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Research Article

Production, Proximate and Hematological Implications of Substituting Black Bean Meal in the Diet Fed Catfish

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Abstract

Background and Objective: Fishmeal also has been regarded as the most essential protein ingredient used in aquafeeds. However, due to the high cost of fishmeal in the markets around the world at large, the quest for alternative sources had become inevitable. This study, therefore, sought to find out the possibility of replacing fishmeal with black bean meal in the diet fed catfish (*Clarias gariepinus*). **Materials and Methods:** *Clarias gariepinus* juveniles were collected and fed with 25, 50, 75 and 100% fishmeal replacement with black bean while commercial fed served as a control. **Results:** The findings of this study showed that the experimental groups fed with 25% black bean substituted feed had more average weight gained and grew longer, had more RBC, MCV, WBC and PCV when compared with other graded levels of substitution and the control. The ash, fat and protein content of the fish carcass ranged from 2.21-2.66, 1.14-1.62, 18.51-20.44%, respectively. Similarly, fish fed supplemented with black bean meal similarly recorded higher mineral concentrations in their carcass as compared to the control. **Conclusion:** Conclusively, black runner bean meal had proven to be an economical and viable option for reducing cost and increasing production.

Key words: Water chemistry, *Clarias gariepinus*, fish, fishmeal, black bean, haematology, catfish

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fish remains one of the most healthy and nutritious diets for feeding the ever-increasing world population, providing about one-sixth of the total protein consumed by humans[1]. The current demand for fish in Nigeria for instance stands at about 2.7 million metric tons while the total domestic supply stands at about 0.7 million metric tons[2]. This high demand for fish has far superseded the supply from the wild and hence the need for aquaculture. The aquaculture industry is one of the fastest-growing food production industries in the world today[3]. The industry produces about 50% of all the fish consumed by humans[4]. Sustainable aquaculture however requires innovative approaches to the provision of inputs in the value chain and not value of the chain of fish products such as feed, seed as well as environmental conservation[5].

Despite the high potential for aquaculture production in Nigeria, the industry is still constrained by the high cost of diets for feeding the culture organism. The aquaculture production processes require fish feeding. Feed procurement, however, had been observed to be an expensive factor in fish production. Ndimele *et al*.[6] noted that the foremost impediment in fish production is the high cost of feed for the different fish production systems. Fish farmers incur more than 60% of the total farm production investments in the procurement of feeds[7,8,9]. The observed high cost of feed is due to the high cost and competing demand for fishmeal which is a major component of fish feed[10]. Fishmeal is a rich source of accessible proteins, essential amino and fatty acids which has made it compulsory for inclusion in fish diets. However, the high cost and competition for fishmeal have necessitated trials on probable alternative protein sources for aquaculture species[11]. Fishmeal has been replaced with cheap plant proteins sources[12]. One of the major local feedstuffs that meet the protein needs of most species is soybean meal[13]. This feed ingredient has also become relatively expensive on account of its competitive value in fish and livestock feeds and as well in human nutrition.

Black bean (*Phaseolus vulgaris* L.) is a leguminous plant whose crude protein content is found to be very high and also capable of providing high amounts of essential antioxidants and nutrients[14]. Black bean commonly abounds in the Nigerian environment. It takes a long cooking period and as such is not well patronized by consumers. Following its low patronage and low competition for use by confectionaries, there is the need for trials on its possible use in aquaculture diets. Although a lot of studies have been carried out on the effects of the replacement of fishmeal with several plant protein sources[10,15,16], in the diet fed catfish, comprehensive data on the replacement of fishmeal with black bean meal is rare. This study, therefore, sought to find out the effects of replacing fishmeal with black bean meal in the diet fed catfish (*Clarias gariepinus*).

MATERIALS AND METHODS

Experimental fish: A total of one hundred and eighty *Clarias gariepinus* juveniles (average weight: 18.54±1.1 g, length: 23.43±0.9 cm) were obtained from the University of Nigeria-West Africa Agricultural Productivity Programme's Fish Seed Multiplication Centre, located at the Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria, from December, 2017 to May, 2018. The fish was first acclimated to the laboratory for 2 weeks to reduce stress and mortality. During acclimatization, the fish was given a standard diet containing 45% protein at the rate of 5% of their body weight in divided rations. All the physicochemical parameters of the water were monitored and maintained within the acceptable range for the culture of the species. The acclimated fishes were then randomly divided into fifteen (145 L) plastic culture tanks comprising five treatment groups replicated thrice. Each replicate contained ten catfishes. The walls and bottom of the plastic culture tanks were thoroughly washed every week to minimize fungal growth. All culture tanks were continuously aerated using Willinger (model mcmlxxvi) air pump and all plastic culture tanks were properly covered with the net to prevent the jumping out of fish. The catfishes were allowed to stabilize for seven days in the new environment. Before the commencement of the feeding trial, the juveniles were starved for 24 h to maintain uniform stomach condition of fish as well as to induce their appetite for the commencement of the feeding experiment[17].

Preparation of experimental diets: Mature seeds of black bean (*P. vulgaris)* was bought from ''Orie Igbo-Eze'' local market were thoroughly washed, cleaned and sorted to remove the stone and damaged ones. The seeds were soaked overnight in water to remove anti-nutritional factors. The soaked seeds were dehulled dried and ground to a fine flour using a milling machine, sieved and stored in an airtight container in a cool and dry environment until required for use. Four diets types were formulated using the flour of the processed black bean. These diet types (B-E), representing: 25, 50, 75 and 100% fishmeal replacement with black bean and the control experimental group (group A) had 0% fishmeal replacement. Formulation of feed from the ingredients followed standard protocols of milling, sieving, dosing, mixing,

Table 1: Production parameters of catfish (*C. gariepinus*) fed graded levels of black bean meal substitution of not at 20weeks

Treatments	A	B	C	D	E
Weight gain (g)	141.67±6.06[a]	122.00±1.15[b]	67.67±0.88[d]	111.00±3.46[c]	44.00±1.73[e]
Specific growth rate	0.157±0.003[b]	0.150±0.000[b]	0.130±0.000[b]	0.140±0.010[b]	0.620±0.289[a]
Total length (cm)	49.67±0.88[a]	41.00±1.15[b]	34.67±1.76[c]	39.00±0.58[b]	31.67±0.33[c]
Condition factor	0.47±0.01[c]	0.78±0.05[b]	1.06±0.06[a]	0.81±0.04[b]	0.82±0.01[b]
Feed conversion ratio	0.028±0.0000[ab]	0.031±0.0003[a]	0.025±0.0029[b]	0.030±0.0003[a]	0.021±0.0003[c]

Data are presented in Mean±Standard error, Treatments A: Commercial control group, B: Experimental group of 25% substitution of black bean meal, C: Experimental group of 50% substitution of black bean meal, D: Experimental group of 75% substitution of black bean meal, E: Experimental group of 100% substitution of black bean meal. Means with different alphab*et al*ong each row represent significant differences at p<0.05

doughing, pelleting, drying and storage[18]. The diets were sundried and their proximate composition analyzed using AOAC methods[19] in Table 1.

Production parameters: At the end of the 20-week feeding trial the following parameters were measured[20,21].

Weight gain: This represents the difference between the initial weight and the final weight gained:

$$\text{Weight gain} = \text{Final weight-Initial weight}$$

Specific growth rate: Specific Growth Rate (SGR) was calculated with the formula:

$$\text{SGR (\%)} = \frac{\text{Loge } W_2 - \text{Loge } W_1}{t_2 - t_1} \times 100$$

Where:

W_2 = Weight of fish at time t_2 (final) days
W_1 = Weight of fish at time t_1 (initial) days
Loge = Natural log
$t_2 - t_1$ = Experimental period in days/56 days

Feed conversion ratio: The Feed Conversion Ratio (FCR) was calculated using the formula:

$$\text{FCR} = \frac{\text{Feed intake}}{\text{Net weight gain}}$$

Condition factor (K): The condition factor (K) of the 20-week old catfishes in the different treatments was calculated every fourth night using the formula:

$$\text{Condition factor (K)} = \frac{100W}{L_3}$$

Where:

W = Weight of fish (g)
L_3 = Total length of fish (cm)

This was carried out every fortnight.

Normalized biomass index: At the end of the experiment, the total number of survived fish from each treatment was taken and the percentage mortality determined. This was used to determine the Normalized Biomass Index (NBI) as follows:

$$\text{NBI} = \frac{W_f \times N_f}{W_1 \times N_1} \times \frac{1}{100}$$

Where:

W_f = Final weight of catfish (g)
N_f = Final number of catfish
W_1 = Initial weight of catfish (g)
N_1 = Initial number of catfish

Analysis of haematological parameters: At the end of the 20-week feeding trial, randomly selected fish were individually restrained manually and blood samples (5.0 mL) collected from the caudal vessels of the fishes from each replicate, using a heparinized plastic syringe fitted with a 21 gauge hypodermic needle and immediately transferred to EDTA tubes. Haematological parameters were then determined using a haemoautoanalyser.

Data analysis: Data resulting from the experiment were subjected to One-way Analysis of Variance (ANOVA) at 0.05 level of significance while significant means were separated using Duncan multiple range test.

RESULTS

Proximate composition of experimental diets: Group C had more moisture (9.11%) and the least ash content (4.85%). On the other hand, group B and D contained more ash (8.32 and 8.25%) and low moisture content (5.05 and 4.46%). The results indicated that group A was higher in crude fat composition (4.14%) and lowest fibre content of 3.13%. Alternatively, group E had the highest fibre content (4.71%) in Fig. 1. Group C had the highest protein content (48.59%) followed by group A and

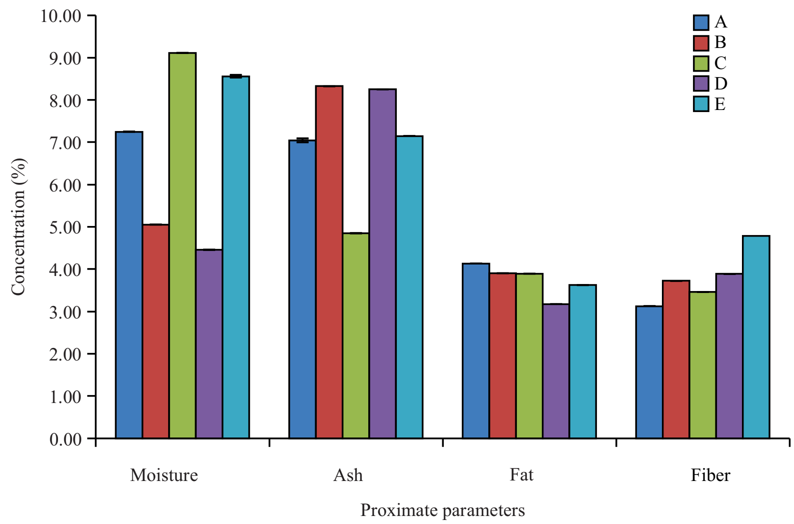

Fig. 1: Proximate composition of experimental diets used in feeding catfish (*C. gariepinus*)

Treatments A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal

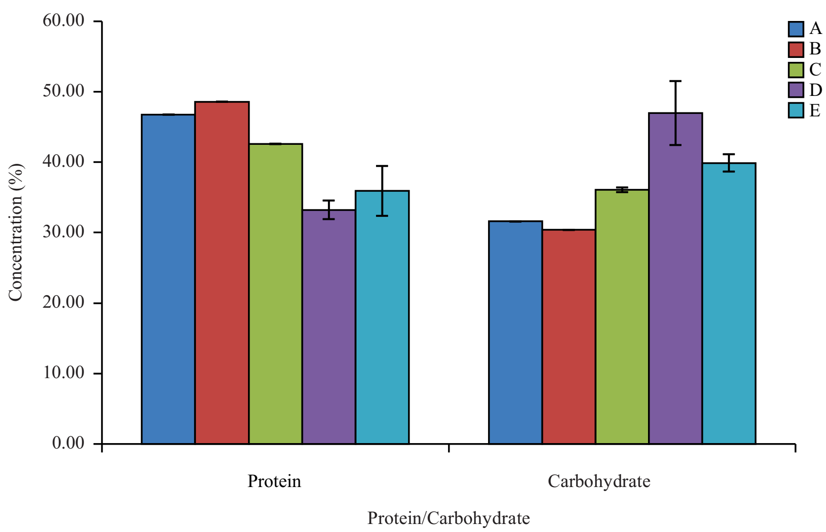

Fig. 2: Protein and Carbohydrate composition of experimental diets used in feeding catfish (*C. gariepinus*)

Treatments A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal

C (46.76 and 42.60% respectively). It was further observed that group D had the highest carbohydrate content (46.98%) while group B had the least carbohydrate content of 30.39% in Fig. 2.

Water chemistry parameters: The results as presented in Fig. 3 showed the average concentration of the parameters used in evaluating the water quality where fish fed with graded levels of black bean meal and commercial feed was grown. From the results, a reduction in water temperature was observed across the water with the application of feds substituted with different levels of black bean meal. The Temperature was highest in group A (28.00±0.577°C) and lowest in group E (23.65±0.375°C). The pH, Dissolved Oxygen (DO) and NH_3 which ranged from 6.92-6.95, 4.90-5.42 and 0.01-0.03 mg L^{-1}, respectively did not vary significantly with the application of the feeds (Fig. 3).

Production parameters: There were significant differences ($p<0.05$) in the weight gain of the different treatments. The

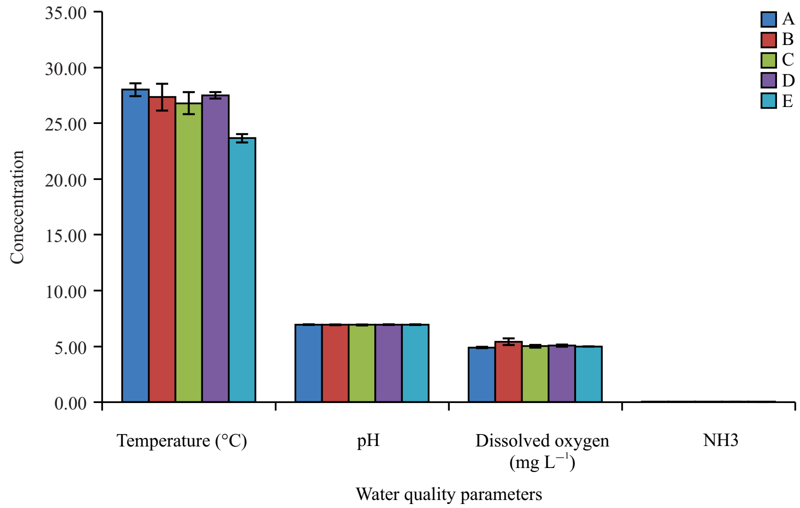

Fig. 3: Water quality used in growing catfish fed with black bean meal

Treatments A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal

highest weight gain occurred in group A (141.67±6.06 g), followed by group B (122.00±1.15 g), while group E gained the least weight (44.00±1.73 g) given in Table 1. There was a slide significant difference in the Specific Growth Rate (SGR) of the catfish fed graded levels of black bean meal substitution. The highest SGR occurred in group E (0.620±0.289), however, the SGR of group A, B, C and D did not vary significantly ($p>0.05$). Fish fed the control diet grew longer (group A) followed by group B (41.00±1.15 cm). The condition factor of the catfish fed graded levels of black bean meal substitution showed that group C had the highest condition factor (1.06±0.06). While all other treatment's condition factor significantly similar except group A. The feed conversion ratio of the different treatments showed that group C showed a higher ratio (1.06±0.06) than that of the other treatments (Table 1).

Haematological investigations of the experimental fish: Group B had more RBC ($2.36\pm0.07\times10^{12}$ mL^{-1}), haemoglobin concentration (g dL^{-1}), HCT (32.54±0.98) and MCV (138.00±0.00 fL). The RBC count was lowest in group C ($1.45\pm0.57\times10^{12}$ mL^{-1}), HTC and MCV were lowest in group E as showed in Table 2. Group E had more MCH (71.23±0.03 pL), MCHC (57.27±0.03%) and RBCD (24.00±0.00). The RBCD content was higher in the fish fed with the substituted black bean meal than the control. The WBC, LYM, MID and PLT ranged from 34.94-63.12, 26.40-50.48, 2.87-9.56 and 13.50-152.67 respectively. Similarly, PCT was significantly ($p<0.05$) highest in group E signifying that substituting feed with 100% black bean will also be more efficient in increasing the PCT content in fish. The MPV content ranged from 8.67-13.87 with group E also topping other groups. Data presented above (Table 2) shows that the average PDWC of 40.77±0.03 for group E was significantly ($p<0.05$) higher than the PDWC values of the other treatment groups (Table 2).

Proximate analysis of fish: As presented in Table 3, the ash content was highest in group E (2.66±0.00%) and lowest in group B (2.21±0.06%), followed by group C and D. As presented, the data also shows that the ash content in these three experimental groups was lower than that of the control groups. The fat content ranged from 1.14-1.62% with group B (1.62±0.11%) topping other groups. It was observed that the fat content for group B and C were higher than the control group (group A), while group D and E had lower fat content. Group D had the highest carbohydrate content (8.09±0.64%). This was however not very much different from the carbohydrate content in group B and C fish. On the other hand, fish fed with the commercial feed (group A) had a very low concentration of carbohydrate.

Mineral profile of the experimental fish: Data presented in Fig. 4 showed that group B had the highest Ca content with an average of 0.66±0.020 mg 100 g^{-1}, while Ca was lower in Group E feed. Similarly, Zn, P and Fe, were also highest in group B. The Mg concentration was highest in group E (0.34±0.012 mg 100 g^{-1}) while as compared to the commercial control, group C and D had lower Mg concentration. The data shows that the K content was highest

Table 2: Hematology of catfish fed with of graded levels of black bean meal and control feed (Aller aqua)

Hematology parameters	A	B	C	D	E
RBC ($\times10^{12}$ mL^{-1})	1.68 ± 0.13^{a}	2.36 ± 0.07^{a}	1.45 ± 0.57^{a}	2.00 ± 0.05^{a}	1.61 ± 0.00^{a}
HGB (g dL^{-1})	9.00 ± 0.64^{ab}	13.00 ± 0.58^{a}	7.30 ± 2.60^{b}	11.00 ± 0.06^{ab}	11.40 ± 0.00^{ab}
HCT	23.34 ± 2.36^{a}	32.54 ± 0.98^{a}	18.96 ± 7.83^{a}	26.21 ± 0.72^{a}	19.88 ± 0.00^{a}
MCV(fL)	137.67 ± 3.18^{a}	138.00 ± 0.00^{a}	125.00 ± 5.20^{b}	131.67 ± 0.33^{ab}	123.67 ± 0.33^{b}
MCH (pg)	53.70 ± 0.46^{b}	55.67 ± 4.19^{b}	47.80 ± 0.80^{c}	55.17 ± 1.07^{b}	71.23 ± 0.03^{a}
MCHC (%)	39.07 ± 1.24^{bc}	40.37 ± 3.03^{bc}	35.33 ± 0.45^{c}	42.00 ± 0.92^{b}	57.27 ± 0.03^{a}
RBCD	18.37 ± 0.61^{a}	22.17 ± 2.40^{a}	23.57 ± 2.33^{a}	22.10 ± 3.75^{a}	24.00 ± 0.00^{a}
WBC ($\times10^{9}$ mL^{-1})	48.26 ± 2.14^{a}	63.12 ± 8.47^{a}	34.94 ± 10.79^{a}	49.84 ± 2.82^{a}	36.41 ± 0.00^{a}
LYM	40.50 ± 3.04^{a}	50.48 ± 7.96^{a}	31.41 ± 9.52^{a}	26.40 ± 8.42^{a}	30.99 ± 0.00^{a}
MID	4.02 ± 0.23^{a}	6.49 ± 0.22^{a}	2.87 ± 1.05^{a}	9.56 ± 2.43^{a}	3.88 ± 0.01^{a}
GRA	3.07 ± 0.79^{bc}	5.82 ± 0.29^{a}	0.67 ± 0.22^{c}	4.17 ± 0.01^{ab}	1.54 ± 0.00^{c}
LYM (%)	79.60 ± 1.96^{ab}	84.77 ± 2.80^{a}	90.57 ± 0.72^{a}	72.27 ± 3.61^{b}	85.17 ± 0.03^{a}
MID (%)	8.55 ± 0.84^{b}	10.80 ± 1.10^{ab}	7.70 ± 0.69^{b}	19.10 ± 4.04^{a}	10.67 ± 0.03^{ab}
GRA (%)	6.63 ± 1.93^{ab}	9.60 ± 0.87^{a}	1.87 ± 0.09^{c}	8.67 ± 0.43^{a}	4.20 ± 0.00^{bc}
PLT	16.67 ± 3.76^{c}	64.67 ± 30.31^{b}	16.67 ± 4.33^{c}	13.50 ± 5.48^{c}	152.67 ± 0.33^{a}
PCT	0.02 ± 0.00^{b}	0.08 ± 0.04^{b}	0.04 ± 0.01^{b}	0.02 ± 0.01^{b}	0.21 ± 0.00^{a}
MPV	9.07 ± 0.09^{b}	10.40 ± 0.87^{b}	8.67 ± 0.09^{b}	10.60 ± 1.04^{b}	13.87 ± 0.03^{a}
PDW	32.27 ± 1.30^{bc}	35.80 ± 1.56^{b}	29.47 ± 0.90^{cd}	26.87 ± 1.53^{d}	40.77 ± 0.03^{a}

Data are presented in mean±standard error; Treatments A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal. Means with different alphabet along each row represent significant differences at $p<0.05$. HGB: Haemoglobin, HCT: Haematocrit, RBC: Red blood cell, MCV: Mean corpuscular volume, MCH: Mean corpuscular haemoglobin, MCHC: Mean corpuscular haemoglobin concentration, WBC: White blood cells, RBCD: Red Blood Cell Deformability, LYM: Lymphocytes, GRA: Granulocytes, MID: mid-range absolute count, PDW: Platelet distribution width, MPV: Mean Platelet Volume, PCT: Plateletcrit, PLT: platelets

Table 3: Proximate composition of the carcass of C. *gariepinus* fed with black bean substitution

	A	B	C	D	E
Moisture (%)	71.55 ± 0.12^{a}	70.50 ± 3.44^{a}	68.47 ± 0.03^{a}	69.59 ± 1.48^{a}	70.33 ± 0.00^{a}
Ash (%)	2.51 ± 0.12^{ab}	2.21 ± 0.06^{c}	2.49 ± 0.04^{ab}	2.41 ± 0.01^{bc}	2.66 ± 0.00^{a}
Fat (%)	1.37 ± 0.09^{ab}	1.62 ± 0.11^{a}	1.60 ± 0.19^{a}	1.41 ± 0.04^{ab}	1.14 ± 0.00^{b}
Protein (%)	20.23 ± 0.09^{a}	20.28 ± 1.82^{a}	19.78 ± 0.22^{a}	18.51 ± 0.80^{a}	20.44 ± 0.27^{a}
Carbohydrate	4.38 ± 0.25^{b}	5.40 ± 1.67^{ab}	7.66 ± 0.43^{a}	8.09 ± 0.64^{a}	4.90 ± 0.02^{b}

Data are presented in mean±standard error; Treatments A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal. Means with different alphab*et al*ong each row represent significant differences at $p<0.05$

Table 4: Vitamins composition of catfish fed with black bean

Minerals	A	B	C	D	E
Vit. A	11.31 ± 0.398^{b}	12.99 ± 0.442^{a}	11.50 ± 0.144^{b}	11.50 ± 0.078^{b}	10.64 ± 0.012^{b}
Vit. D	0.22 ± 0.006^{a}	1.27 ± 0.572^{a}	0.48 ± 0.176^{a}	0.56 ± 0.162^{a}	0.40 ± 0.092^{a}
Vit. E	3.15 ± 0.110^{b}	3.56 ± 0.020^{a}	2.48 ± 0.176^{c}	2.53 ± 0.066^{c}	2.49 ± 0.090^{c}
Vit. K	0.22 ± 0.006^{cd}	0.24 ± 0.003^{abc}	0.25 ± 0.009^{ab}	0.26 ± 0.017^{a}	0.21 ± 0.000^{d}
Vit. B_1	0.70 ± 0.009^{b}	0.82 ± 0.038^{a}	0.25 ± 0.012^{d}	0.63 ± 0.006^{c}	0.73 ± 0.006^{b}
Vit. B_2	0.31 ± 0.012^{c}	0.35 ± 0.006^{a}	0.33 ± 0.000^{b}	0.33 ± 0.006^{b}	0.36 ± 0.009^{a}
Vit. B_6	0.81 ± 0.017^{a}	0.89 ± 0.026^{a}	0.88 ± 0.046^{a}	0.84 ± 0.012^{a}	0.85 ± 0.015^{a}
Vit. B_9	1.38 ± 0.023^{c}	1.47 ± 0.006^{ab}	1.54 ± 0.098^{a}	1.43 ± 0.006^{bc}	1.46 ± 0.012^{abc}

Data are presented in mean±standard error; group A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal

in group A (0.45 ± 0.017 mg 100 g^{-1}) and lowest in group B(0.36 ± 0.040 mg 100 g^{-1}). As compared to the group A, B, C and E had higher Fe, while Fe concentration was lower in group D (Fig. 4).

Vitamin profile of the experimental fish: All the Vitamins (Vit. A, Vit. D, Vit. D, Vit. K, Vit. B_1 and Vit. B_9) varied significantly ($p<0.05$) across the different treatments except Vit. D and Vit. B_6. Data also shows the Vit. B_9 values of all the groups in Table 4 noting that catfish in group D equally had the highest Vit. B_9 (1.54 ± 0.098 mg 100 g^{-1}) and group A had the least values.

Normalized body mass index of the experimental fish: Figure 5 shows the NOR Bio Index (NBI) across the different feed composition. Group B had the highest average NBI which

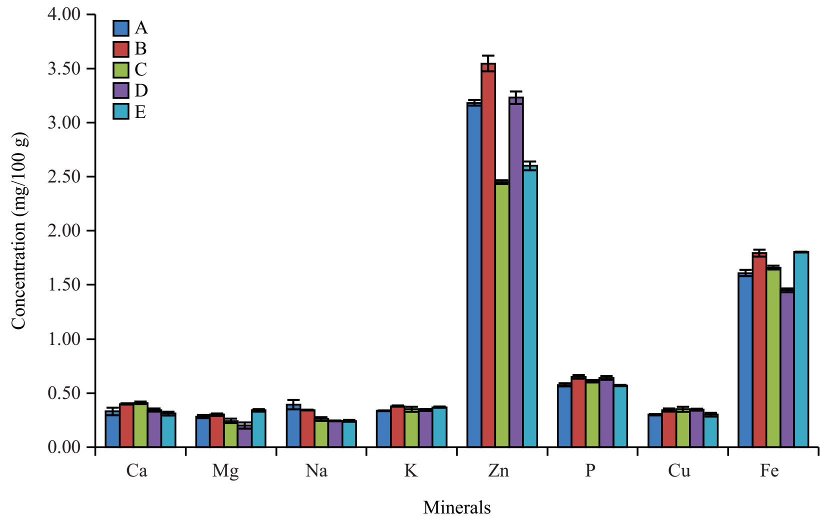

Fig. 4: Mineral composition of catfish fed with bean meal

Treatments A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal

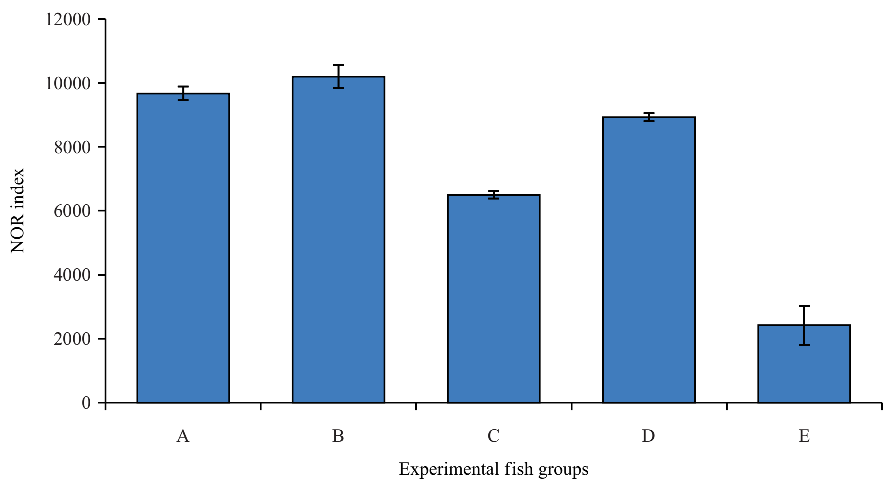

Fig. 5: Normalized biomass index of catfish (*C. gariepinus*) fed graded levels of black bean meal substitution (bars with different alphabets represent significant differences at $p<0.05$)

A: Commercial control group; B: Experimental group of 25% substitution of black bean meal; C: Experimental group of 50% substitution of black bean meal; D: Experimental group of 75% substitution of black bean meal; E: Experimental group of 100% substitution of black bean meal

was not significantly different from that of group A and D at a probability of 0.05. However, the NBI of group E was found to be significantly lower than every other group (Fig. 5).

DISCUSSION

The findings on proximate content of the commercial feed were in agreement with the report of Ajayi *et al.*[22]. This signifies that the substitution of fish meal with black bean would improve the ash, fibre, carbohydrate and protein content of the meal. The results in temperature and pH were within the range recorded by Nsofor *et al.*[23]. The temperature of the water-based ecosystem is decisive for assuring the continual survival, production and adequate metabolic activities in fish. Inability to get used to temperature variations may result in fish mortality. One of the most critical abiotic factors impacting oxygen levels in water-based ecosystems is the temperature of water[12]. Kausar and Salim[24] established that the most favourable temperature for superlative growth of European catfish was between 25 and 28°C. Most excellent outcomes were recorded at 27°C.

Amisah *et al.*[25] had opined that when alternative food sources such as plant protein are used in fish diets, one of the common problems encountered is the acceptability of the feed by fish and this frequently relates to the palatability of the diet. A similar situation was observed as a higher concentration of black bean meal did not show great promise in the development of catfish. The findings of this study were consistent with the report of Defang *et al.*[26], who observed lower weight gain and poorer feed conversion ratio in all birds fed with cowpea and or black common beans substituted meal during the starter period. The low weight gain obtained could be attributed to the poor accessibility of nutrients in the diets by enzymes and the treatment method used in detoxifying the test grains as explained by Michael and Sogbesan[27]. However, in the works of Amisah *et al.*[25], all the experimental diets were accepted by *Clarias gariepinus juveniles*, indicating that the levels of incorporation of *Leucaena* leaf meal did not affect the palatability of the diets. This was attributed to the processing technique which involved soaking and drying techniques that might have reduced the antinutrient in *Leucaena* leaf meal, thereby increasing its palatability in *Clarias gariepinus*. More so, the works of Siddhuraju and Becker[15] reported that reduction in antinutrient by different processing techniques resulted in better palatability and growth in fish. Therefore if the preparation of black bean meal is modified, it is more likely to increase its acceptability by *Clarias gariepinus* to enhance growth. The lower and the higher values of mean condition factor recorded for fish substituted with graded levels of black beans than the controls entails that they could survive better even when biotic and abiotic factors are less favourable[28]. The finding of this study is also supported by the report of other researchers[29] who similarly reported an increase in the condition factor of fish feed with graded levels of earthworm meal in the diet of fingerlings.

The high platelet values observed is an indication that the fish are likely to withstand and heal from bruises that might have been acquired during fighting and prevention of excessive bleeding via enactment of rapid clotting at injury site[30]. It was observed that substituting feed with 100% black bean will be more efficient in increasing the PCT content in fish. The feeds substituted with 25 and 100% concentration of black improved the PDWC of catfish as compared to the commercial control.

The knowledge of the carcass composition of fish feed is important because of the dietary and medical emphasis on the role of these nutrients in human health[31]. Fish feed nutrient composition plays a vital role in the acceleration of feed consumption, fish growth and reproduction. However, protein is an indispensable nutrient that must be incorporated in the diet in correct proportion to guarantee sufficient growth and health of the fish[32]. The lower protein content in the feed substituted with higher graded levels of black beans could explain the lower weight gain and growth rate of fish fed with higher levels of substituted black bean meals. According to another study[33], catfish also have a low capability to digest crude fibre. The result was in agreement with the reports of previous study[34] that commercial catfish feeds typically contain less than 5% crude fibre.

From the data collected for catfish carcass, it was discovered that group A had more moisture content while group C had the lowest moisture content. The data suggests that 50% black bean substituted feed will be more efficient in reducing the moisture content in catfish. The ash content was found to be highest in group F signifying that substituting feed with 100% black bean was more efficient in increasing the ash content in fish. Similarly, it was found out that fish fed with 25% black bean meal had higher protein. The study also reveals that feeds substituted with varied concentration of black improved the carbohydrate content especially 75 and 50% black bean concentrated meal as compared to the controls. The finding indicates that there were protein synthesis and increased tissue production in the treated catfish, implying that fish growth was not due to the increase in weight alone. This was supported by the reports of Koven *et al.*[35] and Fountoulaki *et al.*[36]. The high moisture content might likely be responsible for higher weight gained recorded by the fish fed with the commercial feed. The moderate level of carcass fat in diets indicated an enhanced production of lipids in the fish. Similar studies[37] reported a similar increase in carcass fat as a result of the fat in feed. Fountoulaki *et al.*[36] observed in gilthead bream fingerlings that lipid was associated with increased efficiency of metabolism.

The findings of this study showed a notable reduction in all the minerals and vitamins across all higher levels of black bean substituted meal as compared to both the commercial control feed except K, Vit. B_2 and Vit. B_6. Ca, Mg, Na, Zn, P, Cu, Fe, Vit. K and Vit. B_9 were highest in the feed substituted with 25% black bean. While K, Vit. B_2 and Vit. B_6 content were highest in the commercial feed and lowest in 25, 100 and 75% black bean substituted feed respectively. The remarkable reduction in all the mineral content observed can be attributed to the processing methods except the iron content which was almost retained. This study was in agreement with the report Mosisa and Tura[37] who reported a decrease in mineral composition of 'hepho' beans using different processing methods. They attributed the decrease to be due to removal of the hulls and leaching of the minerals into the water during the cooking treatments. Ejigui *et al.*[38] also reported a great loss of mineral during cooking and dehulling of red kidney beans. This observation was in agreement with the report of Abiodum and Adepeju[39] that cooking caused a 0.75% loss of Ca content in Cowpea. The loss of divalent metals was attributed to their binding to proteins and the formation of phytate-cation in addition to leaching. The findings for the mineral content in catfish also showed that fish fed with feed substituted with 50% black bean had more Ca, while catfish fed with feed substituted with 100% black bean had a reduced Ca concentration. The Mg concentration was highest in fish fed with 100% black bean substituted meal and lowest in fish fed with the 75% black bean meal. As compared to the commercial control, fish fed with 25, 50 and 75% black bean substituted meal had lower Mg concentration. Catfish fed with 25% black bean substituted meal had the highest Na concentration and the fish fed with the 75% black bean meal had the lowest concentration. Catfish fed with 100% black bean substituted meal had higher Fe, while the 75% black bean meal group had lower Fe concentration. Fish fed with the commercial feed recorded the highest NBI and the lowest NBI was observed in fish fed with 100% black bean meal, signifying that using black bean alone as feed is not an option in improving the NBI of catfish.

CONCLUSION

Conclusively, black runner bean meal is an economical and viable option for reducing cost and increasing production. The results of this study indicated that replacing fish meal with black bean meal as low as 25% in the African catfish diet without affecting the physiology or health status of fish improve the haematology, proximate and mineral composition of the fish.

SIGNIFICANCE STATEMENT

This study discovered black runner bean can be beneficial in reducing the cost of producing catfish and increasing production. This study will help the researchers to uncover new areas of supplementing fish feed using black runner bean that. Thus a new theory on the processing techniques may be arrived at.

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