | 20.7 |
| Red oil | 2 | 2 | 2 | 2 | 2 |
| Vitamin/Mineral premixes* | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Chromic oxide (Cr203) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Total | 100 | 100 | 100 | 100 | 100 |
| *Vitamins/Mineral premixes contain:- Vitamin B12, riboflavin, Vit C, D3, K and E, Panthothenic acid, Nicotinic acid, Chlorine chloride, Folic acid, Selenium, Phosphorus, Calcium, Iodine, Copper, Zinc, Manganese, Iron, Terramycin Antioxidant and Anti-caking agent. | | | | | |

**Table 1:** Composition (%) of experimental diet fed to *C. gariepinus*.

## Data collection and analysis

Each sample was then subjected to proxim are analysis using the methods of the Association of Official Analytical Chemists [16] in order to determine its composition in respect of moisture, ash, lipids, crude protein, crude fibre and Nitrogen Free Extracts (NFE). Proximate composition was calculated by using the following formula respectively:

(a) $\%Moisture\,content = \{(W_2 - W_3)/(W_2 - W_1)\} \times 100$

(b) $\%Ash\,content = \{(W_2 - W_3)/(W_2 - W_1)\} \times 100$

(c) $\%CrudeLipid\,Content = \{(W_2 - W_3)/(W_2 - W_1)\} \times 100$

(d) $Crude\,\Pr otein = \%\,Nitrogen \quad (N_2) \times 6.25$

(e) $\%Crude\,Fibre = \{(C_2 - C_3)/W\} \times 100$

(f) NFE= 100−(ash+crude lipid+crude protein+crude fibre).

For the determination of digestibility, the method of [17] was adopted.

The digestibility of the nutrients was expressed from the following equation:

$$\%Nutrient = 100 - \frac{100x(\%Cr_2O_3\,in\quad food}{\%Cr_2O_3\,in\quad faeces} \times \frac{(\%Nutrient\,in\quad faeces)}{(\%Nutrient\,in\quad food)}$$

## Fish feeding and culture

Fish were fed daily at 5% body weight. Feeding was done twice daily: 8 am to 9 am in the morning and 5 pm to 6 pm in the evening. Fish were re-weighed every two weeks and the feed quantity was adjusted to reflect the new body weight.

Growth performances and food utilization parameters were expressed by using the following formulae viz:

[i] Weight gain-this was calculated as the differences between the initial and final body weights for fish.

[ii] Specific Growth Rate (SGR)

$$SGR = \frac{\log_e w2 - Log_e w1}{T - t} \quad [18]$$

Where: w1=initial weight (g at time t1), w2=final weight (g at time t2), e=the base of natural logarithm.

[iii] Food Conversion Ratio (FCR)

$$FCR = \frac{Amount\,of\quad Feed\quad Fed}{Wet\quad Weight\quad gain(g)} \quad [19]$$

[iv] Protein Efficiency Ratio (PER)

$$PER = \frac{weight\quad gain}{\text{Pr}otein\quad fed}$$

$$\text{Pr}otein\quad fed = \frac{\%protein\quad in\quad deit \times total\quad deit\quad consumed}{100} \quad [20,21]$$

[v] Net Protein Utilization (NPU)

$$NPU = \frac{fish\quad protein\quad gain}{\text{Pr}otein\quad fed} \times 100$$

Where: Protein gain=final body protein−initial body protein

Protein consumed=Total dietary protein fed [22]

### Water quality determination

Water parameters such as temperature, pH and Dissolved Oxygen (DO) were effectively determined daily using HANNA instruments Model: HI-98129 and HI-987130 respectively. Dissolved Oxygen (DO) was measured using dissolved oxygen test kit (HANNA instruments model: HI-3810). Water in each tank was continuously aerated using aerators with air stones.

### Statistical analysis

Statistical analysis of the data was carried out using SPSS version 20. A one-way analysis of variance (ANOVA) was used to compare the means. Post-hoc test was also carried out using Duncan Multiple Range Test (DMRT). Values were considered significant at $p<0.05$ [23].

## Results

### Water quality

Table 2 shows the range of water temperature, pH, and Dissolved Oxygen (DO) readings taken during the feeding experiment of *C. gariepinus*. Daily water temperature was always found to be the same for all replicates. However, the water temperature values varied day to day. The water temperature ranged between (24.83 ± 1.11)°C and (25.17 ± 1.34)°C in the course of the experiment. The daily water pH values varied among the replicates. Also there were variations in the water pH values of each replicate aquarium. The mean water pH values ranged between 6.91 ± 0.59 and 7.18 ± 0.68 while the experiment lasted. The mean water Dissolved Oxygen (DO) ranged between 6.61 ± 1.84 and 0.46 ± 0.75. The daily water DO varied among the replicates.

| Diet | Temperature (°C) | pH | Dissolved oxygen (DO, ppm) |
|---|---|---|---|
| D1 (Control) (0 minute) | 24.92 ± 1.38 | 7.09 ± 0.47 | 7.05 ± 0.62 |
| D2 (20 minutes) | 25.17 ± 1.34 | 6.91 ± 0.59 | 7.02 ± 0.77 |
| D3 (35 minutes) | 24.92 ± 1.38 | 7.13 ± 0.25 | 6.83 ± 0.54 |
| D4 (50 minutes) | 25.08 ± 1.38 | 7.18 ± 0.46 | 6.61 ± 1.84 |
| D5 (65 minutes) | 24.83 ± 1.11 | 7.18 ± 0.68 | 7.46 ± 0.75 |
| Values with same superscripts in same row are not significantly different. | | | |

**Table 2:** The range of water parameter readings taken during the feeding experiment for *C. gariepinus* for 84 days.

### Proximate composition of raw and boiled castor seed diets

Table 3 shows the proximate composition of experimental diets fed to *C. gariepinus*. The feeds were formulated to obtain approximately 37% crude protein levels. However, proximate analysis revealed that the mean crude protein content ranged from 43.35 ± 0.51 to 43.88 ± 0.61. There was no significant difference ($p>0.05$) in the percentage crude protein of the control and experimental diets. Diets containing castor seeds boiled for 50 and 65 minutes were shown to have the highest mean percentage protein (43.88% ± 0.17%) each. These were followed by those containing castor seeds boiled for 35, 20 and 0 (control) minutes respectively (43.69% ± 1.00%, 43.44% ± 0.13% and 43.35% ± 0.51%). The mean ash content was highest in diet D2 (7.49% ± 0.03%). This was followed by diets containing castor seeds boiled for 50 (D4), 65 (D5) and 35 (D3) minutes respectively (7.45% ± 0.13%, 6.83% ± 0.77% and 6.56% ± 0.08%). The control diet (D1) recorded the least (5.50% ± 0.04%) ash content. The mean lipid content was highest in diet D5 (4.87% ± 0.36%) and lowest in control diet (D2) containing CS boiled for 20 minutes. The mean crude fibre was highest in control diets D1 and D5 (2.73% ± 0.06% each) and lowest in diet D4 boiled for 50 minutes (1.83% ± 0.04%). The Nitrogen Free Extract (NFE) was highest in the diet D5 (45.69% ± 0.61%) and lowest in diet D2 (42.36% ± 0.08%). The mean dry matter was highest in the control diet (95.40% ± 0.08%) and lowest in the diet D5 (94.08% ± 94.08%).

### Growth performance, digestibility and survival

Table 4 shows the growth performance and utilization of *C. gariepinus* fed the experimental diets. The fish fed diet containing castor seed boiled for 50 minutes (D4) recorded the highest Mean Weight Gain (MWG) value (0.54 ± 0.03). There was however no significant difference ($p>0.05$) between this value and the other diets containing boiled castor seeds D2 (0.50 ± 0.03), D3 (0.44 ± 0.03) and D5 (0.49 ± 0.05) respectively. The MWG of the fish fed control diets containing raw castor seed meal was however significantly different ($p<0.05$) from all the diets containing the processed castor seeds (D2-D5). It has the MWG value, 0.25 ± 0.08. The fish fed diet D4 recorded the highest Specific Growth Rate (SGR) of 0.0036 ± 0.00046, followed by the fish fed diets D2 and D5 which had the same value (0.0032 ± 0.00017 and 0.0032 ± 0.00020 respectively), and those fed diet D3 which had the value of 0.0029 ± 0.00023. The fish fed diet D1 recorded the least SGR value of 0.0017 ± 0.00038. The SGR values of fish fed processed diets D2, D3, D4 and D5 were not significantly different ($p>0.05$). However, the

| Component | Diet | | | | |
|---|---|---|---|---|---|
| | D1 (0 minutes) | D2 (20 minutes) | D3 (35 minutes) | D4 (50 minutes) | D5 (65 minutes) |
| Ash | 5.50 ± 0.04$^{a}$ | 7.49 ± 0.03$^{d}$ | 6.56 ± 0.08$^{b}$ | 7.45 ± 0.13$^{b}$ | 6.83 ± 0.77$^{c}$ |
| Lipids | 4.52 ± 0.06$^{ab}$ | 3.99 ± 0.13$^{a}$ | 4.48 ± 0.06$^{ab}$ | 4.79 ± 0.41$^{b}$ | 4.87 ± 0.36$^{b}$ |
| Crude fibre | 2.73 ± 0.06$^{b}$ | 2.72 ± 0.06$^{b}$ | 2.28 ± 0.07$^{b}$ | 1.83 ± 0.04$^{a}$ | 2.73 ± 0.38$^{b}$ |
| Crude protein | 43.35 ± 0.51$^{a}$ | 43.44 ± 0.13$^{a}$ | 43.69 ± 1.00$^{a}$ | 43.88 ± 0.17$^{a}$ | 43.88 ± 0.61$^{a}$ |
| Sub total | 57 | 57.64 | 57.01 | 54.95 | 54.31 |
| NFE | 43.00 ± 0.18$^{a}$ | 42.36 ± 0.08$^{c}$ | 42.99 ± 0.11$^{a}$ | 45.05 ± 0.06$^{b}$ | 45.69 ± 0.61$^{b}$ |
| Dry matter | 95.40 ± 0.08$^{a}$ | 95.03 ± 0.07$^{a}$ | 94.85 ± 0.03$^{a}$ | 94.92 ± 1.32$^{a}$ | 94.08 ± 0.63$^{a}$ |
| Values with same superscripts in same row are not significantly different. | | | | | |

**Table 3:** Proximate composition of experimental diets (g/100 g) fed to *C. gariepinus*.

| Diet | D1 (0 minute) | D2 (20 minutes) | D3 (35 minutes) | D4 (50 minutes) | D5 (65 minutes) |
|---|---|---|---|---|---|
| Initial mean weight (g) | 9.77 ± 1.3 | 9.74 ± 1.1 | 9.49 ± 4.4 | 9.12 ± 1.6 | 9.66 ± 3.1 |
| Final mean weight (g) | 11.25 ± 1.6 | 12.73 ± 1.9 | 12.12 ± 1.4 | 12.34 ± 2.1 | 12.58 ± 1.5 |
| Weight gain (g) | 1.48 | 2.99 | 2.63 | 3.22 | 2.92 |
| Mean weight gain | $0.25 \pm 0.08^{a}$ | $0.50 \pm 0.03^{b}$ | $0.44 \pm 0.03^{b}$ | $0.54 \pm 0.03^{b}$ | $0.49 \pm 0.05^{b}$ |
| Specific growth rate | $0.0017 \pm 0.00038^{a}$ | $0.0032 \pm 0.00017^{b}$ | $0.0029 \pm 0.00023^{b}$ | $0.0036 \pm 0.00046^{b}$ | $0.0032 \pm 0.00020^{b}$ |
| Feed conversion ratio | $2.44 \pm 0.08^{c}$ | $1.25 \pm 0.05^{a}$ | $1.43 \pm 0.02^{b}$ | $1.14 \pm 0.02^{a}$ | $1.26 \pm 0.03^{a}$ |
| Protein efficiency ratio | $0.008 \pm 0.000^{a}$ | $0.015 \pm 0.0015^{ab}$ | $0.018 \pm 0.0027^{b}$ | $0.020 \pm 0.0010^{b}$ | $0.016 \pm 0.0035^{b}$ |
| Apparent net protein utilization | $33.32 \pm 0.11^{d}$ | $20.68 \pm 0.36^{a}$ | $32.43 \pm 0.19^{c}$ | $28.05 \pm 0.04^{b}$ | $34.12 \pm 0.11^{e}$ |
| Digestibility (%) | 59.27 | 69.29 | 67.11 | 71.39 | 70.11 |
| Survival rate (%) | 90 | 95 | 95 | 95 | 95 |
| Values with same superscripts in same column are not significantly different (p>0.05). | | | | | |

**Table 4:** Growth performance of *C. gariepinus* (fingerlings) fed experimental diets for 84 days.

| Component | Initial composition | Final composition | | | | |
|---|---|---|---|---|---|---|
| | | D1 (0 minutes) | D2 (20 minutes) | D3 (35 minutes) | D4 (50 minutes) | D5 (65 minutes) |
| Ash | 20.9 | $24.23+0.14^{d}$ | $21.10+0.02^{c}$ | $20.47+0.04^{b}$ | $21.17+0.05^{c}$ | $18.77+0.07^{a}$ |
| Lipids | 11.35 | $4.35+0.01^{c}$ | $4.64+0.05^{d}$ | $3.31+0.06^{a}$ | $5.33+0.01^{e}$ | $3.52+0.03^{b}$ |
| Protein | 54.8 | $59.61+0.07^{a}$ | $63.57+0.05^{b}$ | $69.06+0.55^{d}$ | $66.30+0.01^{c}$ | $68.43+0.03^{d}$ |
| Values with same superscripts in same row are not significantly different (p>0.05). | | | | | | |

**Table 5:** Proximate composition of carcasses of *C. gariepinus* (%) before and after the feeding period.

SGR of the fish fed processed diets were significantly higher ($p<0.05$) than those fed with control diet (D1).

The mean Feed Conversion Ratio (FCR) was significantly higher ($p<0.05$) in fish fed control diet (2.44 ± 0.08) than the diets containing boiled castor seeds. There was no significant difference ($p>0.05$) in the mean FCR values of the fish fed diets containing the processed castor seeds. FCR values for all the diets containing boiled castor seeds for 20, 35, 50 and 65 minutes (D2-D5) include 1.25 ± 0.05, 1.43 ± 0.02, 1.14 ± 0.02 and 1.26 ± 0.03 respectively.

There was no significant difference ($p>0.05$) in the Protein Efficiency Ratio (PER) of fish fed diets containing processed castor seeds (D2-D5). The highest value of PER was recorded in the fish fed diet D4 (0.020 ± 0.0010). This was followed by those of the fish fed diets D3 (0.018 ± 0.0027), D5 (0.016 ± 0.0035) and D2 (0.015 ± 0.0015) respectively. The fish fed control diet had the least value of PER (0.008 ± 0.0003). PER values for the fish fed control diet and diet containing castor seed boiled for 20 minutes were not significantly different ($p>0.05$) from each other. The apparent Net Protein Utilization (NPU) was recorded highest in the fish fed diet D5 (34.12 ± 0.11) followed by the fish fed diets D1 (33.32 ± 0.11), D3 (32.43 ± 0.19) and D4 (28.05 ± 0.04) respectively. The least NPU was recorded in the fish fed diet D2 (20.68 ± 0.36). The NPU values recorded for all the fish fed experimental diets differed significantly ($p>0.05$).

Table 5 shows the proximate composition of *C. gariepinus* carcasses before and after the feeding period. The ash, lipid and protein composition of carcasses were the only components determined. The percentage ash of the initial carcass was 20.9%. Percentage ash contents in fish fed diets D2 (21.10 ± 0.02) and D4 (21.17 ± 0.05) were not significantly different ($p>0.5$). They however, differed significantly ($p>0.5$) from the values of other treatments. The highest value was recorded in control diet (24.23 ± 0.14) followed by D4 (21.17 ± 0.05), D2 (21.10 ± 0.02) and D3 (20.47 ± 0.04) respectively. The least was diet D5 (18.77 ± 0.07). All the groups of fish had percentage of lipid lower than the initial percentage lipid content of 11.35%. There were significant differences ($p<0.05$) in the lipid content of the fish fed the experimental diets. The highest content was recorded with the fish fed diet D4 (5.33 ± 0.014), followed by D2 (4.64 ± 0.05), D1 (4.35 ± 0.01) and D5 (3.52 ± 0.03) respectively. The least was recorded in the fish fed diet D3 (3.31 ± 0.06).

The protein gain of every group of the experimental fish was higher than the initial protein level of 54.8%. There were no significant differences ($p>0.05$) in the carcass protein contents of the fish fed diets D3 (69.06 ± 0.55) and D5 (68.43 ± 0.03). Diet D4 (66.30 ± 0.01), D2 (63.57 ± 0.56) and D1 (59.61 ± 0.07) carcass protein contents were not significantly different ($p>0.05$). The digestibility study showed that diets containing processed castor seeds as well as the control diet were highly digestible by *C. gariepinus*. Digestibility was highest in the fish fed diet D4 (71.39). This was followed by the fish fed diet D2 (69.69). Fish fed diets D3 and D5 had digestibility values of 67.11 and 70.11 respectively, while fish fed control diet (D1) had the lowest value of 59.27. 95% survival rate was recorded in all the diets containing processed diets while that of control was 90%.

## Discussion

### Water quality

The average physico-chemical parameters reported in this study showed that the water was suitable for culture of tropical fish such as *C. gariepinus*. The dissolved oxygen values of the water used among the aquaria for the experiment were above 5.0 mg/L, an indication that it was within the tolerable range of 3.30 and 12 $mgL^{-1}$ as reported by Moogouel et al. [24-26]. Boyd [27] recommended the mean dissolved oxygen concentration (6.9 mg/L), pH (7.3) and temperature (28°C) of water suitable for fish culture.

### Proximate composition of the raw and boiled castor seed diets

There was no significant difference ($p>0.5$) in the mean crude protein values of all the experimental diets. However, its values all the diets containing boiled castor seeds were higher than in the control diet. This is in contrast to the values reported by Okorie et al. [28-30]. The present study is higher than the values 36.20%, 35% and 35.74%

reported by them respectively. The disparity noticed could be as a result of environmental and variety differences. It could be observed in Table 3 that boiling of castor seed at 100°C for 50 and 65 minutes increased the crude protein content of the cooked sample by 0.53%. Balogun et al. [31] reported boiling did not affect crude protein content of castor seed. Lipid, crude fiber, nitrogen free extract and dry matter reduced significantly ($p<0.05$) as the boiling period lasted. This could be attributed to leaching of nutrients and softening of seed testa as temperature level increased. This submission corroborates the findings of [32] in the boiled castor seeds included in the diet of layer birds. The fat and fiber contents of the experimental diets however did not exceed 6% as recommended by Annune et al. [33].

### Growth performance, digestibility and survival

The growth performance and feed utilization of *C. gariepinus* fed the processed experimental diets were higher than those fed with control diet. The significant difference ($p<0.05$) recorded is an indication that boiling of castor seed had effects on growth and food utilization. Weight gain particularly is considered to be the most important parameter for measuring fish responses to experimental diets and a very efficient indicator of growth [31].

The experimental fish fed with D4 (diet containing castor seed boiled for 50 minutes) recorded the highest mean weight gain, specific growth rate, protein efficiency ratio and digestibility. The weight gains of *C. gariepinus* fed diets containing processed castor seeds and control diet were however, below expectation, in spite of the conducive physico-chemical parameters of water recorded. This could indicate that there were retention of some amounts of toxic substances (ricin/lectin) and anti-nutritional factors in the experimental diets. Lim et al. [34] reported that improper balance of essential nutrients, such as amino acids and minerals, presence of toxic substances or anti nutritional factors, or decrease in palatability and pellet water stability value of fish diets in some cases reduced growth and caused poor feed efficiency. Corwin et al. [35,36] reported that raw castor seed contained toxic ricin which is proteinous in nature.

Ricin occurs only in the castor oil plant (*R. communis* L.), where it is predominantly found in the seed. The low growth performance, therefore, in the fish fed diet containing raw castor seed could be attributed to the high concentration of ricin. Lord et al. [37] reported that ricin is one of the most poisonous substances in nature and highly toxic to humans and animals. It interferes with nutrient digestion, absorption and utilization [38]. This was corroborated by the report of Nsa et al. [39] who indicated ricin to be a growth depressant in broiler birds. Nonetheless, Balogun et al. [31,40] showed that the process of boiling of castor seed enables its detoxification. The boiling treatment of CS meal used might have reduced the activity of the toxic anti-nutritional factor (ricin); thus enhancing growth performance in the fish fed diets containing boiled processed CS diets. This result is similar to that obtained by Buyukcapar et al. [41] where *Cyprinus carpio* fed with diets having more than 20% inclusion of raw honey locust seeds recorded significantly poorer growth and feed utilization in comparison with those fed diets containing heat-treated honey locust seeds.

There was significant difference ($p<0.05$) in the Feed Conversion Ratio (FCR) and decrease of Crude Fiber (CF) among the experimental diets. The decrease trend in the FCR with low CF across the treatments in this study is in contrast with the report of Ayegba et al. [6] that decrease in FCR of moringa leaf meal in the diet of *C. gariepinus* was due to high fiber content. However, the result obtained in this study in respect of weight gain and FCR is in line with those obtained by Adedeji et al. [9,42] respectively. Adedeji et al. [9] reported feed conversion ratio value ranged between 1.26 in fish fed 25% crude protein diet and 2.09 in fish fed 100% crude protein diet replaced by mango peel meal in the diet of *Oreochromis niloticus* fingerlings. Hence there was increase with increase in level of replacement of mango peel meal in the diets while Kwari et al. [42] reported that there was significant increase ($p<0.05$) in FCR in a study to evaluate the nutritional potential of soaked-dried *Moringa oleifera* leaf meal in the diet of *C. gariepinus*. Result obtained revealed decline in feed conversion ratio as dietary replacement of Moringa leaf meal increased beyond 10% broiler chickens fed diets that were based on fermented and sprouted sorrel seeds.

In this study, the highest growth performance and feed utilization obtained in D4 could be an indication of a higher level of detoxification and presence of higher amounts of growth factors such as methionine and lysine amino acids in the diet containing boiled castor seed in it, compared to other diets [43]. Adegbola [44] reported that amino acid methionine, a major source of methyl group, serves as a source of sulphate ions for the purpose of detoxification. Eyo [45] also reported that lysine possesses growth factor. The investigation carried out by Adebayo [43] corroborated the necessity of methionine and lysine as growth factors in all plants diets formulated for hybrid catfish (Hetero-clarias).

The increase in fish carcass protein and decrease in the lipids level (Table 5) follow the trend of the boiling periods of the diets. This implied that as the fish grows on the diet, lipids are utilized as source of energy for the deamination of the excess protein [31]. There were high percentage of survival rate and increase in feed digestibility by the experimental fish; with the fish fed diet containing 50 minutes boiled castor seeds recording the highest. The improved values recorded could be attributed to boiling process suppressing the activity of digestive enzyme inhibitors. Jobling [46] reported that the utilization of amino acids in a feed ingredient is influenced by digestive enzyme inhibitors (trypsin and chemotrypsin inhibitors), and indigestible compounds formed during processing (Maillard reaction).

The digestibility of protein in control diet was low (59.27%) in *C. gariepinus* but was improved up to 70.11%, by boiling. This followed the same pattern in a similar castor seed meal feeding trial for *O. niloticus* by Balogun et al. [31]. This improvement in protein digestibility could have closely paralleled reductions in ricin's contents during processing, suggesting that ricin's are largely responsible for the low protein digestibility of the control diet. However, Eyo [47] reported that the use of inferior feedstuffs do affect the digestibility and nutritive values of compounded feeds.

## Conclusion

The results obtained in this study in terms of improved growth performance, digestibility and high percentage of survival rate recorded by the experimental fish, it is obvious that 50 minutes boiled castor seeds has the potential of being used in fish feed without deleterious effects on fish.

#### Recommendations

It is recommended that further studies be carried out to assess other processing methods of castor seed (such as soaking and fermentation techniques; treatment with 10% solution of sodium chloride and precipitation with Magnesium sulphate techniques). Study should also be carried out to compare the nutritional efficiency of processed castor seed meal with conventional feedstuff such as fish

meal, soya meal among others. Finally, other culture systems (such as earthen ponds, tanks, race way, or flow-through systems of aquaria) can be used to study the suitability of castor seed meal in fish diets.

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