Original Research Article: full paper

(2023), «EUREKA: Life Sciences»
Number 2

DIETARY SUPPLEMENT USING COCKROACH MEAL: IMPACT ON GROWTH INDICES AND BIOCHEMICAL RESPONSES IN HYBRID CATFISH

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Abstract

Globally the need to substitute fishmeal with other animal protein sources in the fish diet has gained more attention; which is occasioned by the increasing cost of fish. A 12-week trial was conducted to ascertain the growth indices and biochemical response of hybrid catfish (*Clarias gariepinus*(♀) and *Heterobranchus bidorsalis* (♂)) fed cockroach meal supplement. A total of 800 hybrid catfish were randomly distributed into four dietary treatments (Diet A- control feed), Diet B (50 % cockroach and 50 % fishmeal), Diet C (100 % cockroach meal) and Diet D (100 % fishmeal). Each treatment was replicated with 35 fish per experimental pond in a completely randomized design. Progressive weight gain was determined bi-weekly. At the end of the study period, fishes were randomly sacrificed for proximate compositions and plasma biochemical analyses (glucose, triglyceride, cholesterol, total protein, albumin) using standard protocols. The study revealed that growth parameters (Weight gain, Average weight gain, Protein efficiency ratio, Feed Conversion rate, Specific growth rate and Survival rate (SR) were influenced by the dietary treatments (p>0.05). The highest weight gain was recorded in Diet 1 (8847.73±292.65 g)>Diet 2 (7816.33±121.71 g)>Diet 3 (7811.67±566.08 g)>Diet 4 (7022.00±44.193 g). Similarly, the best feed conversion ratio was found in fish fed Diet A (10.12±0.01)>Diet B, C and D had the same values of 0.11 g respectively. There was no significant (p>0.05) difference in plasma biochemical indicators measured when compared to the control (Diet A). Thus, indicating that all the fish were healthy and had normal physiological activities. Cockroach meal can therefore, be used as a feed supplement without having any adverse effect on the growth and well-being of hybrid catfish fingerlings.

Keywords: Dietary supplement, catfish, cockroach, formulated diets, growth indices, biochemical parameters.

DOI: 10.21303/2504-5695.2023.002909

1. Introduction

The report of United Nation [1] anticipated the population of Africa to reach about 2.53 billion people by the year 2050 with the demand for food and protein increasing significantly. One of the agricultural sectors that would caution this effect is aquaculture [2]. Aquaculture occupied the major principal cost in fishery aquaculture with its' sustained advancement in culturing of fishes and shellfish species. Thus, the fastest growing industry with an annual production capacity of 800 million tons [3]; and an annual estimated growth rate of 30 % per year [3, 4]. Fish

are good source of protein, fatty acids, vitamins, minerals and essential micronutrients as they are one of the major sources of cheap and relatively affordable animal protein sources in Nigeria; constituting about 40 % of animal protein in the diet [5]. Hybrid catfish are considered to be highly nutritious fish containing high amounts of nutrients, minerals and proteins and low or no saturated fat as low carbohydrate [6]. These are fishes of the Clariidae family, which are common in the African country due to their cultural characteristics. The utilization of fish as the major source of protein provides all the necessary nourishments needed for healthy growth and proper functioning of the body [7]. The search for alternative animal protein source for fish in fish feed production is gaining more attention. As the early studies using non animal sources [8, 9] have not provided the expected result or has created room for more competition in the resource with human and other animals. This is premised as the conventional ingredient (fish) are becoming costlier, less affordable and less available thus, resulting in high feed prices and unsteady costs for fish meal in market [10].

Traditionally, edible insects have been eaten worldwide as insect nutrition [11]. According to FAO [7] insects are rich in nutritional values (especially protein, fat and minerals) and safer alternative to fishmeal. Insects are good sources of amino acid and are essential nutrients [12]. The production of animal proteins by insects was reportable as being efficiently economical than any traditional animal production [13]. One of the insects gaining global attention with prospective is the Cockroaches.

Cockroach is insects of the order Blattodea. They live in close association with individuals. Cockroach is omnivorous scavengers; that survives in extremely harsh conditions for a longer time in the shape of an egg. They are mostly active in the dark hours or in the early morning, preferring little areas and growing well in dry, damp locations, congregating in sewers, dumps, outbuildings and wood piles during the heat of the year. Cockroach is already a common part of some regional and national diets, as its powder is used to produce medicines [6]. Studies have been conducted to shown the proximate and mineral composition of cockroach as well as its nutritional role in improving the amino acid profile of fish [14, 15]. One of Nigeria's most consumed and preferred fish is the Hybrid catfish, therefore, the need to sustain its production in order to improve fish availability, create job opportunities, boost economy amongst others using cockroach meal as the main protein source to replace fishmeal in its diet during production. Ipso-facto, this study was conducted to determine response of hybrid catfish fed supplemented cockroach meal using growth indices and biochemical indicators.

The purpose of this study was to study the potentials of using cockroach meals as supplementary protein source in the diet of Catfish and to provide the avenue for the growing of cockroach in commercial set up.

2. Materials and Methods

2. 1. Fish collection

A total of eight hundred fingerlings of hybrid catfish with and average live weight of 15 g were purchased from a reputable fish farm (Alhassan fish farm in Abuja). The fishes were transported to biological garden of Ibrahim Badamasi Babangida University in a 50-litre filled plastic container. Acclimation was allowed for two weeks, during which they were fed with commercial fish feed pellets, before gradually introducing them to the formulated feed as they were fed twice daily (Morning and evening). After acclimation, the fish were randomly distributed to the experimental concrete tanks in two replicate, each with thirty-five (35) fingerlings in semi-static bioassay system. The tanks were drained bi-weekly to prevent accumulation of organic matter, as the fish were weighed to measure the growth parameters.

2. 2. Experimental set-up

The experimental set-up consists of twelve (12) outdoor concrete tanks with a capacity of 1.3×0.9×1 m (1.17 m^3). Each tank was assigned to each experimental diet containing different meal levels. The water level was remained at 0.8 m throughout the experimental phase with replenishment at two days interval.

2. 3. Sources of ingredients and diets preparation

Dry fish, baobab, cassava flour, maize flour, brown algae (*Sargassum muticum*), vitalyte (Phed Agrovet Nigeria Ltd) were locally obtained from the market, while five hundred cockroaches were obtained from the environment (houses) and sundried, all the ingredients were ground to powder [16]. Modified Pearson Square Formulation method was adopted for the feed formulation [17]. Four dietary treatments (Diet A- control feed-commercial fish feed), Diet B (50 % cockroach and 50 % fishmeal), Diet C (100 % cockroach meal) and Diet D (100 % fishmeal). Pellets of diets B to D were prepared and air-dried at constant humidity before being packed in airtight containers for further analyses and usage. The percentage component of experimental feed used in the study are presented in **Table 1**.

Table 1

Percentage component of Experimental feed ingredients used in the study

Ingredients (g)	Diet A	Diet B	Diet C	Diet D
Fish meal	-	10.48	-	24.05
Cockroach meal	-	10.48	19.11	-
Vitamin (premix)	-	2.00	2.00	2.00
Brown seaweed	-	3.00	3.00	3.00
Maize	-	64.00	65.89	65.95
Cassava	-	5.00	5.00	5.00
Baobab	-	5.00	5.00	5.00
Total	100	100	100	100

Diet A is conventional feed (2mm) of Aquamax, Diet B is 50 % cockroach and 50 % fishmeal, Diet C is 100 % cockroach meal and Diet D=100 % fishmeal.

2. 4. Determination of Proximate Analysis

The proximate analysis was determined using the standard techniques of AOAC [18]. The parameters determined include Moisture and Dry Matter, Ash content, Lipid, Crude Protein Content, Crude Fibre and Nitrogen Free Extract (NFE).

2. 5. Evaluation of growth parameters

Growth performance was measured in terms of weight gain (WG), specific growth rate (SGR), average daily weight gain (ADG), feed conversion ratio (FCR), the protein efficiency ratio (PER), survival rate (SR). The calculated growth profiles were in accordance with the procedures of [19, 20]. These profiles are:

$$\text{Weight gain (g)}=WG=W_2-W_1,$$

where W_2 is the final body weight, W_1 is the initial body weight,

$$\text{Average weight gain } (\text{g}) = \frac{\text{Final weight}}{\text{Initial weight}} \times \text{ days},$$

$$\text{Protein efficiency ratio } (\text{g}) = \frac{\text{Wet body gain} \times 100}{\text{Protein intake}},$$

$$\text{Feed conversion ratio } (\text{g}) = \frac{\text{Total feed consumed by fish}}{\text{Weight gain of fish}},$$

$$\text{Specific growth rate}(\%\text{ per day}) = \frac{\text{Loge}W2 - \text{Loge}\,W1}{T2 - T1} \times 100,$$

W_2 is the weight of fish at time $T2$ (final), W_1 is the weight of fish at time $T1$ (Initial),

$$\text{Survival rate } (\%) = \frac{\text{Final number of fish}}{\text{Initial number of fish}} \times 100.$$

2. 6. Determination of biochemical parameters

At the end of the experiment, blood samples were randomly collected from twenty (20) fish per pond for determination of biochemical indices. Samples were collected using 5ml disposable syringe and 21gauge disposable hypodermic needle from the vertebral column [21] into anticoagulant lithium heparin test tube and centrifuged (at 1500 rpm for 10 minutes) for plasma [22]. The determined biochemical profiles were glucose, triglycerides, cholesterol, total protein and albumin. These parameters were investigated following the manufacturer's instruction of the commercially available reagent kits (SPECTRUM diagnostic) and absorbance (A) of each sample and the standard were read against the blank with Spectrophotometer (20D PEC Medicals U.S.A) at the respective absorbance.

2. 7. Data analyses

All data were presented as mean±standard mean error (SEM), data were evaluated using a single factor analysis of variance, after which the individual mean was calculated using the multiple comparison tests of Sidak. In all cases the difference was considered statistically significant at $p<0.05$. All statistical analyzes were performed using GraphPad prism software version 6.0 San Diego, C.A.

3. Results

3. 1. Proximate composition of ingredients used for the diet

The Proximate composition of feed ingredients is presented in **Table 2**. Significantly ($p<0.05$) higher moisture content was recorded in cockroach meal (5.70 %) and the lowest was recorded in fishmeal (3.28 %). The highest crude protein content was recorded in fishmeal (55.85 %) and the lowest was recorded in brown seaweed (9.19 %). The highest lipid content of 18.77 % was recorded in fish meal, while baobab (4.09 %) recorded the least value. Similarly, the lowest carbohydrate content was recorded in fish meal and cockroach meal of 3.77 %. Never the less, the ash content was highest (35.73 %) in brown seaweed.

Table 2

Proximate compositions of ingredients used for the diet

Ingredients	Moisture (%)	Crude protein (%)	Crude fibre (%)	Lipid (%)	Ash (%)	CHO (%)	Energy (%)
FM	3.28±0.01^b	55.85±0.01^a	2.61±0.01^c	18.77±0.01^a	14.88±0.01^b	3.77±0.01^d	410.46±0.01^a
CM	5.70±0.01^a	53.76±0.01^a	10.39±0.11^a	16.78±0.01^a	8.95±0.01^c	3.77±0.01^d	384.78±0.01^b
BS	1.95±0.01^c	9.19±0.01^b	8.35±0.01^b	1.99±0.01^c	35.73±0.27^a	42.34±0.01^c	225.24±0.01^c
Baobab	5.62±0.10^a	10.75±0.01^b	11.83±0.01^a	4.09±0.01^b	7.59±0.01^c	60.16±0.01^b	321.59±0.01^b
Maize	3.80±0.01^b	12.31±0.01^b	0.78±0.12^d	3.21±0.01^b	0.84±0.01^d	74.01±0.01^a	370.87±0.01^b
Cassava	3.33±0.01^b	2.56±0.01^c	0.00±0.00^d	2.89±0.01^b	2.21±0.12^d	88.92±0.01^a	40.21±0.01^d

Note: FM – fish meal, CM – cockroach meal and BS – brown seaweed. Values in the same column with different letters are not significantly different (p>0.05) from one another

3. 2. Mineral composition of ingredients used for the diets

The minerals composition of the practical diets are detailed in **Table 3**. Potassium was significantly ($p<0.05$) higher in cockroach meal when compare with fishmeal meal. The highest sodium (530.40 mg/100 g) content was recorded in baobab and lowest (8.51 mg/100 g) was in maize. There was significant ($p<0.05$) differences in cockroach meal phosphorus and calcium contents

as compared to others. The highest (502.02 mg/100 g) magnesium content was obtained in baobab while maize recorded lowest (124.32 mg/100 g) content.

Table 3

Mineral composition of diets ingredients

Mineral	K (mg/100 g)	Na (mg/100 g)	P (mg/100 g)	Ca (mg/100 g)	Mg (mg/100 g)
Fishmeal	285.56±0.11^{b}	514.19±0.11^{a}	241.67±0.12^{b}	417.30±0.12^{b}	332.01±0.12^{b}
Cockroach	355.54±0.12^{b}	157.29±0.11^{b}	405.78±0.11^{a}	585.50±0.12^{a}	340.19±0.12^{b}
Brown seaweed	132.19±0.12^{c}	55.01±0.12^{c}	120.31±0.12^{c}	435.00±0.12^{b}	190.58±0.12^{c}
Baobab	1206.39±0.11^{a}	530.40±0.01^{a}	296.55±0.12^{b}	20.67±0.01^{d}	502.02±0.01^{a}
Maize	229.39±0.01^{b}	8.51±0.01^{e}	187.60±0.11^{c}	171.23±0.05^{c}	124.32±0.01^{c}
Cassava	48.93±0.01^{d}	20.29±0.01^{d}	35.41±0.01^{d}	44.19±0.12^{d}	186.73±0.01^{c}

Note: values in the same column with different letters are not significantly different (p>0.05) from one another

3. 3. Nutrient composition of formulated diets

The nutrient composition of the formulated fish diet is as presented in **Table 4**. There were no significant(p>0.05) differences in the crude protein content of diets B to D. Diet A, a commercial feed had highest crude protein value of 47.26 %.

Table 4

Nutrient composition of diets ingredients

Proximate composition (%)	Diet A	Diet B	Diet C	Diet D
Moisture content	6.72±0.05^{a}	8.91±0.01^{a}	9.11±0.01^{a}	9.22±0.01^{a}
Ash	11.33±0.01^{a}	6.01±0.01^{b}	3.76±0.01^{c}	5.95±0.01^{b}
Lipid	5.01±0.01^{a}	5.88±0.02^{a}	5.71±0.01^{a}	6.51±3.50^{a}
Crude fibre	2.21±0.01^{a}	2.01±0.01^{a}	2.02±0.02^{a}	3.31±0.01^{a}
Crude protein	47.26±0.01^{a}	35.04±0.01^{a}	35.84±0.03^{a}	35.12±0.04^{a}
CHO	27.52±0.01^{b}	42.29±0.01^{a}	43.59±0.01^{a}	42.06±0.01^{a}
Energy	342.71±0.01^{a}	361.90±0.10^{a}	362.84±0.04^{a}	354.08±0.01^{a}

Note: values in the same row with different letters are not significantly different (p>0.05) from one another. Diet A is conventional feed (2 mm) of Aquamax, Diet B is 50 % cockroach and 50 % fishmeal, Diet C is 100 % cockroach meal and Diet D=100 % fishmeal

3. 4. Growth performance of Hybrid catfish

The growth performance of hybrid catfish fed supplemented cockroach meal (**Table 5**) revealed the highest survival rate was in fish fed Diet A>Diet C>Diet B>Diet D in the order of magnitude. The fish fed diet D recorded the least WG (7022.00 g) followed by that of diet C (7811.67 g). The maximum WG values were obtained in fish fed diets A and B with 8847.73 g and 7816.33 g respectively. There was significant (p<0.05) difference in the average weight gain (AWG) of fish fed on the different diets. Fish fed on diet A had the highest mean weight gain (106.92 g), while those on diet C had the lowest weight gain of 60.39 g. The Specific Growth Rate (SGR) revealed no significant (p>0.05) difference between fish fed different diets with respect to the overall growth rate. The best SGR results were obtained in fish fed diet A, with the highest value (1.88 %), then that of diet B (1.77 %), whilst fish fed diets C and D recorded the same value of 1.76 %.

The feed conversion ratio (FCR) of the fish fed diet A was 0.12 g which was not significantly (p>0.05) different from that of fish fed diets B, C and D that recorded 0.11 g. However, the values of PER revealed significant (p<0.05) between the fish fed the varying diets. Fish fed diet A had the lowest PER value of 94.94 g, whilst the highest 104.41 g value was recorded in fish fed diet B.

Table 5

Growth performance of hybrid catfish fed practical diet

Growth indices	Diet A	Diet B	Diet C	Diet D
Weight gain (g)	8847.73±292.65^a	7816.33±121.71^a	7811.67±566.08^a	7022.00±44.193^a
Specific growth rate (%)	1.88±0.02^a	1.77±0.01^a	1.76±0.05^a	1.76±0.03^a
Average daily weight gain (g)	106.92±2.57^a	92.34±1.45^a	60.39±6.74^b	81.99±0.53^a
Feed Conversion ratio (g)	0.12±0.01^a	0.11±0.00^a	0.11±0.01^a	0.11±0.00^a
Protein efficiency Ratio (g)	94.94±1.91^a	104.41±1.36^a	101.83±7.02^a	100.71±0.44^a
Survival rate (%)	85.71±0.00^a	82.19±4.76^a	82.67±9.52^a	80.00±2.86^a

Note: values are the mean ± SEM of triplicate groups of 20 fish. Values in the same column with different letters are not significantly different ($p>0.05$) from one another. Diet A is conventional feed (2mm) of Aquamax, Diet B is 50 % cockroach and 50 % fishmeal, Diet C is 100 % cockroach meal and Diet D=100 % fishmeal

3. 5. Plasma biochemical parameters of hybrid catfish fed practical diets

The plasma biochemical parameters of the experimental catfish fed practical diets are shown in **Table 6**. The highest (156.10 mg/dL) glucose level was recorded in fish fed diet D. The cholesterol level was observed to be directly proportional to the glucose level recording the highest 210.27 mg/dL value in diet A. The value of albumin was recorded to differ significantly ($p<0.05$) as the lowest level of albumin was recorded in fish fed diet B; which was as observed in the total protein level. The triglyceride level was observed in fish fed the diets C<B<A<D order of magnitude.

Table 6

Plasma biochemical parameters of hybrid catfish fed practical diets

Parameters indices	Diet A	Diet B	Diet C	Diet D
Glucose(mg/dl)	89.60±18.09^b	152.17±20.84^a	127.83±28.20^a	156.10±21.27^a
Triglyceride(mg/dl)	291.73±17.50^b	413.20±28.15^a	584.73±29.64^a	269.93±13.24^b
Cholesterol(mg/dl)	210.27±10.34^a	165.13±8.84^b	170.20±30.97^b	154.60±7.32^b
Total protein(g/dl)	7.66±0.34^a	2.78±0.08^b	3.40±0.33^b	4.78±0.14^a
Albumin(g/dl)	4.83±0.15^a	4.66±0.32^a	5.28±0.44^a	5.15±0.18^a

Note: values in the same column with different letters are not significantly different ($p>0.05$) from one another. Diet A is conventional feed (2mm) of Aquamax, Diet B is 50 % cockroach and 50 % fishmeal, Diet C is 100 % cockroach meal and Diet D=100 % fishmeal

4. Discussion

4. 1. Nutrient and mineral compositions

Fish feed is significant because of the dietary focus on the role of these nutrients in fish and human health [6]. Studies has been advocating for the inclusion or supplementing of fish meal with insect protein in fish diets [14, 15]. Insect protein serves as dietary protein, which plays a significant role in the supply of amino acids for body biosynthesis that, are important for fish growth [23]. The moisture content observed in this study was within the recommended range of feed nutrient composition, which is an indication that the moisture content of catfish should not exceed 12 % in order to prevent the molding of the feed [24]. The ash content is a measure of the total amount of mineral elements such as calcium and phosphorus within a feed [25]. The ash content in this study varied significantly ($p<0.05$) between practical diet and the control diet (diet A). There was no rejection of feed between fish fed realistic diets; however, the acceptability of diets varied considerably among treatments. Some studies found that the growth quality of *Clarias gariepinus* was better with a diet containing 9.3 % ash [26]. Lipids are easily digestible and are important source of concentrated energy that plays role in the growth and development of fish [24]. The lipids content of the feeds shows no significant difference ($p>0.05$) among the experimental diets. The overall lipid content of fish fed experimental diets is directly proportional to the feed moisture content and has also shown that the higher the level of inclusion of insect protein in the diet of hybrid catfish fingerlings, it has the potential for increasing lipid deposition. Crude fibre is very important in fish feed

as it gives fish physical bulkiness. The presence of fibre in feed improves binding and moderates the passage of feed through the alimentary canal [25]. However, high level of fibre content more than 8–12 % in fish feed lowers feed digestibility of nutrient and causes slow growth [27]. There was no significant difference in crude fiber content among practical diets, with the highest fibre content in diet D as [28] reported a substantial high growth output of *Clarias gariepinus* juveniles that is fed with diet containing less than 2 % fiber content; thus may be responsible for the trend of growth monitored in this study.

Protein is an essential nutrient that needs to be integrated into a proper diet to ensure adequate growth and wellbeing of fish [29]. The crude protein value in this study shows no significant difference between different the diets. This work is also consistent with the work [30] which evaluates the growth, feed utilization, survival and body composition of fingerlings of slender walking catfish (*Clarias nieuhofii*) fed diets containing different protein levels, at the end of the experiment, body weight, weight gain and overall growth rate improved as dietary protein levels rose from 32 % to 40 % protein. In its findings [31] also indicated that the protein requirement for fish should be more than 35 %. Therefore, the crude protein in this study falls within the limit. The carbohydrate content of the different diets differs significantly ($p<0.05$) as the supplemented cockroach meal recorded much higher values of carbohydrate than the control diet. Similarly, the energy value exhibit no significant difference ($p>0.05$) among the diets, but the supplemented diets containing different amount of cockroach meal recorded much higher energy value than the control meal. The carbohydrate content and the energy value obtained in this study are within the recommended ranged for fish feed [24].

Some authors [3, 20] reported that fish feed constituents play a vital role in promoting the development and commitment of fish growth and survival rate. Amongst the essential elements (K, Ca, Na, Mg, P) mg/100 g, minerals play important roles in osmoregulation, intermediate metabolism, and skeleton and scale formation lall. These elements are needed by the body because they make up parts of the rigid body structure of soft tissues and body fluids. Minerals generally worked in conjunction with each other and also with other nutrients. Therefore, the deficiency of any minerals can cause health problems as these study revealed that these minerals are not deficiency in the diets.

4. 2. Growth performances and Feed utilization

The suitability of the inclusion of alternative ingredients in the fish diet in terms of growth performance has been shown to vary greatly between fish species and experimental conditions [4, 32]. The weight gain, specific growth rate (SGR) and average daily weight gain (ADW) showed no significant difference ($p>0.05$) between fish fed with control diet and the practical diets with a significant increase during the 12-week experimental phase; was an indication that the feed were properly metabolized for these indicator parameters of growth. Therefore, the fish were able to convert the protein fed to the muscles [8, 9]. Therefore, the nutritional value of the control feed and the supplemented diets encouraged good growth and higher yields in fish [33]. The findings of [31] also indicated that the protein requirement for fish should be above 35 %; thus, is in conformity with report of this study. The feed conversion rate (FCR) in this study was similar, as the fish fed with control diet and the practical diets showed no significant ($p>0.05$). According to [34] a lower FCR value implies an efficient use of fish feed, the importance of fish feed intake as a determinant of fish performance has been strongly emphasized by the possibility of protein saving effects on other nutrients in a feed. That is, more energy is given for metabolism through other nutrients; more protein intake was required for fish growth and tissue production; thus, the reflection in this study. The survival rate (SR) was above 80 % in the study, thus, less than 20 % mortality rate. The mortality recorded at the first quarter of the study, an indication that as they were exposed to the fed, they were able to adjust to the environmental variables. The protein efficiency ratio (PER) decreased with an increase in the rate of dietary inclusion. Feed value and quality depends on how well the feed meets the nutritional requirements of the fish [27]. It is therefore, noted that the inclusion of cockroach meal in diets of hybrid catfish meets the criterion.

4. 3. Plasma biochemical parameters of fish fed practical diets

Examination of blood and biochemical biomarkers are useful diagnostic tools used in evaluating the physiological status of fish [35] and in assessing the effect of replacement of ingredient on fish health [3]. Blood is a good indicator for the health of the organism as studies have been conducted on serum biochemical catfish [17, 36]. Serum total protein levels can be used as a diagnostic tool and as a valuable measure for determining the general physiological status of fish [37]. The total protein value in this study differs significantly among fish fed the practical diets with the least value observed in fish fed diets B and C (diets with the inclusion of cockroach meal). However, the values were in conformity with some previous reports of maximum serum protein levels of 2.8 to 8.2 g/dL [17, 38]. Similarly, the average (4.08±0.74) plasma protein in *Clarias gariepinus* was documented [38]. Whilst other researcher has reported less values in the fish and other fish species [39]. Thus, the presences cockroach inclusion on the diet of the hybrid catfish has no negative consequences on the recorded total protein level. Albumin plays important role sustaining immune response of fish. Albumin is the most abundant serum protein representing 55–65 % of the total protein [40] thus the value reported in the study and is in consistent with those reported for hybrid catfish under laboratory condition [17, 41]. Of interest was the higher albumin value observed in fish fed diet C (cockroach meal), an indication of stronger immune response in the fish.

Glucose is derived from the breakdown of carbohydrate obtained from daily diet that is regulated through the process of glycogenolysis and gluconeogenesis; thus, provides the major energy source for fish. In this study, the glucose level was higher in practical diets compared to the control. However, they were within the acceptable range for catfish [42]. The high blood glucose may be attributed to its role in homeostasis by filtration and reabsorption. Thus, signifying the presences of cockroach meal boosting the level of glucose, thereby providing energy for metabolism and growth.

Cholesterol is an important component of cell membranes and functions as precursors to the synthesis of sex hormones, a number of fish species have seasonal variations in cholesterol with increased levels during spawning. The level of cholesterol monitored in this study was lower in cockroach inclusion diets compared to the control, following similar trend with the level of total protein monitored. This is in consistent with those obtained in other studies [39]. Some authors attributes the variations in cholesterol level to fish species, human handling and sexual development [43]. This study has demonstrated that supplementation/inclusion of cockroach meal in the feed of hybrid catfish at different percentage inclusion levels can improve the health and blood biochemical parameters as well as the cellular immune system of the fish.

The study was designed to study the growth of catfish fed supplemented cockroach meal. However, getting the insect protein in large quantity was a little difficult as no any form of growing outlet of the insect is available.

The ability to grow fish on insect protein source is the way forward. Insect that serves as nuisance for man and it environment may not constitute any threat of competition in Asian countries commercial growing of cockroach as feed is gaining more grounds. Thus, with this study other researchers would conduct more studies on the gap created to solving and giving room for the use of insect protein source.

5. Conclusions

In conclusion, the study have shown that crude protein level of 35 % (average) with cockroach meal inclusion and can provide the adequate and competitive growth for hybrid catfish with other fish feed sources. The growth performance indices have proven that the inclusion of the cockroach meal can provide the desired growth for the test with proper utilization of nutrients. The values of biochemical parameters monitored revealed that the inclusion of cockroach meal has the tendency to improve the metabolism (glucose), immune and health (albumin) and structure (cholesterol) of the test fish.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

Manuscript has associated data in a data repository.

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Received date 15.01.2023
Accepted date 17.03.2023
Published date 31.03.2023

How to cite: *Kolawole, A. O., Adamu, K. M., Usman, I. B., Mohammed, Y. M., Aliyu-Paiko, M. (2023). Dietary supplement using cockroach meal: impact on growth indices and biochemical responses in hybrid catfish. EUREKA: Life Sciences, 2, 3–13. doi: https://doi.org/10.21303/2504-5695.2023.002909*