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Effect of Hydrolyzed Feather Meal as Substitute for Fish Meal in the Diet of *Clarias gariepinus* (Burchell 1822)

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Abstract

Clarias gariepinus is a globally popular aquaculture species and it's distributed throughout Africa. The study was aimed at examining the effects of hydrolysed feather meal as a substitute for fish meal in the diets of African catfish *Clarias gariepinus* fingerlings. Three months feeding trial was conducted to examine the partial replacement of fish meal (65% CP) with hydrolyzed feather meal (85% CP) in the diets of Clarias gariepinus. One hundred and eighty (180) fingerlings were selected with the mean weight of 9.5g. They were randomly grouped into six (6) treatments and three (3) replicates with ten (10) fish per 200L truncated conical aqua drum plastic tanks with the diameter at the top and bottom as (0.62 and 0.50m); the height and slant height as 0.8m and 0.82m. This experiment was designed with two control treatments T_1, (a standard commercial diet, Coppens 2mm) and T_2 (a diet with 0% FTM, 100% FM); the remaining treatment feeds had FTM inclusions at 25%, 50%, 75% and 100% in substitution for fish meal which represented T_3, T_4, T_5, and T_6 respectively. The control feed in T_1 (Coppens) turned out to be the best feed, mostly acceptable when considering the time of feed intake, growth performance and nutrient utilization, but was at a disadvantage when analyzing its cost hence, became the most expensive amongst the treatment feeds. The profit index ranged from 7.55 in T_5 (75% inclusion of FTM) to 1.91 in control T_1 (Coppens). The result indicates that T_5 had the best growth performance and cost effectiveness. T_5 also had the best survival rate which was a plus to its sales. therefor, feather meal can be substituted for fish meal up to 75% to obtain optimum yield, higher survival rate and at a lower cost in the diet of *Clarias gariepinus* fingerlings.

Keywords: Hydrolyzed, Feather, Meal, Substitute and *Clariid fish*

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INTRODUCTION

Aquaculture in the early 1970‟s only had 3% of total world global fisheries. Today, aquaculture production is responsible for over 27% of global fisheries and channel over 36% of food fish to the consumer. This coincides with a period when conventional global capture fisheries have reached about 95 million metric tonnes. It is the world's fastest growing food production system for decades with the average growth rate of 8.9% per year since 1970, compared to only 1.2% for capturing fisheries and 2.8% for terrestrially farmed meat-production over the same period. The exponential growth of the aquaculture sector during the past two decades is as a result of the improvement in the intensification of production systems and use of quality feeds, which meets the nutritional needs of cultured fish. Stimulated by higher global demand for fish, world fisheries and aquaculture production reached 157million tons in 2012 and is projected to reach about 172 million tons in 2021, with most of the growth coming from aquaculture. This increase of aquaculture production is supported by a corresponding increase in the production of improved diets for the cultured aquatic animals [50].

Catfish grown in ponds and tanks are the most cultured species in Nigeria, hence responsible for over half of the total aquaculture production by volume. African catfish *Clarias gariepinus* is a globally popular aquaculture species and it's distributed throughout Africa and Asia. It is widely cultured in freshwater ponds because they can easily reproduce, have high growth rate, can tolerate high densities culture conditions, can resist diseases, have excellent flesh quality and have the ability to accept a wide variety of feed. Nonetheless, its concentrated culture is very restricted in light of the great operational expense because of the great protein business eats less carbs which expands the expense. The African catfish (Clarias gariepinus) has been recognized as one of the fish animal varieties with the best potential to add to fish creation in Nigeria. Regardless of expanded creation, benefit of culture can be exceptionally low. The significant reason for low productivity is significant expense of imported feed, and significant expense of fishmeal [30].

Feed is by and large recognized by fish ranchers to be the costliest contribution to fish culture tasks and records for about 70% of the creation cost. The financially attainable catfish cultivating can be accomplished when it depends on savvy feed compound of locally accessible horticultural result. One of the vital spaces of consideration has been coordinated towards the subject of feed detailing and specifically the degrees of marine proteins, for example, fish feast, giving the greater part of the dietary protein. Accordingly, aquafeed organizations have grown new details and feed the board frameworks trying to address these worries. Moreover, development of hydroponics around the world has brought about a drive towards the decrease of utilization of non-practical marine determined proteins and oils with exploration to discover options [3].

Fishmeal is the principal element for most fish abstains from food due to its high protein content, adjusted amino corrosive profile, high fundamental unsaturated fats substance, minerals and nutrients. As an outcome of fast development of hydroponics, fish dinner costs have expanded essentially in the previous few years and are probably going to increment further with proceeded with development popular. Considering the worldwide expanding of human populace, taking care of fish supper to cultivated fish on any critical scale is neither productive nor supportable, particularly in agricultural nations where the

utilization of fish feast in fish feed is regularly monetarily restrictive [29]. The study was aimed at examining the effects of hydrolysed feather meal as a substitute for fish meal in the diets of African catfish *Clarias gariepinus* fingerlings.

MATERIALS AND METHODS

Study Area

The experiment was conducted in the Biological Garden, Department of Biological Sciences, Fisheries and Aquaculture Unit Kaduna State University, Kaduna Nigeria. (Latitude 10º 31' 3" North; Longitude 7º 26' 52" East). It has an elevation of 619 meters (2031 feet) and an average annual temperature of 25.2ºC (77.3ºF) [42].

Harvesting and Processing of Poultry Feathers

Poultry feathers (waste materials) were collected from abattoir (slaughterhouse) in the Central Market Area of Kaduna Metropolis. They were washed thoroughly with tap water and boiled for an hour at 100°C to disinfect; then air dried for 72 hours on a very clean large polythene sheet. The dried feathers were then packed and sealed in large polythene bag awaiting hydrolysis [34].

Hydrolysis of Poultry Feather

The feathers were gently immersed into the solution of six molar hydro-chloric acid (6N HCL) in a large beaker to destroy the keratin (di-sulphide bond) in the feather at the temperature of 350°C –400°C for 45minutes. They were thoroughly rinsed with tap water to remove treatment chemicals. It was further immersed in yeast solution at the temperature of 30°C for 12 hours. It also underwent steaming process at the temperature of 200°C – 300°C for 30 minutes. Oven dried at 50°C– 60°C for 10 hours and milled to powder. The dried feather meal was packed and sealed in large polythene bag. The protein analysis of feather meal was carried out using the method adopted by [41].

Feed Formulation

The crude protein values of feather meal derived from the proximate analysis was used to formulate the experimental feed for *Clarias gariepinus* fingerlings. The various feeds ingredients were weighed and thoroughly mixed until uniformly blended followed by wet mixing. Five iso-nitrogenous diets were formulated according to the nutritional requirements of the experimental fish (45% CP) using the Pearson's square method. Treatment I contained standard commercial feed (Coppens 2mm) as control; treatment II, III, IV, V and VI contained hydrolyzed feather meal used to replace fishmeal as animal protein source at various inclusion levels namely 0%, 25%, 50%, 75% and 100%. The formulated diets were packaged, labeled and stored in airtight containers. Each of the five diets formulated were subjected to proximate analysis using the method adopted by [41].

Experimental procedure

The experiment was completely randomized design with six treatments and three replications. The experiment was carried out in eighteen 200L truncated conical aqua drum plastic containers with the

diameters at the surface and bottom as 0.62m and 0.5m and the slant height and the height as 0.82m and 0.8m. Each drum had a square shaped cover $0.75m^2$ at the top with 2mm mesh size net to prevent external factors like lizards, birds and cats from trespassing. The drums were thoroughly washed and water was filled to the depth of 0.7m (170L), stocked and aerated with aquarium water pumps. Water exchange rate of the pond volume was once every two days as adopted by [42].

Experimental Fish

Three hundred (300) fingerlings of African catfish *Clarias gariepinus (*3-5g*)* were purchased from Federal Ministry of Agriculture and Rural Development State Office Livestock House, Mando Kaduna. The fish were harvested and kept over the night and were packed in fifty (50) liters Jerry Can and transported very early in the morning to the experimental site. Upon arrival, and on day one, the fish were given 10g of granulated Vitamin C tablets in order to boost their appetite and reduce stress. The fish were acclimatized and familiarized with the control diet (Coppens 2mm) for 14 days. One hundred and eighty (180) experimental fish were carefully selected from the group acclimatized with the average weight of 9.5g randomly grouped into six (6) treatments and three (3) replicates of ten (10) fish per plastic tank [24].

Feeding of Experimental Fish

The fish were fed (5) % of their total body weight daily for 12 weeks. Feeding of the fish was carried out twice daily (in the mornings and evenings between 7am and 6pm). Sampling of fish were carried out fortnightly (14 days interval) using electric sensitive scale. The fish were not fed on sampling days until several hours after the whole exercise. Mean weight and percentage mean weight gain were recorded [13].

Proximate Analysis of the Experimental Feed

The proximate composition (carbohydrate, crude protein, lipid, ash, crude fiber, moisture and carbohydrate of the compounded fish feeds were determined in National Research Institute of Chemical Technology (NARICT) using the standard methods of the Association of Official Analytical Chemist.

Determination of Crude Protein

One gram of sample was weighed and placed onto a 50ml digestion flask and the Kjeldahl mixture which acts as a digestion catalyst was added with 5ml of concentrated sulphuric acid (H_2SO_4). Some pumice stones (anti-bumping granules) were also added. The flask containing the sample mixture was heated gently at an inclined angle in a Kjeldahl digestion rack until frothing subsided. It was then boiled until the solution became colourless. Heating of the mixture released the nitrogen in the various samples which was then converted to ammonia with the concentrated sulphuric acid. It was later allowed to cool. The sample was transferred to a 100ml volumetric flask and diluted with distilled water to the mark. It was then mixed thoroughly. The mixture was further allowed to cool before distillation. A blank containing only the sulphuric acid and catalyst was also heated.

A known aliquot (10ml) was moved to the example expansion pipe of the refining contraption and afterward acquainted with the example chamber. 10ml of 40% sodium hydroxide was added to the example option pipe and delivered to the example chamber at a sluggish rate. The smelling salts was ensnared in an accepting arrangement containing 10ml 2% boric corrosive arrangement into which four

drops of bromocresol green, two drops of methyl red marker had been put. Refining was proceeded until the pink tone became greenish.

Titration with standard HCL acid (0.01N) was then carried out and the percentage of crude protein determined with the following calculation.

$$\% \text{ Nitrogen} = \frac{\text{Titre value}(a-b) \times 0.01 \times 14.0057 \times C}{d \times e} \times 100 \quad [46].$$

Where a = Titre value for sample.

b = Titre value for blank

c= Volume to which digest was made up with distilled water.

d=Aliquot taken.

e= Weight of dried sample taken (mg).

0.01 = Molarity of acid.

14.0057 =Nitrogen constant (the relative atomic mass of nitrogen in mg).

Determination of Crude Lipid

This is the continuous extraction of fat content from a sample using a suitable solvent in a Soxhlet extractor. Two grams of the dried sample (residue from moisture determination was used) was placed into a pre-weighed extraction thimble (W_1) and the weight recorded (W_2). A dried 250ml round bottom quick fit was weighed (W_3) with a few anti-bumping granules inside. The timble was fitted into the extraction unit of the Soxhlet .5.2extraction apparatus using a pair of forceps.

300 ml of petroleum ether $(40-60)^0$C boiling point was poured into the quick fit flask at the rate of 2 to 3 drops. After reflux extraction for 8 hours, the thimble was removed and the ether was reclaimed using the apparatus by distilling out some ether. The removal of ether from the flask containing a mixture of ether and extracted fat was completed on a boiling water bath and the flask dried in an oven at 105^0C for 30 minutes. After this, the flask with the pure fat content was cooled in a desiccator and weighed (W_4). The percentage crude fat was calculated as follows:

$$\% \text{ Crude Fat} = \frac{W_4 - W_3}{W_2 - W_1} \times 100 = \frac{\text{Fat}}{\text{Sample}} \times 100 \quad [11].$$

Where W_1 = Weight of sample + thimble before extraction.

W_2 =Weight of sample + thimble after extraction.

W_3 =Weight of dried flask before defatting.

W_4 =Weight of flask and fat after defatting.

Determination of Fiber Content

Procedure: two grams of the defatted dreid sample obtained from crude fat determination was transferred into a 600 ml beaker. The digestion mixture was prepared by mixing 500ml glacial acetic acid, 450 ml distilled water and 50 ml concentrated nitric acid 20g of trichloro acetic acid was dissolved in this mixture and mixed thoroughly. The quickfit flask was attached to a condenser. It was brought to a boil and refluxed for 40 minutes. Timing commenced from the time the mixture started to boil. Thereafter, The content of the flask was filtered through a weighed Whatman No. 4 ashless filter paper which was placed in a Buchner funnel over a conical flask. During filtration, residue from the digestion was washed six times with hot

water and once with industrial methylated spirit to wash down particles adhering to the sides. The filtrate was dried at 105^0C for 12 hours, cooled and weighed to get the residue. The residue now made up of crude fibre and ash was incinerated in weighed crucible at 600^0C for 12 hours. This was then cooled and weighed to obtain the weight of the ash. The loss on ignition was the crude fiber [23].

Determination of Ash Content

An empty crucible was dried in the oven, after drying, it was cooled in the desiccator and weighed (W_1). 2g of the already dried sample obtained after moisture extraction was put into the crucible and the weight also recorded (W_2). This was then put into a muffle furnace and incinerated at 525^0C for 24 hours. After this it was placed in a desiccator for cooling and then reweighed (W_3). Percentage ash content was computed as follows:

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

$$= \frac{\text{Ash}}{\text{Sample}} \times 100$$

Where W_1 = Weight of crucible in (g)
W_2 = Weight of crucible + sample in (g)
W_3 = Weight of crucible + ash in (g) [36].

Determination of Moisture Content

Crucibles were washed and dried to a constant weight in an oven at 100C. They were later removed and placed in a desiccator (W_1). 5g of the sample was placed in the weighed crucible (W_2). The crucible containing the sample was kept in an oven at 100C for 24 hours and then weighed. It was kept back in the oven and reweighed after about 3 hours to ensure a constant weight (W_3). Loss in weight was equal to water content of the original sample. The moisture content was calculated as:

$$\% \text{ Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$ [7].

Where W_1 = Weight of an empty crucible
W_2 = Weight of a known amount of sample (fresh) + crucible
W_3 = Weight of oven dried sample.

Determination of Carbohydrate Content

Each sample was crushed into fine powder and 0.2g was precisely weighed into a bubbling cylinders. 10ml of 1.5m of sulphuric corrosive was added and warmed in a bubbling water for 20 minutes while mixing at times to hydrolysis polysaccharide and other non-decreasing sugars. The resultant combination was cooled and 12ml of 10% NaOH was added and blended, it was then sifted into 100ml volumetric flagon with refined water. This was made up to volume with refined water and blended well by reversal [23].

Determination of Water Temperature

Water temperature was taken by the utilization of Hanna instrument (H198129) model. The temperature was taken day by day. The Hanna instrument was usually lowered into the plastic aquaria for about 2-4 minutes before readings were taken [27].

Determination of Dissolved Oxygen (D.O).

Water test was filled a 300ml BOD bottle. 2ml $MnSO_4$ arrangement and 2ml soluble base iodide azide reagent was added, at that point stoppered with care to radiate air bubbles. It was then blended delicately by reversing the jug various occasions until a reasonable supernatant was obtained. It was then permitted to agree to two minutes after which 2 ml concentrated H_2 SO_4 was added by permitting the corrosive summary the neck of the jug. It was stoppered again and blended in with delicate reversal until disintegration was finished. 100ml of the pre-arranged arrangement was moved into a funnel shaped carafe, titrated with 0.0125N of $Na_2S_2O_3$ 〖.5H〗$_2$O answer for a pale straw/yellow colour.2ml of newly pre-arranged starch arrangement was added and the shading became blue. Titration was proceeded by adding the thiosulphate drop astute until the blue tone vanished [5].

Determination of Water P^H (Hydrogen Ion Concentration)

Water P^H was determined using Hanna instrument (H198129) model. The instrument was standardized with buffer solution at P^H of 4.0, 7.0 and 9.0. The Hanna instrument was usually lowered into the plastic aquaria for about 2-4 minutes before readings were taken. The readings were taken every week [27].

Determination of the Time of Feed Intake

It was determined from the time it took the fish to strike index to the time it took to consume the whole of feeds (5%) body weight per each diet type per each feeding period. It was measured per seconds [33].

Determination of growth parameters.

Growth parameters were taken while considering the sub parameters like weight gained, length of fish, percentage weight gain, specific growth rate, survival rate and condition factor as described below:

Determination of Standard weight of the Experimental Fish

The weights of treatment fish were determined using digital electric weighing balance. This was done after acclimatization period. The initial weight of plastic bowl and water was taken (W_1), treatment fish were then scooped and placed carefully in the plastic bowl and water then weighed (W_2). Determination of the Mean weight in grams (g) of fish W_2 - W_1 was continued fortnightly for the period of three (3) months [10].

Determination of Standard Length of the Experimental Fish

The lengths of treatment fish were determined using a white thread and a meter rule. Treatment fish were scooped and placed carefully on a clean tray; The thread was used to measure from the anterior end of the snout to the posterior end of the peduncle. Both ends of the thread were marked with a pencil and carefully

placed on the meter rule where the readings were taken. Determination of the Mean length was continued fortnightly for the period of three (3) months [25].

Determination of Mean Weight Gain (MWG) of the Experimental Fish

The Fish mean weight gain (MWG) was calculated as the difference between the final mean weight of the fish at the end of the experiment and the initial mean weight in grams.

Mean Weight Gain (MWG)= $W_2 - W_1$(g)

Where W_1 = Initial mean weight(g)

W_2 = Final mean weight (g) [8].

Determination of Percentage Weight Gain (LWG) of the Experimental Fish

The percentage live weight gain was computed as the difference between the final mean weight gain and the initial mean weight gain divide by the initial mean weight gain expressed as a percentage Weight Gain (PWG %)

PWG= $\frac{W_2 - W_1}{W_1} \times 100$ [49].

Where W_1 = Initial mean weight(g)

W_2 = Final mean weight (g)

Determination of Specific Growth Rate (SGR %) of the Experimental Fish

This is the mean percentage increase in body weight per day over a given period of time interval

Specific Growth Rate SGR= $\frac{\mathrm{Log_e}W_2 - \mathrm{Log_e}W_1}{T_2 - T_1} \times 100$

Where W_1= Initial weight of fish at T_1 in days

W_2= Final weight of fish at T_2 in days

$\mathrm{Log_e}$= Natural log to base e.

T_1 = Initial time in days

T_2 = Final time in days [18].

Determination of Survival Rate (SR %) of the Experimental Fish

This was calculated as the total number of fish harvested divide by the initial number of fish stocked multiplied by 100. This is represented by the formula as follows.

SR = $\frac{Total\ fish\ harvested}{Initial\ number\ of\ fish\ stocked} \times 100$ [45].

Condition Factor

Condition factor (CF), K= $\frac{100W}{L3}$ [19].

Where, K is the condition factor, L is the total length of fish in cm while W is the weight of fish in grams.

Determination of Nutrient utilization Parameters of the of the Experimental Fish

Nutrient utilization parameters of the experimental fish were taken while considering the sub parameters like feed intake, crude protein fed, protein efficiency ratio, feed conversion ratio and gross feed conversion efficiency as described below:

Determination of Feed Intake of the Experimental Fish

This is the total amount of feed consumed by treatment fish during the time of the study measured in grams (g)

Determination of Protein Intake of the Experimental Fish

This was calculated as total feed intake in grams multiply by percentage protein in the diet.
Protein Intake (PI) = Feed intake (g) x % protein in the diet [28].

Determination of Protein Efficiency Ratio (PER)

This is the efficiency with which the fish utilizes dietary protein and is defined by the equation (Osborne *et al.,*1919)

$$\text{PER} = \frac{\text{Wet weight gain by fish (g)}}{\text{Weight of crude protein fed (g)}}$$ [48].

Determination of Feed Conversion Ratio (FCR)

The productivity of a fish is ordinarily estimated by the sum important to create a unit weight of fish. This is known as the feed transformation proportion or FCR. The FCR is the unit weight of feed given, isolated by the live weight or wet load of the creature delivered (Hepher, 1988)

$$\text{FCR} = \frac{\text{Total weight of dry feed fed (g)}}{\text{Total live weight gain (g)}}$$ [17].

Determination of Gross Feed Conversion Efficiency (GFCE%)

The gross feed conversion efficiency (GFCE) is calculated as the reciprocal of the feed conversion ratio (FCR) expressed as a percentage.

$$\text{GFCE} = \frac{1}{\text{FCR}} \times 100$$ [14].

Cost Benefit Analysis

A basic monetary examination was directed to survey the expense viability of the trial consumes less calories. Just the expense of feed was utilized in the computations with the suspicion that any remaining working costs stayed consistent. Expenses of the feeds were determined utilizing market costs of fixings as at the hour of the trial. Economic evaluation of the experimental diets was calculated by evaluating the feed cost (FC) in naira needed to produce 1kg of live weight gain of each experimental fish group. The currency used was Naira.

Investment Cost Analysis (ICA)

ICA = Cost of feeding + cost of juveniles [31].

Gross Profit (GP)

GP = Net Profit Value of fish – Investment Cost Analysis [35].

Net Profit (NP)

NPV = Mean weight + total no. of survival fish x cost per kg [4].

Profit Index (PI)

PI = Net profit value – cost of feeding fish [40].

Incident of cost (r)

$$R = \frac{\text{Cost of feeding}}{\text{Weight of fish produced}}$$ [51].

Benefit of Cost Ratio (BCR)

$$BCR = \frac{\text{Net profit value}}{\text{Investment Cost Analysis}}$$ [2].

Data Analysis

Analysis of variance (ANOVA) was used to find out if there was significant difference ($P<0.05$) between the treatment means. Duncan multiple range test (DMRT) was used to rank the means where significant.

RESULTS

Proximate Composition of the Experimented Diets Using Hydrolyzed Feather Meal as Protein Source at Different Inclusion Levels

Treatment-6 produced the highest protein content of 46.54±0.80, followed by treatment 5 that recorded 46.01±0.94. The least protein content was recorded in treatment 4 with 42.53± 1.84. Treatment 1 produced the highest crude lipid content of 13.86 ± 0.82, followed by treatment 6 that recorded 7.18±0.75. The least crude lipid content was recorded in treatment 2 which recorded 5.89± 0.56. There was significant difference ($p<0.05$) between the treatments and the control. The results of the fibre in the experimental feeds presented in table 1 showed that treatment 6 recorded the highest content of 7.47 ± 0.45. the least crude fibre content was recorded in treatment1 with 3.22 ± 0.17. The highest ash content of 8.57 ± 0.22 was recorded in treatment 1, followed by treatment 5 with 7.30±0.41. The least value of 5.39 ± 0.10 was recorded in treatment 2 (Table 1).

Table 1: Proximate Composition of the Experimented Diets Using Hydrolyzed Feather Meal as Protein Source at Different Inclusion Levels

TRT/FTM (%)	Protein	Lipid	Fibre	Ash	Moisture	Energy
T1(control	44.57±0.26^{a}	13.86±0.82^{a}	3.22±0.17^{d}	8.57±0.22^{a}	7.98±0.17^{b}	406.31±1.32^{a}
T2(0%)	44.99±0.92^{a}	5.89±0.56^{b}	5.09±0.15^{c}	5.39±0.10^{d}	6.32±0.11^{d}	389.92±3.36^{c}
T3(25%)	44.84±1.97^{a}	6.41±0.62^{b}	6.16±0.16^{b}	5.57±0.15^{d}	7.68±0.14^{b}	390.30±1.30^{c}
T4(50%)	42.53±1.84^{a}	6.47±0.28^{b}	6.17±0.33^{b}	6.36±0.24^{c}	10.07±0.15^{a}	392.31±5.93^{bc}
T5(75%)	46.01±0.94^{a}	6.68±0.41^{b}	5.37±0.15^{bc}	7.30±0.41^{b}	6.90±0.16^{c}	400.72±1.39^{ab}
T6(100%)	46.54±0.80^{a}	7.18±0.75^{b}	7.47±0.43^{a}	6.38±0.22^{c}	5.58±0.0^{e}	402.57±1.64^{a}

Means with the same latter in a column are not significantly different (p>0.05). KEYS: Treatment1 = control, treatment 2 = 0%, treatment 3 = 25%, treatment 4 = 50%, treatment 5 = 75%, treatment 6 = 100%

Water quality parameters measured during the experimental period

The results of the temperature in the experimental mediums were presented in table 2. The means of the temperature in experimental mediums ranged from 26.00 ± 0.58 to 27.33 ± 0.33 which represents T_4 (50% FM: 50 FTM) and T_1(100% FM: 0% FTM) respectively. There was no significant difference (p>0.05) between the temperature of all the mediums when compared with the controls T_1 (Coppens) and T_2 (100%FM, 0%FTM) respectively.

The means of the dissolved oxygen in the experimental mediums ranged from 5.20 ± 0.12 to 5.50 ± 0.06 which represents T_1 (Coppens) and T_2 (100%FM, 0%FTM) respectively. There were no significant differences (p>0.05) between the dissolved oxygen of all the mediums when compared with the controls T_1 (Coppens) and T_2 (100%FM, 0%FTM) respectively.

The results of the hydrogen ion concentration (P^H) in the experimental mediums presented in table 2 showed that P^H in the experimental mediums ranged from 6.99 ± 0.01 to 7.01 ± 0.01 which represents T_6 (0% FM: 100% FTM) and T_1 (Coppens) respectively. There were no significant differences (p>0.05) between the hydrogen ion concentration of all the mediums when compared with the controls T_1 (Coppens) and T_2 (100%FM, 0%FTM) respectively.

Table 2: Water Quality Parameters of Fish Medium During the Experimental Period.

TRT/FTM (%)	Temperature ^{o}C	Dis. Oxygen mg/l	pH
T1(control)	27.33±0.33^{a}	5.50±0.06^{a}	7.00±0.01^{a}
T2(0%)	26.33±0.33^{a}	5.20±0.12^{a}	7.00±0.01^{a}
T3(25%)	26.67±0.33^{a}	5.40±0.10^{a}	7.01±0.01^{a}
T4(50%)	26.00±0.58^{a}	5.30±0.12^{a}	7.00±0.01^{a}
T5(75%)	27.67±0.33^{a}	5.43±0.12^{a}	7.00±0.01^{a}
T6(100%)	26.33±0.88^{a}	5.46±0.09^{a}	6.99±0.01^{a}

Means with the same latter in a column are not significantly different (p>0.05). KEYS: Treatment1 = control, treatment 2 = 0%, treatment 3 = 25%, treatment 4 = 50%, treatment 5 = 75%, treatment 6 = 100%

Growth Performance of Clarias gariepinus Fed Experimental Diets

Mean Initial Length

The average initial length of the experimental fish ranged from 11.00 ± 0.01 to 11.04 ± 0.01 which represents length of fish in T_1 and T_6 respectively. There were no significant differences ($p>0.05$) between the mean initial length of *Clarias gariepinus* of all the treatments when compared with the controls T_1 and T_2 respectively. This indicates a complete random distribution of individual fish at the start of the experiment (Table 3).

Mean Final Length

The results of the mean final length of *Clarias gariepinus* fed the experimental diets showed treatment 1 that produced 26.02 ± 0.01, it was followed by treatment 5 with 20.08±0.01. The least value of 15.70 ± 0.06 was produced by treatment 6. There was significant difference ($p<0.05$) between the mean final length of *Clarias gariepinus* in all the treatments when compared with the controls T_1 and T_2 respectively (Table 3).

Mean Initial Weight

The mean initial weight of *Clarias gariepinus* ranged from 9.00 ± 0.58 to 9.08 ± 0.01 which represents weight of fish in T_1 and T_6 respectively, showing no significant difference at p-value <0.05. This indicates a complete random distribution of individual fish at the commencement of the experiment (Table 3).

Mean Final Weight

The mean final weight of *Clarias gariepinus* during the course of this study ranged from 221 ± 0.64 to 21.38 ± 0.01 which represents weight of fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between the mean final weight of *Clarias gariepinus* of all the treatments when compared with the controls T_1 and T_2 respectively (Table 3).

Mean Weight Gain

The highest weight gain of *Clarias gariepinus* fed experimental diets was produced by treatment 1 with 212.64 ± 0.12, while least value 12.31 ± 0.01 was recorded in treatment 6. There was significant difference ($p<0.05$) between the mean weight gain of *Clarias gariepinus* of all the treatments when compared with the controls T_1 and T_2 respectively (Table 3).

Percentage Weight Gain

The highest percentage weight gain of *Clarias gariepinus* fed the experimental diets was recorded in treatment 1 with 2362.67 ± 0.01 while the least percentage weight gain of 135.72 ± 0.01 was produced by T_6. The was significant difference ($p<0.05$) between the percentage weight gain of *Clarias gariepinus* of all the treatments when compared with the controls T_1 and T_2 respectively (Table 3).

Specific Growth Rate

The specific growth rate of *Clarias gariepinus* during the course of this study ranged from 0.04 ± 0.01 to 0.01 ± 0.00 which represents T_1 and T_6 respectively. There was significant difference ($p<0.05$) between the specific growth rate of *Clarias gariepinus* in T_4 (50% FM: 50% FTM) and T_6 (Table 3).

Condition Factor

The condition factor which determines the welfare and health of the experimental fish *C. gariepinus* fed the experimental diets during the course of this study were presented in table 3. The condition factor of *C. gariepinus* during the course of this study ranged from 1.29 ± 0.00 to 0.55 ± 0.10 which represents T_2 and T_6 respectively. There was significant difference ($p<0.05$) between the condition factor of *C. gariepinus* in all the treatments when compared with the controls T_1 and T_2 respectively.

Table 3: Growth performance of *Clarias gariepinus* fed experimental diets

TRT/FTM (%)	Mean IL	Mean FL	Mean IW	Mean FW	Mean WG	Percent. WG	Specific GR	Survival R	Condition F
T1(control)	11.00±0.01^{a}	26.02±0.01^{a}	9.00±0.58^{a}	221.64±0.01^{a}	212.64±0.12^{a}	2362.67±0.01^{a}	0.04±0.01^{a}	93.33±0.01^{b}	1.26±0.01^{b}
T2(0%)	11.00±0.01^{a}	19.67±0.01^{c}	9.03±0.01^{a}	97.91±0.01^{b}	88.88±0.01^{b}	984.27±0.01^{b}	0.03±0.00^{ab}	76.67±0.01^{d}	1.29±0.00^{a}
T3(25%)	11.02±0.01^{a}	20.06±0.01^{b}	9.03±0.01^{a}	96.77±0.01^{c}	87.74±0.01^{c}	971.65±0.01^{c}	0.03±0.01^{ab}	90.00±0.58^{c}	1.20±0.00^{c}
T4(50%)	11.00±0.01^{a}	16.97±0.01^{d}	9.07±0.01^{a}	37.33±0.01^{e}	28.26±0.01^{e}	311.58±0.01^{e}	0.02±0.01^{bc}	26.67±0.01^{f}	0.76±0.01^{e}
T5(75%)	11.00±0.01^{a}	20.08±0.01^{b}	9.07±0.01^{a}	95.53±0.01^{d}	88.46±0.01^{d}	953.25±0.01^{d}	0.03±0.01^{ab}	100.00±0.00^{a}	1.18±0.10^{d}
T6(100%)	11.04±0.01^{a}	15.70±0.06^{e}	9.08±0.01^{a}	21.38±0.01^{f}	12.31±0.01^{f}	135.72±0.01^{f}	0.01±0.00^{c}	50.00±0.58^{e}	0.55±0.10^{f}

Means with the same latter in a column are not significantly different ($p>0.05$). KEYS: Treatment1 = control, treatment 2 = 0%, treatment 3 = 25%, treatment 4 = 50%, treatment 5 = 75%, treatment 6 = 100%.

Feed Intake

The mean feed Intake of *C. gariepinus* during the course of this study ranged from 139.08±0.01 to 28.58±0.01 which represents the experimental fish in T_1 and T_6 respectively. The was significant differences ($p<0.05$) between the mean feed Intake of *C. gariepinus* of all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) respectively (Table 4).

Protein Intake

The mean crude protein fed to *C. gariepinus* during the course of this study ranged from 1826.93±0.01 to 311.17±0.01 which represents the experimental fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between the crude protein fed to *C. gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) respectively (Table 4).

Protein Efficiency Ratio

The mean protein efficiency ratio of *C. gariepinus* during the course of this study ranged from 3.26±0.01 to 0.59±0.01 which represents the experimental fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between the protein efficiency ratio of *C. gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) respectively (Table 4).

Feed Conversion Ratio

The mean feed Intake of *C. gariepinus* during the course of this study ranged from 0.68±0.01 to 3.74±0.01 which represents the experimental fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between the mean feed conversion ratio of *Clarias gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) respectively (Table 4).

Gross Feed Conversion Efficiency

The mean gross feed conversion efficiency of *C. gariepinus* during the course of this study ranged from 146.65±0.01 to 26.70±0.01 which represents the experimental fish in T_1 and T_6 respectively.
The was significant differences ($p<0.05$) between the gross feed conversion efficiency of *C. gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) respectively (Table 4).

Table 4: Nutrient Utilization of *C. gariepinus* Fed Experimental Diets

TRT/FTM (%)	Mean WG	Feed Intake	Crude PF	Protein ER	Feed CR	Gross FCE
T1(control)	212.64±0.12^a	139.08±0.01^a	62.59±0.01^a	3.26±0.01^a	0.68±0.01^f	146.65±0.01^a
T2(0%)	88.88±0.01^b	69.48±0.01^d	31.27±0.01^d	2.28±0.01^d	0.97±0.01^c	102.75±0.01^d
T3(25%)	87.74±0.01^c	72.48±0.01^c	32.62±0.01^c	2.45±0.00^c	0.91±0.01^d	110.07±0.01^c
T4(50%)	28.26±0.01^e	34.84±0.01^e	15.68±0.01^e	0.75±0.01^e	2.98±0.00^b	33.54±0.01^e
T5(75%)	88.46±0.01^d	76.44±0.01^b	34.40±0.01^b	2.51±0.01^b	0.88±0.01^e	113.07±0.01^b
T6(100%)	12.31±0.01^f	28.58±0.01^f	12.86±0.01^f	0.59±0.01^f	3.74±0.01^a	26.70±0.11^f

Means with the same latter in a column are not significantly different ($p>0.05$). KEYS: Treatment1 = control, treatment 2 = 0%, treatment 3 = 25%, treatment 4 = 50%, treatment 5 = 75%, treatment 6 = 100%.

Feed Intake Cost

The mean feed intake cost of *C. gariepinus* fed the experimental diets during the course of this study ranged from 1038.06±0.01 to 14.95±0.01and showed a high significant difference ($p<0.05$) between all the treatments when compared with the control (Table 5).

Cost of Experimental Fish

The mean initial fish cost of *C. gariepinus* per treatment during the course of this study was 300.00±0.0 naira which remain constant for all the treatments respectively and hence showed no significant differences ($p>0.05$) between them. The mean final fish cost of *C. gariepinus*per fish during the course

of this study was 221.64±0.01 to 21.38±0.01 naira and a grate significant difference ($p<0.05$) between them.

Investment Cost Analysis

The results of the investment cost analysis of *C. gariepinus* during the course of this study were presented in table 5. The mean investment cost analysis of *C. gariepinus* during the course of this study was 1338.06±0.01 to 314.95±0.01 naira which represents the experimental fish in T_1 and T_4 respectively. There was significant difference ($p<0.05$) between the investment cost analysis of *C, gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) (Table 5).

Gross Profit

The mean gross profit of *C. gariepinus* during this study were from 1983.93±0.01 to 61.55±0.01 naira which represents the experimental fish in T_1 and T_6 respectively. There was significant differences ($p<0.05$) between gross profit of *C, gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) (Table 5).

Net Profit

The mean net profit of *C. gariepinus* during this study were from 645.88±0.01 to -260.35±0.01 naira which represents the experimental fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between gross profit of *C. gariepinus* in all the treatments when compared with the controls T_1 (coppens) and T_2 (100% FM: 0% FTM) (Table 5).

Profit Index

The mean profit index of *C. gariepinus* during the course of this study ranged from 7.55±0.01 to 1.91±0.01 which represents the experimental fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between gross profit of *C. gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) (Table 5).

Incidence Cost

The mean incidence of cost of *C. gariepinus* during the course of this study ranged from 0.52±0.01 to 0.13±0.01 which represents the experimental fish in T_1 and T_6 respectively. There was significant difference ($p<0.05$) between the incidence of cost of *C. gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and no significant difference ($p>0.05$) between T_3 (75% FM: 25% FTM) and T_5 (25% FM: 75% FTM) when compared with T_2 (100% FM: 0% FTM) (Table 5).

Benefit Cost Ratio

The mean cost benefit ratio of *C. gariepinus* during the course of this study ranged from 2.07±0.01 to 0.18±0.01 which represents the experimental fish in T_5 and T_6 respectively. There was significant difference ($p<0.05$) between the cost benefit ratio of *C. gariepinus* in all the treatments when compared with the controls T_1 (Coppens) and T_2 (100% FM: 0% FTM) (Table 5).

Table 5: Cost Benefit Analysis of *C. gariepinus* Fed Experimental Diets for 12 Weeks Feeding Trials

Trt./FTM (%)	MFIC/TRT	Fish C Init.	Fish C Final	Fish no.	Investm. C A	G Profit	Net Profit	Profit Indx.	Incid. Of Cost	Benft.C.R.
Std	111.26	300.00±0.00^{a}	221.64±0.01^{a}	9.33±0.01^{b}	141.26±0.01^{b}	1983.93±0.01^{a}	645.88±0.01^{a}	1.91±0.01^{e}	15.27±0.0^{a}	1.44±0.01^{d}
0	12.22	300.00±0.00^{a}	97.91±0.01^{b}	7.87±0.01^{d}	42.22±0.01^{b}	699.49±0.01^{d}	303.31±0.01^{b}	7.27±0.01^{c}	3.94±0.01^{e}	1.64±0.01^{c}
25	12.20	300.00±0.00^{a}	96.77±0.01^{c}	9.00±0.01^{c}	42.20±0.01^{b}	789.66.01^{c}	379.86±0.01^{b}	7.19±0.01^{b}	4.13±0.01^{c}	1.88±0.01^{b}
50	5.60	300.00±0.00^{a}	37.33±0.01^{e}	2.67±0.01^{f}	35.60±0.01^{b}	75.45±0.01^{e}	-239.50±0.01^{b}	5.05±0.01^{d}	3.38±0.01^{f}	0.22±0.01^{e}
75	11.71	300.00±0.00^{a}	95.53±0.01^{d}	10.00±0.00^{a}	41.71±0.01^{b}	884.60±0.00^{b}	467.50±0.01^{b}	7.55±0.01^{a}	4.06±0.01^{d}	2.07±0.01^{a}
100	4.38	300.00±0.00^{a}	21.38±0.01^{f}	5.00±0.01^{e}	34.38±0.01^{b}	61.55±0.01^{f}	-260.35±0.01^{f}	2.81±0.01^{e}	8.18±0.01^{b}	0.18±0.01^{e}

DISCUSSION

Among the different available protein source ingredients, animal protein sources are known to contain better crude protein and energy value. High demand of some conventionally used animal protein source ingredients increased its rate and consequently resulted in increased feed prices. A simple way to counter it is to, identify such abundantly used ingredient and replace it. Feather meal is among the high protein rich by-products. Some nutritionists have concern on its digestibility because of its disulfide bond. Poultry feathers are processed under different conditions to increase its digestibility [47]. Although it lacks few of the essential amino acids like lysine, methionine and leucine but it carries extremely high contents of amino acids like cystine, threonine, arginine and serine. The utilization of poultry feather meal as fishmeal substitute in other fish species has been a serious challenge basically because of its incomplete amino acid profile and low palatability hence causes diminished feed consumption and decreased weight [38].
The protein content recorded in the current investigation was isoproteinous. Huge contrasts were seen in the lipid substance of all eating routine as the control diet recorded a lot higher worth when contrasted and other treatment. Nonetheless, the general lipid content in FTM in this examination was seen to be a lot higher than that announced [9].

The water quality parameters (Temperature, Dissolved oxygen and Hydrogen ion concentration) recorded during the experimental period showed no significant difference ($P>0.05$) between the experimental treatments [55]. The temperature range observed is in agreement with the report of [15]. while dissolved oxygen (D.O) measured were within the recommended range for African catfish culture. The hydrogen ion concentration (P^{H}) observed was similar to the finding of [52]. Optimal water quality parameter was maintained by frequently changing the water using the flow through method and all the values recorded were within the recommended rates for catfish culture.

Feed acceptability and timing was observed just before feeding, during feeding and the time it took to consume the experimental feed from start to finish [37]. The commercial feed T1 (Coppens, Control) was mostly acceptable by experimental catfish *Clarias gariepinus* hence found to be most active just before and during feeding [21]. The acceptability was due to the method and procedure used in the preparation of feather meal and feeds as well. Furthermore, the feed ingredients used to prepare feed contained all the essential amino acid required by the experimental fish *Clarias gariepinus* [32].

The growth performance of the fishes under study was significantly different ($p<0.05$) when compared with the control diets T_1 and T_2. The survival of *Clarias gariepinus* was high (above 75%) during the two (2) months feeding trial and was probably as a result of the overall quality and stability of the experimental conditions. Similar report was reported by [20]. In the present study the lowest survival rate recorded is in conformity with result obtained by [6]. The growth performance of *Clarias gariepinus* fingerlings was affected positively. This present study is an improvement on the work of [34] who recommended that the substitution of feather meal into formulated fish feed should be limited to less than 40% except in the diet of trout and Tilapia. The low feed intake in T6 (100% Feather meal) was due to low palatability and digestibility as reported by [39]. These experimental fish utilized their body protein and lipid as their energy source for survival from starvation [12]. Experimental fish fed with the feeds in T1, T2, T3 andT5 all had a very good growth performance which corresponds with the work of [16] who worked on a meta-analysis of the effects of replacing fish meals with insect meals on growth performance of fish and reported that a mixture of protein source in the replacement of fish meal improves the growth performance of fish. The current investigation showed that consideration of hydrolyzed feather dinner in replacement of marine protein sources in the eating routine of *Clarias gariepinus* is practical. The outcomes showed that incorporation of at FTM at 0%, 25% and 75% had constructive outcome on development rate and weight acquire when contrasted and other tried eating regimens, defined with lower FTM consideration. There were no critical contrasts in explicit development rate (SGR) of all eating regimens when contrasted and the control. The lower SGR esteems saw in the eating regimen containing 100% FTM may be because of higher consideration of wheat grain. Feeds containing high debris substance may have high protein content and positive fundamental amino corrosive profile yet at the same time have helpless edibility [1].

Nutrient utilization was also affected positively by the increased level of hydrolysed feather meal up to 75% inclusion as reported by [39]. The protein efficiency ratio (PER) and feed conversion ratio (FCR) are also generally related to digestibility of nutrients [26]. Feather meal was found to be deficient in certain amino acid including lysine, methionine and histidine [43], these constituents are required for fish growth and health, although the partial inclusion of fish meal and blood meal in some of the treatment diets replaced completely or partially the lost nutrients in the feather meal. [44] reported that the biological value of protein source depends largely on its amino acid profile as well as its digestibility. An optimal essential amino acid EAA profile is a requisite for fish growth and nitrogen retention [53].

The profit index implies that with the amount invested on each treatment, more profit was derived from feed in T5 (75% inclusion of FTM) when compared with other treatments. Feed in T5(75% inclusion of FTM) is more economical looking at the availability of hydrolyzed feather meal as protein substitute and absolutely no competition by humans as reported by [54] who worked on replacement of fish meal with poultry by-product meal and hydrolyzed feather meal in feeds for finfish.

CONCLUSIONS

The control feed turned out to be the best feed, mostly acceptable when considering the time of feed intake, growth performance and nutrient utilization, but was at a disadvantage when analyzing its cost hence, became the most expensive amongst the treatment feeds. The profit index ranged from 7.55 in T_5 (75% inclusion of FTM) to 1.91 in control T_1 (Coppens). The result indicates that T_5 had the best growth performance, survival rate and cost effectiveness which was a plus to its sales. finally, feather meal can be substituted for fish meal up to 75% to obtain optimum yield, higher survival rate and at a lower cost in the diet of *Clarias gariepinus* fingerlings

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