EVALUATION OF COMMERCIAL AND LOCALLY MADE FEED IN THE CULTURE OF AFRICAN CATFISH (*Clarias gariepinus*) IN NIGERIA

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ABSTRACT

This study was conducted to determine the growth, feed conversion efficiency and economic effectiveness of *C. gariepinus* juveniles fed five diets, Skretting commercial feed (S), Bluecrown commercial feed (B), Skretting cum local feed (SL), Bluecrown cum local feed (BL). and local feed (L). The growth and survival were observed for 12 weeks in a complete randomised design in triplicate. Fish fed on S diet showed significantly better ($p<0.05$) growth rate and final weight than fish fed the L diet. No significant difference ($p>0.05$) was detected among treatment groups fed B, SL, BL and L diets. The growth reflected the crude protein content in the Skretting feed (37.18%) which was significantly higher ($p<0.05$) than the Bluecrown feed (35%) and local feed (32.55%). The feed conversion ratio was lowest in the group fed the S diet (1.35) significantly lower ($p<0.05$) than the other treatments, followed by treatment B (1.97) and treatment SL (1.97) which were the same but significantly different ($p<0.05$) to treatment BL (2.65) and treatment L (2.81). However, *C. gariepinus* fed diet L indicated a better profit index and lower incidence cost over other treatments. The study showed that diets S, B, SL and BL may increase diet cost over diet L by 47%, 43%, 11.9% and 11.6%, respectively. Equally, the combined diets indicate a viable result and had a better cost effectiveness on fish growth than the commercial diets solely. The fish in all treatments had no significant ($p>0.05$) condition factors. This study indicates a potential for growth performance, nutrient utilisation, condition factor and profitability in the local diet if well formulated. The study suggests that the local diet has a potential to be used for catfish culture at reduced cost.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Aquafeed in Nigeria

Nigeria is the most populous country in Africa with approximately 180 million people and among the largest fish consumers in the world with over 1.5 million tonnes of fish consumed annually. Yet its domestic fish catch is estimated at 450,000 metric tonnes per year (Udo & Dickson, 2017).

Fish has continued to be a source of hope towards solving the global problem of protein malnutrition due to its nutritive value above other animal proteins. Moreover, about 50% of the world fish harvest is captured by the less developed countries and a large proportion of this catch is consumed internally (Ibiyo *et al.,* 2018b). In Nigeria, animal protein is supplied through fishing (Ibiyo *et al.,* 2018). To increase the availability of fish and fish consumption, aquaculture development has been encouraged in recent times in Nigeria. As aquaculture production becomes more intensive, fish feed is a significant factor in increasing the productivity and profitability of aquaculture (Mogaji & Ibiyo, 2016). Fish feed production is a challenge, as feed is a major component in the production cost for aquaculture production (Mogaji & Ibiyo, 2016; Ibiyo *et al.,* 2018b).

Catfish (Figure 1) is the most farmed species of fish in Nigeria. The advantage of African catfish (*Clarias gariepinus*) for aquaculture is in its ability to withstand adverse environmental conditions, utilise atmospheric oxygen and effectively convert different feedstuff to flesh (Okomoda *et al.,* 2017).

Figure 1: *Clarias gariepinus* juveniles

Over time, there have been increasing attempts to develop standard diets for farmed fish in Nigeria using by-products from animal and crop processing industries. Some of these feedstuffs are competitively used for both terrestrial animals and fish (Udo & Umoren, 2011; Ahmad & Ibrahim, 2016). The formulation of diets will play a major role in the nutritional and economic success (Ovie & Eze, 2013; Ahmad & Ibrahim, 2016). There are two identified kinds of fish feeds in Nigeria: farm-made and commercial feeds. The farm-made accounts for 69-75%, while the commercial feed accounts for less. (Ahmad & Ibrahim, 2016). The two main types of fish feed produced are the tilapia fish feed of 30-35 % crude protein and carnivorous fish (catfish) feed of 45-50 % crude protein content (Ahmad & Ibrahim, 2016). The primary objective of

feed formulation is to provide fish with acceptable nutrition according to requirements at different stages of life and to obtain maximum production at minimum cost (Ahmad *et al.,* 2012). The feedstuffs used in fish feeds are derived from crop residues, mill by-products, food processing wastes or agro-industrial by-products. However, feedstuff resources in Nigeria are declining due to stagnant or diminishing output of some traditional crops (Fasakin *et al.,* 2001). Hence, in recent years, Nigeria has relied heavily on imports to supplement domestic production of conventional feedstuffs to meet the needs of the expanding fish culture industry (Ahmad & Ibrahim, 2016). The high cost of fish meal is daunting and has been a major factor affecting the growth of fish culture in Nigeria. To reduce the use of fish meal without adversely affecting the nutrient quality of fish feed, some plants and animal sources of protein have been studied over time (Joshua *et al.,* 2019). Although they are less expensive, they often have deficiencies or excesses of essential nutrients. (Joshua *et al.,* 2019).

For productive and sustainable aquaculture, a reliable supply of nutritionally balanced feed containing adequate amounts of all essential nutrients such as protein, fat, carbohydrate, vitamins, and minerals is a necessity (Zafar & Khan, 2020). Minerals are important inorganic micronutrients involved in several physiological functions including formation of skeletal tissue, maintenance of acid-base balance, membrane potential generation, electron transfer and osmoregulation (Zafar & Khan, 2020). The deficiency or excess of one or more nutrients in the diet may lead to reduced growth and pathological conditions. Iron which has been demonstrated to be an essential mineral element in fish (Zhang *et al*., 2016) is found in the red blood cell (heme) and is an essential element for blood production that is most readily absorbed by the body (Zafar & Khan, 2020). The deficiency of iron has been shown to cause poor growth in juvenile Jian carp (*Cyprinus carpio var.* Jian) (Ling *et al.,* 2010) and juvenile cobia (*Rachycentron canadum*) (Qiao *et al.,* 2013).The growth of fish primarily depends on the growth of muscle which is the major edible portion for consumers (Zhang *et al*., 2016). Thus, flesh quality is very important. The fish flesh quality is a complex set of characters involving muscle nutritive composition and chemical (or physic) properties such as muscle pH, cooking loss and firmness (Zhang *et al*., 2016). It has been reported that iron improved the fillet lipid content of rainbow trout (Senadheera *et al.,* 2012) and increased the body protein content in juvenile Jian carp (Ling *et al.,* 2010).

The gut morphometry also has a role in the absorption of nutrients in fish. The study of Abdel-Tawwab *et al.,* (2018) showed longer and thick villi resulted in an increased absorption area that resulted in greater absorption of available nutrients from the feed, resulting in improved growth performance and feed utilisation (Zharan *et al.,* 2014).

The increasing demand for aquafeed can be met through the availability of local raw materials for indigenous feed production by the fish farmers (Udo & Dickson, 2017). Different strategies such as pricing policies, input subsidies, production credit and flexible approach by governments and individuals have been adopted to increase the output of aquafeed enterprises. Yet the demand of the fish industry has not been met. The industry has grown rapidly in recent years and has the potential for both self-sustainability and commercial production (Udo & Umanah, 2017). This study is to evaluate the performance of different diets and feed combinations on the growth of African catfish in the Nigerian aquaculture industry.

1.2 Problem statement

The sustainability of aquaculture in Nigeria requires the availability, accessibility, nutritional and technical knowledge of standardised cost-effective fish feed and feeding arrangements. A

focus on local farm made feed production is due to the high cost of commercial fish feed in Nigeria. The most important and valuable animal protein ingredient in formulated fish feed in Nigeria is the clupeid fish meal. However, clupeid fish is used for human consumption and demand is high, increasing the cost of fish meal and aquaculture production. This has caused many farmers to cut corners due to the cost of fish meal in feed production by manipulating the required quantity and quality in terms of crude protein requirement for African catfish propagation; thereby, hindering the overall output in growth performance of African catfish production (Agboola *et al.,* 2019). Total replacement to local farm made fish feed to fish culture or feed combination of commercial and locally farm made feed could be a remedy to the information dearth in feed formulation, profitability, and sustainability of the aquaculture industry in Nigeria. Therefore, evaluation of commercial and locally made fish feed in the culture of African catfish in Nigeria forms the bedrock of this study.

1.3 Research Objectives

In Nigeria, there is partial adherence to standard for local fish feed formulation to increase sustainable aquaculture in the country. This is as a result of different practices by fish farmers who rely on their individual discretion and accessibility to potential raw materials. The goal of the study is to establish best practices on the use of commercial and locally made fish feed in the diet of African catfish in Nigeria. The study objectives are:

General objective

- To evaluate the impact of different combinations of fish feed on the growth performance of African catfish juveniles.

Specific objectives

- To compare the contribution of commercial fish feed and locally made fish feed in the culture performance of African catfish.
- To assess the effect of combined and single feed diets on growth performance.
- To determine the feed cost of production of catfish farming using different feeds and combinations of feeds based on fish growth and feed utilisation.

2 LITERATURE REVIEW

2.1 Aquaculture in Nigeria

Until recently, capture fisheries have dominated fish production rather than aquaculture in Nigeria. In 2007, about 460,000 tonnes of fish came from capture fisheries and less than 50,000 tonnes from aquaculture (Ayinla, 2007). However, by 2012, the aquaculture sector had grown five-fold to 250,000 tonnes (FAO 2012). The need to close the gap between production and demand for fish is the major driver of aquaculture growth in Nigeria. The domestic demand for fish is estimated at 1.5 million metric tonnes (Agboola *et al.*, 2019). This, coupled with recent investments in the private sector and a renewed political will to empower the private sector, are responsible for the country's position as the largest aquaculture producer in sub-Saharan Africa. Catfish production takes place in all the geopolitical areas of the country (figure 2) but the South-South and South-West regions produce the largest shares (Agboola *et al.*, 2019).

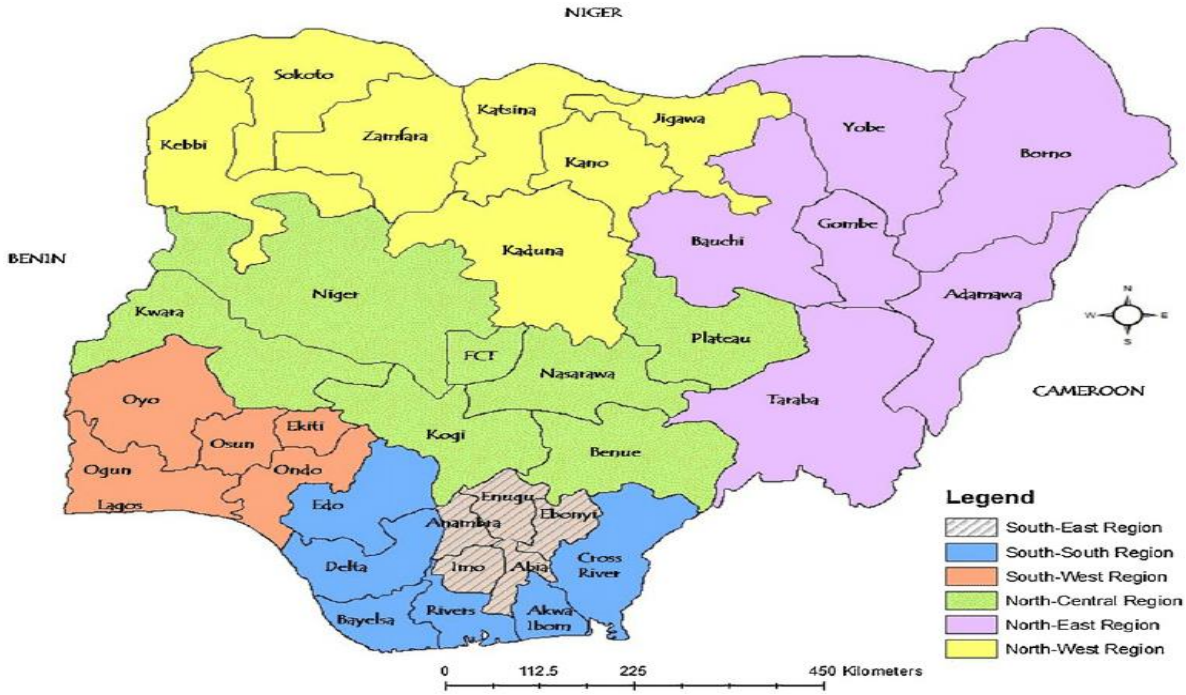

Figure 2: Geo-political zones of Nigeria

2.2 Aquafeed industry in Nigeria

The development of aquafeed in Nigeria has always been in correspondence with the growth of commercial fish farming. Before 2000, the contribution of aquafeed to total animal feed production was negligible. An estimated 35,570 tonnes of aquafeed was used in 2000, representing less than 1% of national feed production (Fagbenro & Adebayo, 2005). Poultry feed has always been the main product accounting for 90% of animal feed produced. In 2015, an estimated 5.3 million metric tonnes of feed were produced, of which aquafeed contributed about 12 %, second behind poultry feed (Udo & Umanah, 2017). The production is dominated by large-scale commercial feed industries. The commercial feeds are largely high-quality starter feeds. The farmers prefer using commercial starter feeds throughout the early phase (1-2 months) before switching to local feeds to reduce cost of production with optimum growth (Agboola *et al.*, 2019).

It is also recorded that farm-made feeds accounted for 70% of total aquafeed produced in 2000 (Ibiyo & Olowosegun, 2005). However, recent investments by feed companies like Skretting, Olam, and others establishing their factories in the country have contributed to the increase of more local production of commercial fish feeds. Nonetheless, some farmers still produce feeds on-farm to reduce the cost of feed. The quality of locally made feeds depends on the feed formulation, ingredient quality and the manufacturing processes (Udo & Umanah, 2017; Agboola *et al.*, 2019). A farm feed is mostly made from locally available raw materials (Table 1).

Table 1: Commonly available ingredients (both plant and animal origin) for aquafeed production in Nigeria

Ingredient	Source
White maize meal	Local
Yellow maize meal	Local
Maize bran	Local

Wheat meal	Local
Wheat bran	Local
Cotton seed cake	Local
Cassava peel	Local
Groundnut seed cake	Local
Distiller dried grain	Imported
Blood meal	Local
Fish meal	Local and Imported
Feather meal	Local
Poultry meal	Local and Imported
Maggot meal	Local
Noodles and biscuit waste	Local

Adapted from: Agboola *et al.,* 2019.

Apart from the conventional feed ingredients, there are other cheaper resources, not suitable for human consumption, which have been characterised, explored and investigated as fish feed ingredients. Some of these non-conventional fish feed ingredients are mucuna seed meal, jack bean, pigeon peal, brewer's dry grain, insect meal, winged bean, sesbania, leucania, maggots, earthworms, toad meal and rumen epithelial scrapings (Agboola *et al.,* 2019). The use of these non-conventional feed ingredients is limited because they are not readily available in quantities for large-scale fish feed production. Non-conventional feed materials like insect meal are a viable alternative in fish feed in terms of cost, feed quality, and yield for several fish species such as rainbow trout (*Oncorhynchus mykiss*), channel catfish (*Ictalurus punctatus*), tilapia (*Oreochromis spp*.), and African catfish (*Clarias spp.*) (Mogaji & Ibiyo, 2016).

2.3 Feeding practices of catfish production in Nigeria

Clarias gariepinus has an advantage over other aquaculture species cultured in many parts of the world because of its ability to withstand adverse environmental conditions, utilise atmospheric oxygen and effectively convert different feedstuff to flesh (Okomoda, 2018). This edge over other fish species comes with some challenges that hinge on its commercial propagation ranging from poor water quality to the practices of feeding (Okomoda *et al.,* 2017; Tiamiyu *et al.,* 2018). Significant mortality can occur from poor feeding practices at different stages of development of the fish. A study by Hossain *et al.,* (2001) shows that the growth advantage and size homogeneity linked with ad libitum feeding of *C. gariepinus* is detrimental to the survival rate of the fish; especially if feeding is done too frequently (Okomoda *et al.,* 2019). This is because aggressive swimming behaviour increases, consequent upon heightened anticipation of the fish for food, eliciting cannibalism and increased mortality as well as energy expenditure (Muntaziana *et al.,* 2017; Al-Khafaji *et al.,* 2017).

The study of Okomoda *et al.,* (2019) shows that the response of fish to feeding and its utilisation of feed can be greatly influenced by its stage of development as well as the timing of feeding (Okomoda *et al.,* 2019). Feed optimisation in terms of feeding rate and quantity has become a crucial area of study in the culture of many aquaculture species (Tiamiyu *et al.,* 2018). By identifying the optimum feeding practices, farmers can successfully optimise production time, maximise feed utilisation, improve the rearing environment (water quality) and facilitates the production of even-sized fish (Oh *et al.,* 2013; Oh & Venmathi, 2015). These practices may differ for different species, size/age, feed composition, and rearing environment (Xie *et al.,*

2011; Okomoda *et al.,* 2019). This study on *C. gariepinus* fingerlings affirm that growth and survival were significantly increased when the fish were fed twice daily (Marimuthu *et al.,* 2010) but growth was not affected by feeding either three or six times per day at the larvae stage as established in the work of Kaiser *et al.,* (1995).

2.4 Commercial and locally made feed in Nigeria

The growth of fish is influenced by its feed utilisation which in turn is a function of the nutrient composition and digestibility of the feed (Moshood *et al.,* 2014). A few studies have compared the growth performance of fish to commercial and locally made feeds (Moshood *et al.,* 2014) but different results have been reported due to different species of fish and various methods of formulating the local feeds from a variety of sources. The locally made feed has led to questionable formulations, nutrients composition and production techniques by most farmers who opt for cheaper feed without considering salient factors like proximate composition and processing technique. Some of these studies which investigated feed types on different parameters in fish include Mollah *et al.,* (2010) who compared local feeds and commercial feeds on the growth and survival of riverine catfish Rita rita; Shapawi *et al.,* (2011) who compared the growth performance and body composition of humpback grouper *Cromileptis altivelis* fed on farm-made feeds and commercial feeds and Ekanem *et al.,* (2012) who compared the growth performance and food utilisation of *C. gariepinus* fed on local Unical aquafeed and Coppens commercial feed.

The study of Moshood *et al.,*(2014) comparing the effect of local and commercial feeds on the growth and survival of *C. gariepinus* juveniles in Nigeria, showed better performance with commercial Coppens feed in weight gain, specific growth rate, protein efficiency ratio and food conversion ratio than the local feed. However, the growth performance reflected the proximate composition of the two diets with the crude protein of Coppens feed having 42 % and local feed with 11 %.

C. gariepinus does not utilise large amounts of carbohydrate for growth but needs protein as observed in fish fed with Coppens, which contained a high percentage of protein as reported by Moshood *et al.,* (2014). This study also linked the slow growth performance in fish fed with the local feed with the high percentage composition of fibers in the feed and could be due to the inability of the fish digesting and utilising the feed (Moshood *et al.,* 2014). A high level of fiber content in feed has been observed to slow the growth of *C. gariepinus* fingerlings (Adewolu *et al.,* 2010, Agbabiaka *et al.,* 2013).

2.5 Haematological indices for good condition factor for fish

Dietary requirements for optimum growth and prevention of various deficiency signs is important for aquatic species. Haematological indices such as minerals, protein and nutrients reflect the overall well-being of fish. Iron (Fe) is an essential mineral for all animals including fish due to its vital role as a functional constituent of proteins (Zafar & Khan, 2020). It is involved in a wide range of biological processes such as oxygen transport, DNA synthesis and energy production (Luo *et al*., 2017; Tarifeno-Saldivia *et al*., 2018). Mineral like iron can be obtained by fish through rearing water as well as from the diet, though, diet is regarded as the chief source (Kwong *et al*., 2013). Deficiency of minerals are also known to influence oxidative stress in mammals (Zafar & Khan, 2020) as well as fish (Zhang *et al*., 2016; Luo *et al.,* 2017; Guo *et al*., 2018). Other studies have also reported on the importance of iron for immune response in fish (Behera *et al*., 2014; Zhang *et al*., 2016).

2.6 Fatty acids in feed and fish flesh

Dietary fatty acids (FA) in fish and terrestrial monogastric organisms have been reported by Ballester-Lozano *et al.,* (2011) to absorb unchanged with highly predictable effects on whole body FA composition. However, factors other than diet (genotype, gender, age and production system) have a significant influence on the fillet lipid level and the FA composition of most animal products (Wood *et al*., 2008). The association between dietary and fillet FA composition is likely to be stronger in oily fish than in lean fish (Ballester-Lozano *et al.*, 2011). Earlier studies on gilthead sea bream (*Sparus aurata*) have shown that the muscle tissue is especially sensitive to changes in dietary FA composition (Benedito-Palos *et al*., 2010). Fillets of gilthead sea bream fed diets rich in plant oils show increased levels of linoleic acid (18:2n-6) and linolenic acid (18:3n-3) with a concurrent decrease of eicosapentaenoic (20:5n-3) and docosahexaenoic acids (22:6n-3) which is consistent with shifts in diet composition (Benedito-Palos *et al.,* 2008; Ballester-Lozano *et al.,* 2011). Furthermore, the study of Sourabié *et al.,* (2017) in "fish proteins not lipids are the major nutrients limiting the use of vegetable ingredients in catfish nutrition", suggested that it is possible to completely substitute fish oil with a mixture of linseed oil and cotton seed oil in diets of African catfish without affecting growth and feed utilisation in the case of high protein quality, while fish meal substitution by a mixture of lupine meal and soybean cake has negative effects on growth-related parameters whatever the oil quality. Thus, confirming that African catfish can bio-convert poly unsaturated fatty acids into long chain-poly unsaturated fatty acids from vegetable oils whereas dietary protein source is the major limiting factor affecting its growth performance.

2.7 Effects of feed on fish flesh quality

The quality of fish flesh which is composed of muscle reflects a nutritional diet. The study of Zhang *et al*., 2016 reported that muscle lipid, calcium, phosphorus, moisture and protein contents, responded to iron levels in grass carp. It was also reported that the fish muscle tissue with high levels of PUFA is sensitive to oxidation (Samples, 2013). Another report surmised that oxidative damages are the main non-microbial cause of quality deterioration of fish flesh (Terevinto *et al*., 2010). Lipid oxidation is thought to induce changes in protein structures and thereby influence firmness and water-holding capacity of fish muscle (Lund *et al.,* 2011). Furthermore, another report has shown that nutrients like myo-inositol deficiency depressed antioxidative capacity of muscle leading to loss of flesh quality in Jian carp (Jiang *et al*., 2010).

3 MATERIAL AND METHODS

3.1 Description of study areas

A feeding trial was undertaken at the Department of Aquaculture and Fisheries Management, University of Ibadan, Nigeria and some analyses were done at Matis laboratory, Reykjavik, Iceland.

3.2 Experimental Diets

The feed ingredients for the locally made fish feed were compounded according to the formulation of the University of Ibadan fish farm unit. These ingredients were sourced and purchased in consideration of their similarities to the ingredients commonly used as catfish diet in Nigeria. Fish offal was procured from the fish farm unit of the University of Ibadan. The offal was cleaned and cooked gradually to a 100 ºC for 15 minutes before blending with other ingredients. The mixture was further ground with a Unitech hammer mill to homogenous size,

mixed in an appropriate ratio, made into dough, pelleted into 2 mm size and sun-dried for 24 hours. The dried feed was packaged in an air-tight polythene bags and stored in a container at room temperature. The commercial 2 mm size feed was purchased at a feed depot in Ibadan. The two commercial diets, Skretting and Bluecrown were used in this experiment. The gross composition of ingredients in the local feed is shown in table 2. The feed formulation of the commercial diets was not available from the producers.

The experiment lasted for 12 weeks. Experimental feeds were nomenclated in alphabetic letters as treatment S, B, SL, BL and L for the five different treatments for the feeding trials, respectively. Treatment "S" and "B" were fed commercial feed of Skretting and Bluecrown until the end of the trial; treatment "SL" was fed Skretting for six weeks and locally made feed the latter six weeks; treatment "BL" was fed bluecrown for the initial six weeks and locally made feed for the latter six weeks; and treatment "L" was fed locally made diet throughout all the 12 weeks.

Table 2: Gross composition of local diet

Ingredient	**(%)**
Cassava flour	17
Maize	10
Soya bean meal	20
Groundnut cake	17
Fish offal	15
Poultry by-product	15
Palm oil	0.75
Premix*	1.0
Methionine	0.5
Lysine	0.5
Salt	0.25
Dicalcium phosphate	3.0
Total	**100**

*Provides per Kg diet: Vitamin A 25,000 IU; Vitamin D3 2,000 IU; Vitamin E 200 IU; Vitamin K 8mg;Vitamin B2 20mg; Vitamin C 500mg; Niacin 150mg; Pantothenic Acid 50mg; Vitamin B6 12mg; Vitamin B12 0.05mg;Folic Acid 4mg; Biotin 0.8mg; Choline Chloride 600mg; Cobalt 2mg; Copper 4mg; Iodine 5mg, Iron 40mg; Manganese 50mg; Selenium 0.2mg; Zinc 40mg; Antioxidant 100mg, Lysine 100mg; Methionine 100mg.

The proximate analysis (%) of different feeds (crude protein, crude fiber, ether extract, moisture, ash and nitrogen-free extract) were done on dry matter basis.

3.2.1 Moisture content (AOAC 1990)

Moisture content was analysed by drying 2 g of diet samples in an oven at 105 ºC for 4 hours, cooled in a desiccator and reweighed using the following formula:

$$\text{Moisture (\%)} = (\text{sample weight (g)} - \text{dry sample weight g}) / \text{sample weight (g)}) \times 100$$

3.2.2 Ash (AOAC 2000)

Clean and dried silica crucibles were accurately weighed (W_1); 1g of sample (W) was taken in the crucible and burnt in heater until the sample became smokeless. Crucibles containing smokeless samples were kept in a muffle furnace at 550ºC for 3 hours. Weight of crucible with ash was recorded after cooling (W_2). Ash (%) was calculated by the following formula:

$$\text{Ash (\%)} = \frac{W_2 - W_1}{W} \times 100$$

3.2.3 Crude fiber (AOAC 2005)

This was achieved by subjecting the residual sample from the ether extraction to a successive treatment with boiling acid (0.25N sulphuric acid) and alkali of defined concentration (0.313N sodium hydroxide) under controlled condition (AOAC, 2005).

3.2.4 Nitrogen Free Extract (NFE)

This was obtained by subtracting the sum of percentage crude protein (CP), total lipid (TL), crude fibre (CF) and ash from 100. That is, NFE (%) = 100 – (% CP + % TL + % CF + % Ash).

3.3 Experimental Design

The experiment was a completely randomised design of 5 treatments in triplicate. A total of 900 *Clarias gariepinus* juvenile was bred at the fish farm of the University of Ibadan, acclimated for 14 days before the commencement of the study. The fish was sampled averagely within the weight of 15-17 grams and randomly stocked at a density of 60 juveniles per tank in triplicate in experimental concrete tanks of 1m×1m×1m in 750 litres of fresh water. The fishes were hand-fed twice daily (9:00 am and 5:00 pm) to satiation for 12 weeks.

3.4 Determination of growth performance

The sampling was done every fortnight and data collection of weight, length, and survival were done. The water parameters like pH, temperature, dissolved oxygen and nitrite was recorded in the morning of the sampling days. Water temperature (°C) was recorded with the use of an ordinary thermometer (0 to 50°C), pH by using digital pH meter (Metler) and dissolved oxygen by Winkler's method. The rate of fish survival in each treatment was determined by comparing the live fish recovered at the end of the experiment with that of total fish stocked. Other parameters were calculated in regard to the net weight gain (NWG), per cent net weight gain (% NWG), specific growth rate (SGR), condition factor (K), feed conversion ratio (FCR) and protein efficiency ratio (PER) for every treatment according to the following formulae:

$$Apparent\ feed\ intake\ (FI) = amount\ of\ feed\ fed\ during\ the\ experiment$$

$$Weight\ gain = final\ average\ weight\ (g) - initial\ average\ weight\ (g)$$

Net weight gain = $average\ final\ body\ weight(g) - average\ initial\ body\ weight(g)$

$$\%\ \text{NWG} = \frac{Final\ body\ weight\ (g) - initial\ bady\ weight\ (g)}{initial\ body\ weight\ (g)} \times 100$$

$$\text{Specific growth rate (\%/day)} = \frac{ln\ final\ body\ weight\ (g) - ln\ initial\ body\ weight\ (g)}{culture\ days} \times 100$$

Where ln = natural logarithm

$$\text{Condition Factor (K)} = (Body\ weight\ (g))/(Body\ length\ (cm)^{3}) \times 100$$

$$\text{Feed conversion ratio} = (Feed\ given\ (g))/(Weight\ gain\ (g))$$

$$\text{Protein efficiency ratio} = (Weight\ gain\ (g))/(Protein\ intake\ (g))$$

$$\text{Survival (\%)} = (Number\ of\ fish\ harvested/Number\ of\ fish\ stocked) \times 100$$

3.5 Evaluation of gut morphometry

The guts of the experimental fish were collected, sterilised and prepared aseptically into sterile universal bottles based on Culling (1974) and Drury *et al.,* (1967). Measurements of villi length (VL), villi weight (VW) and muscle thickness (MT) (Figure 11) were taken in triplicates with a micrometer rule as described by Eyarefe *et al.,* (2008). The ratio of villus length to villus width (Figure 12) was also evaluated after the end of the study. Gut analysis such as length of villi, width of villi and thickness of the muscle layers was done on intestinal folds.

3.6 Determination of haematology

The blood samples of *Clarias gariepinus* were collected from un-anaesthetised fish as described by Morgan & Iwama (1997). The blood samples were taken from the dorsal fin of the fish following Klontz & Smith (1986) for haematological analysis according to Dacie & Lewis (2011). Plasma total protein was estimated through the biuret method (Garry & Williams, 1977). The creatinine, globulin, and albumin/globulin ratio by the standard methods described by Coles (1986). Determination of fatty acid composition of the experimental diets and fish flesh

Samples of the experimental diets and fish flesh were analysed using the Bligh & Dyer (1959) fat extraction method. The total lipid was estimated in a chloroform, methanol and potassium chloride ratio to extract the pure lipid content. Methylation of the extracted fat was analysed with a Sodium hydroxide in methanol solution before subjecting it to a gas chromatography to separate fatty acid methyl esters on a Varian 3900 GC equipped with a fused silica capillary column (Omegawax™ 250 30m × 0.25mm × 0.25µm film), split injector and flame ionisation detector fitted with Galaxie Chromatography Data System, version 1.9.3.2 software.

3.7 Evaluation of carcass composition

Samples of whole fish were taken from each treatment at the beginning and end of the study to evaluate the initial and final proximate body composition respectively. The samples were ground using a blender. Each content was put on a plate and placed inside FOSS scan Near Infrared spectrophotometer (Foss Hillerod, Denmark). The parameters analysed for included: moisture content, ether extract, crude protein and ash.

3.8 Economic consideration of different diets fed African catfish after the study

The economic analysis of the feed was evaluated to assess the feed cost of the different treatments used in the experiment. Profit index (PI), incidence of cost (IC) and economic conversion ratio (ECR) were used to estimate the economic benefits of the diets according to Faturoti & Lawal (1986) and Mazid *et al*., (1997).

$$PI = \frac{Value\ of\ fish\ (Naira)}{Cost\ of\ feed\ (Naira)}$$

$$IC = \frac{Cost\ of\ feed\ (Naira)}{Total\ fish\ biomass}$$

Economic conversion ratio (ECR) = Cost of diet × FCR (Piedecausa *et al*., 2007)

3.9 Statistical analysis

The statistical analysis of the data was performed with a statistical package (SPSS 20.0 for Windows, SPSS Inc., Richmond, CA, USA). Data obtained were subjected to One-way

analysis of variance (ANOVA) to test between the means of treatments and Turkey's tests to compare the variance amongst the mean at $p < 0.05$.

4 RESULTS

The culture conditions in the study period were within acceptable limits in terms of temperature, pH and dissolved oxygen and without significant difference among the treatments. The temperature of water ranged between 27 and 28.6°C, while the pH of water ranged between 7.5 and 7.9 (Table 3) in different treatments during the experiment. The dissolved oxygen (DO) and nitrite were analysed accordingly during the culture period. Morphologically, the treatments fed local diet showed faster pollution of water by the feed compared to the fed commercial diets due to the pellet quality. This is reflected in the dissolved oxygen level of the treatment L and also a slight decrease in the combined treatments compared to the treatments fed commercial diets, which is a factor of the local feed inclusion during the study period. The nitrite was negligible during the study period.

Table 3: Water analysis during the experimental study. Values are Mean ± S.E of three replicates.

Diets	Temperature (°C)	pH	Total ammonia (mg/L)	Dissolve oxygen (mg/L)	Nitrite (mg/L)
S	28.5±2.45	7.9±0.6	0.1±0.06	7.0±1.2	0±0.0
B	28.8±2.21	7.7±0.2	0.1±0.02	7.0±0.8	0±0.0
SL	28.3±2.74	7.5±0.2	0.15±0.06	6.4±1.4	0±0.0
BL	28.6±2.66	7.7±0.8	0.14±0.06	6.2±1.4	0±0.0
L	28.6±2.38	7.5±0.4	0.25±0.02	5.8±1.8	0±0.0

4.1 Proximate analysis of experimental diets and fish

The proximate analysis of the experimental diets (Figure 3) showed some difference in chemical composition. The Skretting feed was significantly different ($p<0.05$) and had the highest crude protein level (37.18) compared to the Bluecrown (35.0) and local diets (32.55) respectively. The lipid content was significantly higher in the local diets (7.3), than in the Bluecrown (6.7) and Skretting diet (6.4) respectively. The fibre content in the skretting and local diets were significantly higher that the diet B. The proximate analysis reflects the nutrient quality of the diets.

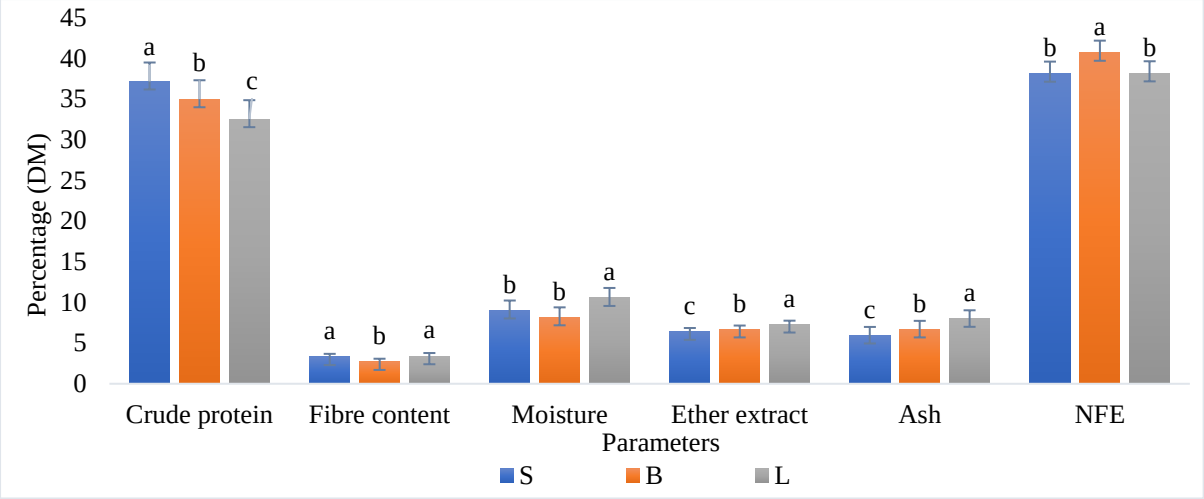

Figure 3: Proximate analysis of experimental diet used for the study
Values are Mean ± S.E of three replicates. Treatments having different letters in a group are significantly different at P<0.05

The proximate analysis of the fish on dry matter basis (Figure 4) among different treatments after the study period showed that treatment B (57.12) had the highest crude protein content in the fish flesh and significantly different (p<0.05) to the other treatments. However, there was no significant difference in the crude protein content among treatments SL, BL and L. The result showed no significant difference in the ether extract content of the treatment S and SL; and B and BL. Though treatment L showed the highest ether extract content among the treatments. The result showed the reflection of different diets on fillet proximate composition.

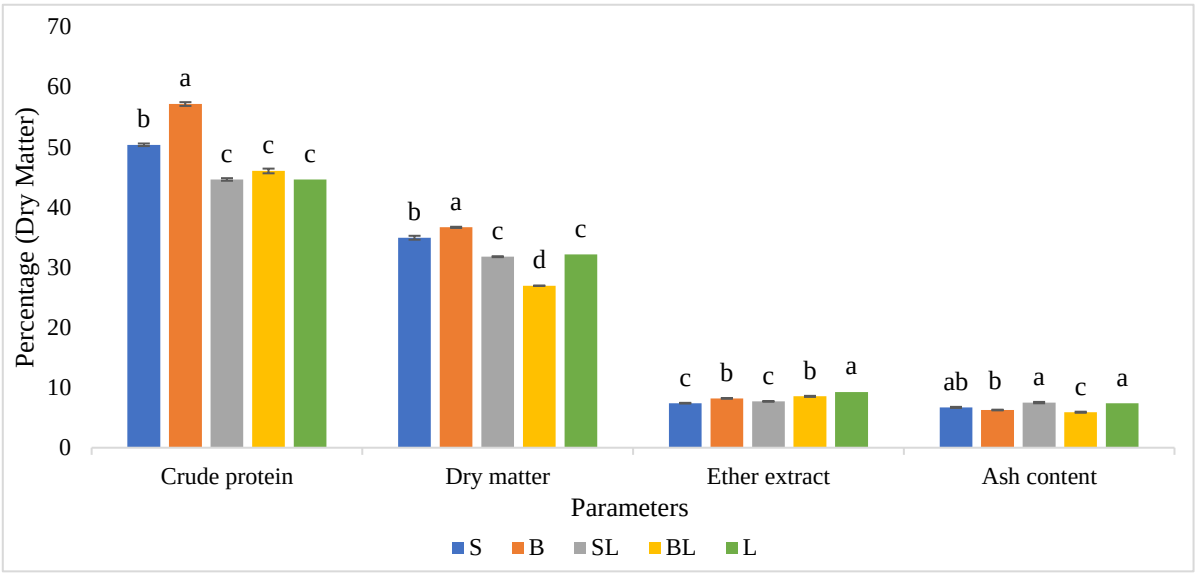

Figure 4: Proximate analysis of whole fish samples after feeding trial
Values are Mean ± S.E of three replicates. Treatments having different letters in a group are significantly different at P<0.05

4.2 Growth evaluations of experimental fish fed different diets

The increase in average fortnightly body weight for *C. gariepinus* juvenile during the study is shown in Figure 5. The final weight was 406.6 (S), 304.8 (B), 282.74 (SL), 296.19 (BL) and 222.77 (L) for *C. gariepinus* fed different diets, respectively. The final weights did not differ significantly among treatment S, B, SL, and BL. Though treatment S was significantly different

(p<0.05) to treatment L, the result showed that treatment L did not differ from the treatments B, SL, and BL. There was no difference in the growth trend of the treatments fed commercial and combined diets for the first 6 weeks because the commercial diets fed the treatment S and B was same for the treatments SL and BL respectively before the introduction of the local diets for the second 6 weeks of the study. The trend of depressed growth in the L group compared to the fish fed commercial diets is already clear after 6 weeks.

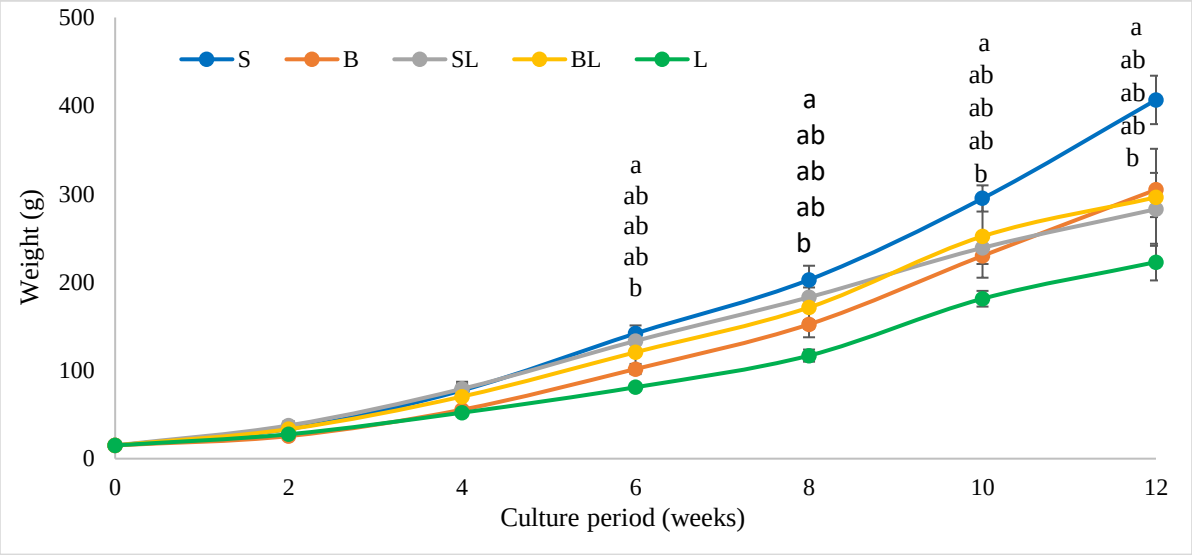

Figure 5: Average body weight of treatments during the culture period
Values are Mean ± S.E of three replicate. Treatments having different letters in a group are significantly different at P<0.05

Table 4: Mean average body weight of treatments during the culture period

Treatments	Week 0	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12
S	15.01± 0.01	33.62± 3.71	77.36± 8.91	141.92± 15.73 [a]	202.76± 27.54 [a]	294.91± 25.72 [a]	406.59± 47.53 [a]
B	15.01± 0.01	25.56± 0.63	55.50± 2.42	101.60± 9.97 [ab]	152.25± 8.25 [ab]	229.89± 16.07 [ab]	304.80± 33.06 [ab]
SL	15.01± 0.0	37.63± 8.36	79.15± 13.86	133.43± 4.95 [ab]	182.94± 19.19 [ab]	238.96± 19.8 [ab]	282.74± 15.54 [ab]
BL	15.01± 0.01	33.43± 12.95	70.38± 25.66	120.63± 39.49 [ab]	171.41± 58.62 [ab]	251.94± 81.14 [ab]	296.19± 95.24 [ab]
L	15.01± 0.01	27.62± 2.59	52.13± 4.09	80.96± 1.83 [b]	116.80± 11.9 [b]	181.25± 15.42 [b]	222.77± 35.99 [b]

Values are Mean ± S.D of three replicates. Treatments having different letters in a group are significantly different at P<0.05

The results on specific growth rate (SGR) for *C. gariepinus* during the study (Figure 6) showed no difference between the treatments fed commercial and combined diets, and the treatments fed combined and local diets during the first 8 weeks of the study. The significant difference recorded between the treatments fed commercial and combined diets within week 10 and week 12 suggests the response of the combined treatments to the local diets. The overall SGR of the study showed no difference among treatment S, B, SL and BL. Though, there was a significant difference between treatment S and L, treatments B, SL, and BL did not differ from treatment

L. The trend of the SGR of the study showed that *C. gariepinus* had decreased growth rate as fish grows bigger.

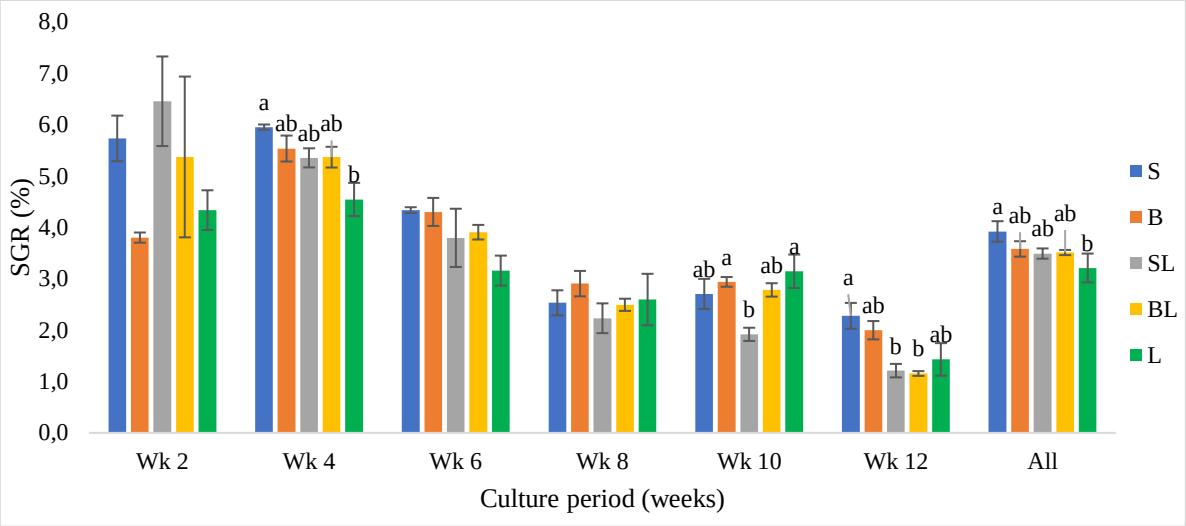

Figure 6: Specific growth rate of fish during the culture period
Values are Mean ± S.E of three replicates. Treatments having different letters in a group are significantly different at P<0.05

Initially, in the first 2 weeks of the study, there were variability within the treatments in SGR which might be due to the acclamation of the diets.

The FCR at the end of the first 6 weeks of the study showed that there was no significant difference (p>0.05) in treatment fed the commercial diet (S, B) or in the groups SL and BL since they were fed the same types of commercial diets respectively. However, in the same period, there were significant difference (p<0.05) in treatment L compared to others. At the end of the study, the overall FCR in treatment S (1.35) performed best and significantly different (p<0.05) among all the treatments; followed by treatment B (1.97) and treatment SL (1.97) which were same and significantly different to treatment BL (2.65) and treatment L (2.81).

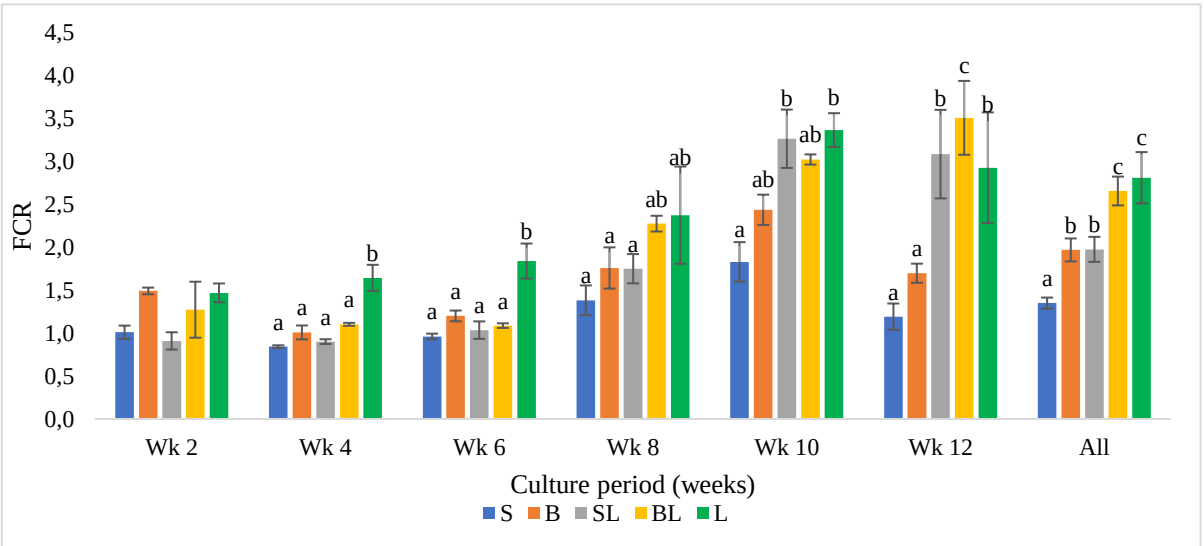

Figure 7: Feed conversion ratio (FCR) for different treatments during the culture period
Values are Mean ± S.E of three replicates. Treatments having different letters in a group are significantly different at P<0.05

The results of the protein efficiency at the end of the study is shown in Figure 8. The protein efficiency is highest in the initial periods, when the fish is smaller and correlated to the growth rate. At week 10 and 12, the protein efficiency ratio in treatment S was significantly different ($p<0.05$) compared to other treatments except treatment B. However, treatment B, SL, BL and L were not significantly different. This PER of this study indicate that diet S and B had a better utilisation of protein in the feed, compared to the combined and local diets. This further showed that the protein efficiency correlates to the nutritional composition of diet. The overall PER indicate treatment S with a significant performance ($p<0.05$) than others, while treatment B and SL were significant ($p<0.05$) to treatment BL and L.

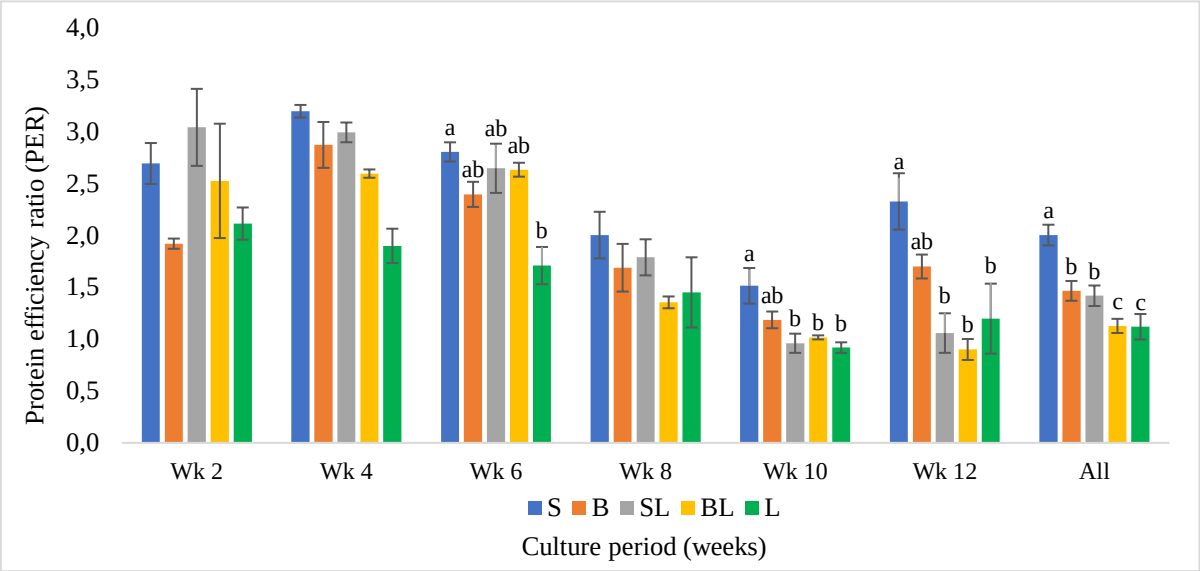

Figure 8: Average protein efficiency ratio (PER) of the treatments during the culture period Values are Mean ± S.E of three replicates. Treatments having different letters in a group are significantly different at $P<0.05$

The length frequency and weight distribution of the treatments during the study are presented in figure 9. There was no significant difference in the condition factor values during the entire study period. However, the highest mean K value of 1.08 was recorded in treatment S, while the lowest mean K value was recorded in treatment BL (0.75). There was a consistent increase in the K values for the treatments fed commercial diets throughout the duration of the study compared to other treatments. This may be due to the unchanged diet during the study period.

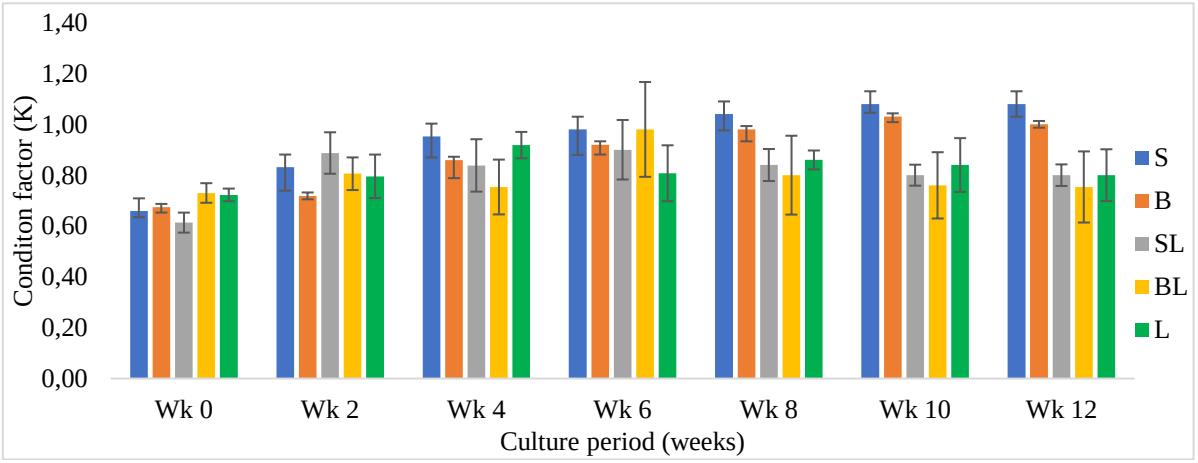

Figure 9: Average condition factor of the treatments during the culture period Values are Mean ± S.E of three replicates.

The present study has indicated similar percentage survival between *C. gariepinus* fed on different diets. There was a consistent survival rate in the culture of *C. gariepinus* in all the treatments within the second week till the end of the study. This is because of its resistance to water quality stress as well as diseases (Limbu, 2015). However, the drop in survival of the fish was recorded during the first 2 weeks of the study for all the treatments. This might not be associated with the treatments but adjustments into the experimental system. The acclamation after the 2 weeks drop in survival showed that the diets do not have any detrimental effect on the survival of the fish during the study period as all diets provided essential nutrients required for survival and water quality parameters were optimum for *C. gariepinus* survival in the tanks.

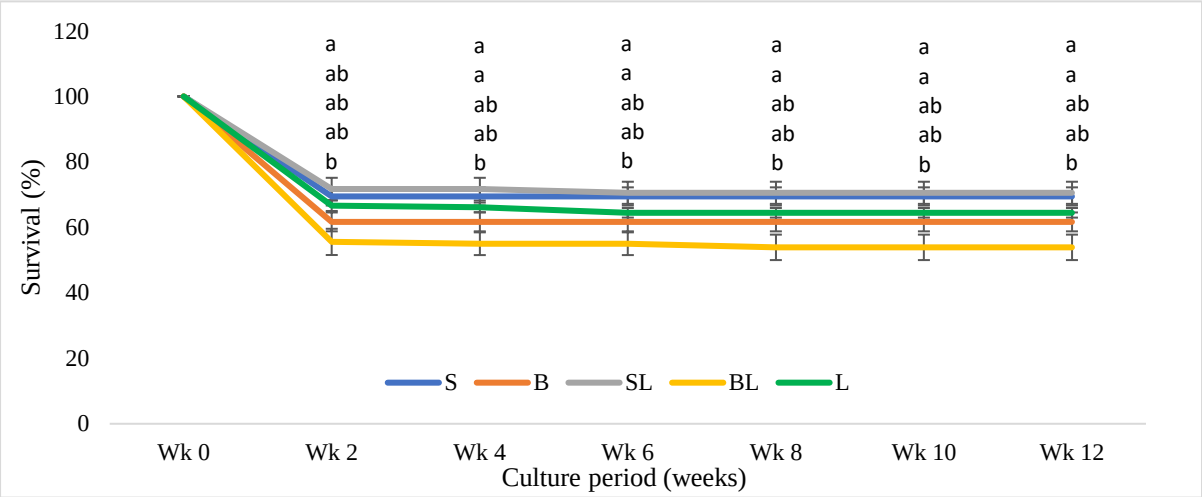

Figure 10: Development of survival during the culture period
Values are Mean ± S.E of three replicates. Treatments having the same letter in a week are not significantly different at P<0.05.

4.3 Morphometric gut evaluation of different treatments in African catfish

The result showed the relationship of diets to gut morphology as shown in figure 11. The feeding of different diets during the study showed significant relative increase on the villi length and villi width in African catfish compared to the initial treatment. The initial treatment showed lowest values of intestinal morphometry parameters. The ratio of the villi length to villi weight (Figure 12) showed that all the treatments responded well to the nutrient in the diets, respectively. There was no significant difference (p>0.05) in the VL and VW ratio of all the treatments. The villi length correlated with the villi width in the treatments after the study.

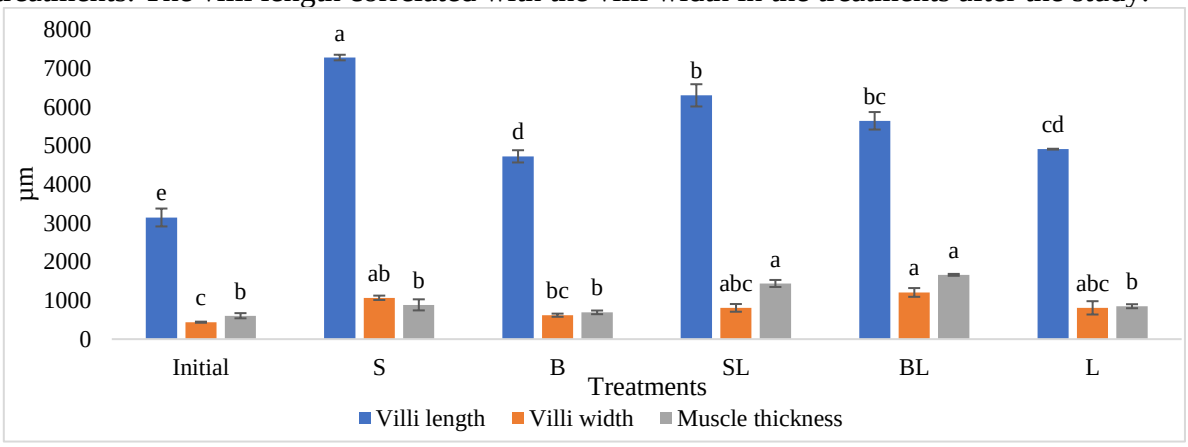

Figure 11: Gut morphometry of experimental fish at the start and end of the study
Values are Mean ± S.E of three replicates. Treatments having the same letter in a parameter are not significantly different at P<0.05

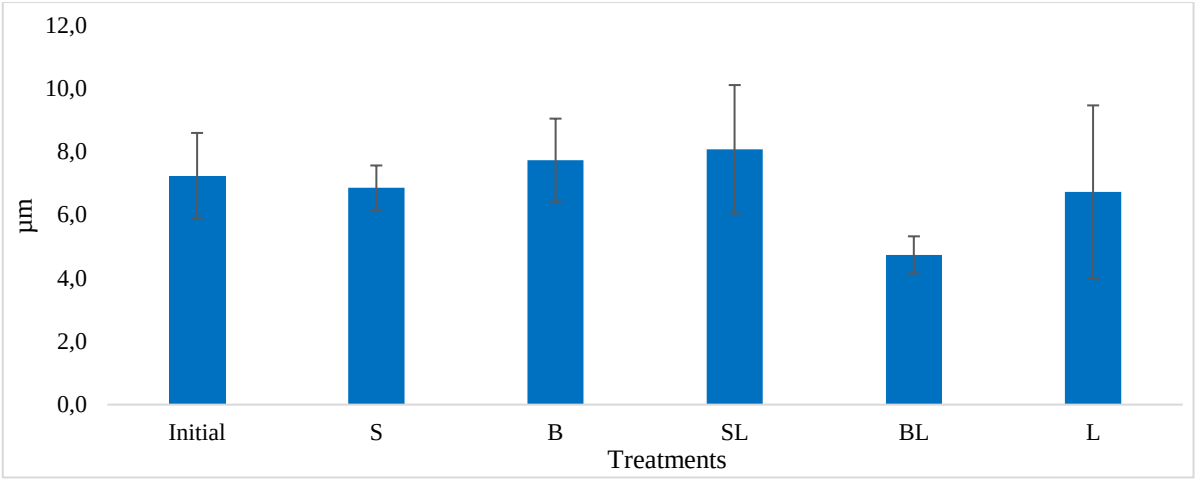

Figure 12: Ratio of villi length to villi weight of the fish at the start end of the study. Values are Mean ± S.E of three replicates. Treatments having the same letter are not significantly different at P<0.05

4.4 Haematological evaluation of different treatments in African catfish

The blood parameters were evaluated and recorded in table 5. The results of the haematological serum biochemistry of *C. gariepinus* fed different diets showed no major negative indication of diets in the parameters before and after the study. The PCV, haemoglobin and RBC levels in all the treatments indicated a well transfer of oxygen and nutrients through the body. The WBC, MCHC, MCV and platelet levels in all the treatments indicated the immunity of the fish against any diseases. This indicated the acceptability of the diets in the treatments during the study period.

Table 5: Haematological serum biochemistry parameters of African catfish fed different diet at the start and end of experiment

Parameter	**S**	**B**	**SL**	**BL**	**L**	**INITIAL**
a. PCV (%)	20	26	29	35	27	27.67 ± 8.9
b. Haemoglobin (g/dL)	6.8	8.8	9.5	11.6	9.3	8.87 ± 2.9
c. RBC ($x10^6$/µL)	1.83	2.82	3.69	3.69	3.74	2.05 ± 1.0
d. WBC ($x10^3$/µL)	12.0	21.0	13.7	18.6	16.4	14.6 ± 1.5
e. MCV (FL)	1.1×10^{-4}	9.2×10^{-5}	7.9×10^{-6}	9.5×10^{-6}	7.2×10^{-6}	1.3×10^{-4}
f. MCHC (%)	34	33.85	32.76	33.14	34.44	32.06
g. MCH (pg)	3.7×10^{-4}	3.1×10^{-4}	2.6×10^{-4}	3.1×10^{-4}	2.5×10^{-4}	4.3×10^{-5}
e. Platelet ($x10^3$/µL)	150	138	154	168	166	147.67 ± 10
f. Lymphocytes (%)	68	65	70	73	64	63.67 ± 5.0
g. Heterophil (%)	25	27	23	18	28	28.33 ± 3.5
h. Monocytes (%)	2	4	3	3	5	3.33 ± 1.5
i. Eosinophil (%)	5	4	4	5	2	4.33 ± 0.58
j. Basophil (%)	0	0	0	1	1	0.33 ± 0.58

k. TPC (g/dL)	5.8	6.2	5.4	4.8	4.7	6.30 ± 0.26
l. A.C (g/dL)	1.2	1.3	1.1	0.8	0.8	1.30 ± 0.1
m. G.C (g/dL)	4.6	4.9	4.3	4	3.9	5.0 ± 0.17
n. A : G	0.2	0.2	0.2	0.2	0.2	0.23 ± 0.06
o. AST (µl)	193	205	200	185	180	192.67 ± 8.5
p. ALT (µl)	20	22	19	18	18	30.33 ± 1.53
q. ALP (µl)	329	334	342	279	358	211 ± 29.1
r. BUN (mg/dL)	7.6	8.6	7.7	6.5	6.6	17.63 ± 0.21
s. Creat (mg/dL)	0.7	0.7	0.6	0.6	0.5	0.50 ± 0.0

Key: PCV = packed cell volume; RBC = Red Blood Cell; WBC = White Blood Cell; MCV = Mean Cell Volume; MCH = Mean Cell Haemoglobin; MCHC = Mean Cell Haemoglobin Concentration; TPC = Total Protein Content; A.C = Albumin Content; G.C = Globulin Content; A:G = Albumin : Globulin; AST= Aspartate aminotransferase; ALT= Alanine transaminase; ALP= Alkaline phosphatase; BUN = Blood Urea Nitrogen; Creat = Creatinine.

4.5 Fatty acid analysis of experimental diets for the study

The fatty acid profile of the diets (Table 6) showed an increase in the C18:3n3 level of the Skretting diet compared to the Bluecrown diet (2.0) and local diet (1.7). Though the DHA was higher in the Skretting diets, the results showed that the Bluecrown recorded the highest level (1.4) of combined DHA and EPA. However, the PUFA and total omega 3 was highest in the Skretting diets and lower in the Local diets. The results indicate a close correlation in the fatty acid profile between the Bluecrown and Local diets.

Table 6: Fatty acid composition (% fatty acid methyl esters) of experimental diets for the study

S/N	Fatty acids	Diet S	Diet B	Diet L
1.	C12:0	0.1	0.1	0.4
2.	C14:0	0.9	1.7	0.9
3.	C14:1	0.1	0.1	0.1
4.	C15:0	0.1	0.2	0.0
5.	C16:0	14.7	21.3	21.6
6.	C16:1n7	2.8	3.1	2.4
7.	C16:2n4	0.0	0.1	0.0
8.	C17:1	0.1	0.1	0.0
9.	C16:3n4	0.0	0.0	0.0
10.	C17:1	0.2	0.3	0.2
11.	C18:0	4.2	7.5	6.7
12.	C18:1(n9+n7)	36.6	33.5	38.4
13.	C18:2n6	20.7	23.0	20.5
14.	C18:3n6	0.1	0.2	0.6
15.	C18:3n3	12.9	2.0	1.7
16.	C18:4n3	0.2	0.1	0.1
17.	C20:0	0.3	0.4	0.5
18.	C20:1(n11+n9)	0.6	1.1	1.1
19.	C20:2	0.0	0.2	0.0
20.	C20:3n6	0.1	0.0	0.0
21.	C20:3n3	0.1	0.3	0.2
22.	C20:4n6	0.4	0.5	0.1

23.	C20:4n3	1.1	0.0	0.1
24.	C20:5n3 (EPA)	0.2	0.6	0.2
25.	C22:1(n11+n9)	0.2	0.2	0.6
26.	C22:5n3	0.2	0.2	0.1
27.	C22:6n3 (DHA)	1.0	0.8	0.5
28.	C24:1n9	0.1	0.0	0.0
29.	SFA	20.4	31.2	30.1
30.	MUFA	40.5	38.4	42.7
31.	PUFA	67.9	28.0	24.1
32.	Unknown	5.2	3.2	4.2
33.	EPA+DHA	1.2	1.4	0.8
34.	Total omega 3	15.6	3.9	3.0

4.6 Fatty acid analysis of treatments fed experimental diets during the study

The fatty acid profile of the fish fillet in the study showed an increase in the C18:3n3 level of the treatment L (7.0), followed by SL (4.0), S (2.6), BL (1.6) and B (0.7). The DHA was higher in the treatment SL while the EPA was highest in the treatment L. The result showed that the combined DHA and EPA was more in the treatment L (4.3). However, the PUFA level in the treatment S recorded the highest level which connoted a relationship of the PUFA in the diet in the fish fillet. Total omega 3 was highest in the treatment L.

Table 7: Fatty acid composition (% fatty acid methyl esters) of whole African catfish fed different experimental diets.

S/N	Fatty acids	S	B	SL	BL	L
1.	C12:0	0.1	0.1	0.1	0.1	0.2
2.	C14:0	1.0	0.8	1.1	1.3	1.4
3.	C14:1	0.2	0.2	0.2	0.1	0.2
4.	C15:0	0.2	0.2	0.2	0.4	0.1
5.	C16:0	21.4	22.5	20.7	23.6	18.8
6.	C16:1n7	2.5	2.8	2.6	3.3	3.0
7.	C16:2n4	0.0	0.2	0.1	0.1	0.1
8.	C17:1	0.2	0.0	0.0	0.0	0.1
9.	C16:3n4	0.0	0.0	0.0	0.0	0.0
10.	C17:1	0.2	0.2	0.0	0.3	0.2
11.	C18:0	6.5	5.8	6.1	8.0	6.1
12.	C18:1(n9+n7)	37.6	37.9	37.1	34.4	35.2
13.	C182n6	15.3	13.8	15.2	13.8	15.6
14.	C18:3n6	1.1	2.1	1.3	0.7	0.5
15.	C18:3n3	2.6	0.7	4.0	1.6	7.7
16.	C18:4n3	0.3	0.3	0.5	0.2	0.6
17.	C20:0	0.3	0.3	0.3	0.2	0.2
18.	C20:1(n11+n9)	0.6	1.1	1.2	1.5	0.3
19.	C20:2	0.3	0.3	0.2	0.4	0.9
20.	C20:3n6	1.5	1.4	0.2	0.5	0.6
21.	C20:3n3	1.0	1.2	1.4	1.6	0.3
22.	C20:4n6	0.1	0.1	0.9	1.2	1.3
23.	C20:4n3	0.2	0.0	0.0	0.0	0.1
24.	C20:5n3 (EPA)	0.6	0.3	0.8	0.8	1.3
25.	C22:1(n11+n9)	0.3	0.5	0.1	0.1	0.2
26.	C22:5n3	0.4	0.3	0.5	0.4	0.7
27.	C22:6n3 (DHA)	2.5	1.7	3.1	2.5	3.0

28.	C24:1n9	0.1	0.0	0.0	0.0	0.1
29.	SFA	29.7	29.8	28.4	33.6	26.9
30.	MUFA	41.4	42.7	41.2	39.6	39.1
31.	PUFA	55.2	22.3	28.3	23.1	33.0
32.	Unknown	5.2	3.2	4.2	3.2	4.2
33.	EPA+DHA	3.1	2.0	3.9	3.3	4.3
34.	Total omega 3	7.3	4.5	10.3	6.5	13.7

4.7 Economic evaluations of African catfish fed different diets.

Table 8: Cost analysis of different diets fed African catfish juvenile during the study period. Prices estimated in Nigerian Naira (₦)

S/N	Parameters	S	B	SL	BL	L
1.	Total fish biomass increase (g)	37798	23198	27498	17998	17398
2.	Total feed given (g)	49014	42326	49745	41773	42433
3.	Feed cost (₦/kg)	625	427	289	225	176
4.	Total feed cost (₦) (2×3)	30634	18060	14400	9402	7447
5.	FCR	1.35	1.97	1.97	2.65	2.81
6.	[a]Profit index (PI)	1.1	1.2	1.7	1.7	2.1
7.	Incidence of cost (IC) (₦/kg) (4÷1)	810	779	524	522	428
8.	[b]Economic conversion ratio (ECR) (3×5)	844	841	569	596	495
9.	Total value of fish (₦/kg) (1×₦900)	34018	20878	24748	16198	15658

Note: Only the cost of purchasing and processing the material was computed for the local ingredients and cost of fish offal used for formulating the local diet was estimated at 50% of feed production cost. [b]Cost of feed to produce 1Kg of fish. [a]Benchmark for cost of fish per kg was at ₦ 900.

5 DISCUSSION

All the water parameters measured were within the levels recommended by Boyd, (1983) for general fish survival and growth. Though, the dissolved oxygen in the treatment L was lower than the other treatments but within acceptable range of D.O for catfish culture. This may be due to the nature of the local feed which pollutes the water. The effect on the oxygen and water quality in general on the growth condition cannot be excluded. The mortality of fish mainly occurred in the first 2 weeks of the study across the 5 treatments. This might not be a function of the feeding trial but might be connected to the adjustment into the experimental system or handling stress at the initial setup of the experiment since survival was stable until the end of the study period.

Previous studies have shown that feed composition and nutrient quality of fish feed is a major determinant to the performance of the African catfish and many other fish species (Keremah & Esquire, 2014). Properly formulated and balanced diet, which fulfill all nutritional requirement of the fish, is a prerequisite to gain optimal growth. The results of the protein

composition analysis (Figure 7) of the different experimental diets showed that diet S (37.18%), B (35.00%) and L (32.55%) were significantly different at $p<0.05$. The study showed that crude protein content in the diet is one of the important factors and proportionate for the growth of catfish which in turn is inversely proportional to feed cost. This corroborates the study in comparative effect of local and commercial feeds on the growth and survival of *Clarias gariepinus* juveniles (Moshood *et al.,* 2014).

The growth performance of *C. gariepinus* fed different commercial feed, a combination of commercial and local feed, showed that fish fed on Skretting feed grew significantly better ($p<0.05$) than treatment L and performed best among other treatments with lesser protein contents respectively. Growth of fish fed B, SL, BL and L were not statistically different ($p>0.05$). A similar result was recorded in the study of Joshua *et al.,* (2019) in substituting higher protein fishmeal diet with sesame seed meal in catfish. Also, the study showed that the growth response fed combined diets SL and BL were not significantly different ($p<0.05$) to the treatments fed the commercial diets (S and B) only. The combined diets might be viable economically, although it will take some additional time to reach similar average weight compared to fish fed the Skretting diet alone. Other factors that may influence the growth output of the treatments fed local diets, may be due to the less compactibility of the local feed which may leach out nutrients faster than the commercial diets. This edge enables the floating commercial diets to retain its nutrients longer in water compared to the sinking, less compacted local diet. The study of Ibiyo *et al.,* (2018) on the evaluation of different fishmeal-based diets in growth of catfish reported that floating feed has no significant difference over sinking diet in growth provided the crude protein is the same.

There was no significant difference in the specific growth rate in all the treatments in the first 6 weeks of the study. Between the introduction of the local diets till the end of the study, treatment fed the Skretting diet performed better than the other treatments. Though, treatment S was only significantly different ($p<0.05$) to treatment L, other treatments (B, SL and BL), showed relativeness to treatment L with no significant difference. This reflects that the fish responded according to the protein compositions of the feeds respectively. Initially, in the first two weeks of the study, there was variability within the treatments in SGR which might be due to the acclamation of the diets. It is also reflected in the increased mortalities in the first two weeks.

The FCR at the end of the first six weeks of the study showed that there was no significant difference ($p>0.05$) in treatment fed the commercial diet (S, B) or in the groups SL and BL since they were fed the same types of commercial diets respectively. However, in the same period, there were significant difference ($p<0.05$) in treatment L compared to others. At 12 weeks, treatment S (1.35) performed best and significantly different ($p<0.05$) among all the treatments; followed by treatment B (1.97) and treatment SL (1.97) which were same and significantly different to treatment BL (2.65) and treatment L (2.81). This study reflected the relationship in diet protein content to FCR, which corroborated the study of Heuze *et al.,* (2015) in nutrients for fish growth and optimum performance as protein requirement for varying species of fish; and the report in the principles of protein and fish meal in the fishery industry (Ahmad & Ibrahim, 2016). It was observed in the study that FCR increased within week six and week ten. This reduced feed intake may be due to erratic water supply during this period. However, other factors that may affect feed intake in cultured fish species include management practices, environment conditions, feed quality, inherent genetic factors and physiological condition of the fish (Eriegha & Ekokotu, 2017).

The protein efficiency is highest in the initial periods, when the fish is smaller and correlated to the growth rate. The protein efficiency ratio in treatment S was significantly different ($p<0.05$) compared to other treatments except treatment B. However, treatment B, SL, BL and L were not significantly different. This PER of this study indicate that diet S and B had a better quality of protein in the feed, compared to the combined and local diets. This further showed that the protein efficiency most probably correlates to the nutritional composition of diet and the protein quality /digestibility.

The maximum value of condition factor 'K' was recorded in treatment S (1.1) followed by B (1.0), SL and L (0.8), and BL (0.8). The values of 'K' recorded in the diets of treatment S was higher than others but not significantly different ($p<0.05$). The condition factor showed the growth and degree of wellbeing of the fish in the study and may also be a measure of various ecological and biological factors such as degree of fitness, gonad development and the suitability of the environment regarding the feeding condition (Mac Gregoer, 1959). When condition factor value is higher it means that the fish has attained a better condition. The condition factor of fish can be affected by several factors such as stress, sex, season, availability of feeds, and other water quality parameters (Khallaf *et al.,* 2003). Mean condition factor for the treatments increased from the beginning of the study to the end. Thus, indicated that K, in *C. gariepinus* may be influenced by the quality of feed and sampling stress during the study period. A previous study on condition factor of *Clarias gariepinus* in lake Naivasha observed that condition factor (K) values were high in the larger fish and better adapted to the ecological status than the small sized fishes (Keyombe *et al.,* 2015).

The gastrointestinal tract of fish consists of the mouth, oesophagus, stomach, pyloric caeca, mid-intestine, distal intestine and the rectum (Merrifield *et al*., 2011). The chemical composition of feed may have effect on the digestive system. Thus, histological examination of the digestive system is important. The villi length (VL) of treatment S was significantly different ($p<0.05$) to other treatments. Treatment SL, BL, and L were not significant which may be because of local diet introduction with the commercial diet. However, the villi width (VW) and VL:VW were not significantly different ($p<0.05$) among all the treatments. Furthermore, there was a significant difference ($p<0.05$) in VL and VW between the initial treatment and other experimental treatments. This may be due to the absorption of nutrients in the diets, respectively. In previous studies, Yadav *et al*., (2014) found that diets with fish oil, soybean oil, linseed oil and beef tallow allowed increase in number of intestine villi of Asian catfish (*Clarias batrachus*); Zaki *et al*., (2015) found that dietary chitosan incorporated into feed formulation on the intestine morphology of Sea bass (*Dicentrarchus labrax*) increased the villus height in duodenum and jejunum; Heidarieh *et al*. (2013) found that aloe vera incorporated in the Rainbow trout (*Oncorhynchus mykiss*) feed increased the villus length and decreased the villus width in proximal intestine. This result showed that various nutritional diet composition may affect intestine villi morphology. The report of Raskovic *et al.,* (2011) stated that intestine histology can vary due to the selected species and ingested feed.

Changes in the haematology of fish in response to stressing agents are indicators of the stressful stage of fish, producing useful information to curb any unfavorable condition that may affect the fish health (Bello-Olusoji *et al.,* 2006). There were higher PCV, Hb, RBC and platelet level in the combined and local treatments compared to the initial treatment and treatments fed with the commercial diets. The study of George *et al*., (2007) observed that when 50% fish meal was replaced by soybean meal in the diet for *Clarias gariepinus*, there was increase in PCV, Hb and RBC of the fish fed the diet which indicated high oxygen absorption and transportation

capacity of the cells of the fish. The report of Fagbenro *et al.,* (2013) showed that decrease in haematological parameter with increasing level of incorporation of sesame meal might not be unconnected to the presence of tannin and phytate present in the seed meal. Though, there was no privy information on the formulations of the commercial diets. The study also showed a lower WBC in treatment S among other treatments. This opined with the report of Akinwande *et al.,* (2004) that a measurable increase in white blood count of fish is a function of immunity and resistance to some vulnerable illness or disease. Though, no illness was recorded during the study period, the blood status of the fish is a valuable means of evaluating the physiological condition of cultured fish with respect to determining the effect of diets and other stress factors on fish health (Fagbenro *et al*., 2013).

The fatty acid composition in African catfish muscle is known to reflect dietary fatty acid composition (Ng *et al.,* 2003). This positive correlation between dietary and muscle fatty acid compositions has also been widely reported in other fish species such as Atlantic salmon (Bell *et al.,* 2002), rainbow trout (Borquez *et al*., 2011) and Eurasian perch (Geay *et al.,* 2015). According to the fatty acid analysis the ratio of poly-unsaturated fatty acids (PUFA) is more than double in the Skretting diet compared to Bluecrown and the locally made diet. The level of linolenic acid (C18:3n3) is also remarkably higher in the Skretting diet compared to the other diets. The DHA and EPA level in the commercial diets are similar but the DHA + EPA is lowest in the locally made diet. The level of saturated fat is lowest in the Skretting diet. In previous report, these C18 PUFAs are not only accumulated in tissues but can also be bio-converted into LC-PUFAs (Zheng *et al.,* 2005). The fatty acid analysis of fish flesh in this study showed that the dietary PUFA content is reflected in the fish but not the DHA, EPA or linolenic fatty acid content. The high level of linolenic acid in the Skretting diet is not preserved in the fish flesh nor transformed to DHA or EPA through elongation and desaturation processes. Previous studies have shown growing evidence that the most important limiting factor for the replacement of marine lipids with plant oils in fish feeds is related to possible effects on fillet quality and fatty acid composition rather than to fish growth performance (Ballester-Lozano *et al.,* 2011). The ingredient composition (feed formulation) for the commercial diets were not accessible in this experiment. According to the fatty acid profile of the diets there seem to be similarities of lipid sources in the Bluecrown and local-made diets, but the Skretting diet presumably contain lipids of different origin. Although the ratio of the important fatty acids DHA and EPA is lowest in the local made diet, the ratio is highest in the fish fed this diet. This fluctuation may be due to extreme storage temperature (- 80 °C) of the fish samples before the analysis. The study of Sahari *et al.,* (2014) in the effect of frozen storage on fatty acid composition of the different tissues of four *scombrid* and one *dussumeriid* species showed that during the frozen storage, oxidative processes cause deterioration of the fish sensory properties due to accumulation of primary and secondary products of lipid peroxidation. Storage time at -18°C had a significant impact on the storage stability of the fish. It also reported that changes observed in fatty acid constituents revealed that all fish species are susceptible to significant changes during frozen storage, especially during a long-term period of preservation. A marked reduction in the content of fatty acids such as MUFA and PUFA as well as in the EPA+DHA/C16, PUFA/SFA, and Ω3/Ω6 ratios indicated that nutritional values of the fish samples decreased.

The results of economic analysis showed that the commercial diets had comparatively higher cost kg^{-1} than the combined and local diet (figure 13). This may be due to the cost of importing

some of the ingredients used in formulation, intensive labour cost, marketing, taxation etc. These variables are contributory factors to the cheaper cost of the local diet since the local diet is formulated with available raw materials from farmers, cheaper labour cost and not imported.

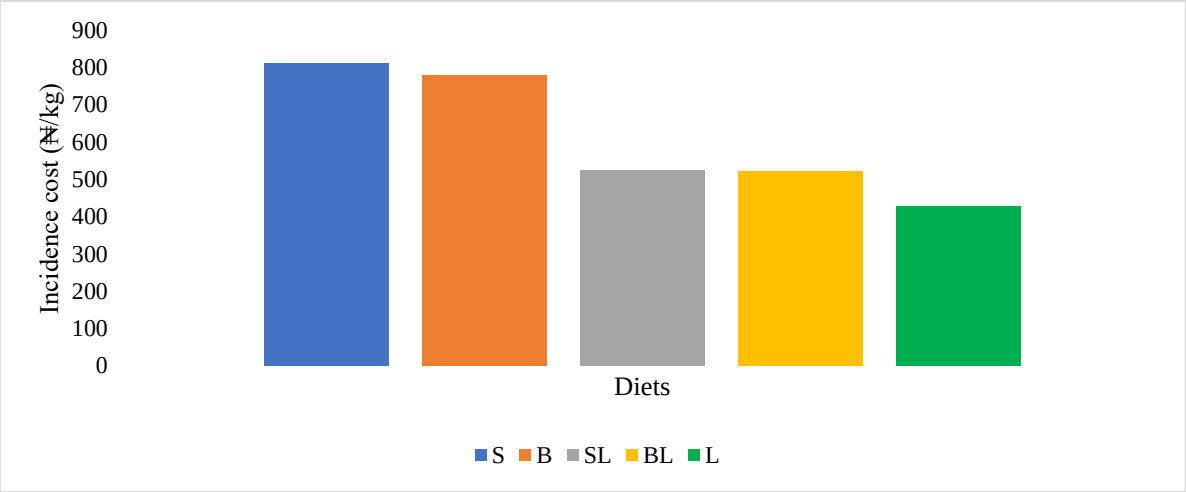

Figure 13: The incidence cost for production of *C. gariepinus* using commercial, combined and local diets during the study.

The study showed that diets S, B, SL and BL may increase cost of diet L by 47%, 43%, 11.9% and 11.6%, respectively. This present study corroborates the report in the effect of different diets on growth and cost effectiveness of African catfish, that incidence cost reflects the cost of feed used to produce a kilogram of fish (Limbu, 2015). The incidence cost was between 11.9% to 11.6% higher in the combined diets, and 47% to 43% more in the commercial diets than the local diet. Thus, the local diet may have the potential to reduce the cost of *C. gariepinus* culture than the commercial and combined diets. This implies that, based on the current results, *C. gariepinus* farmers may reduce cost of feeding up to 12% by using local diet. Accordingly, local diets when correctly formulated may increase benefits to *C. gariepinus* farmers. However, this study showed that the treatments with the combined diets were similar in IC and PI. Thus, had a better incidence cost and profit index than the commercial diets.

The total value of fish which estimated the total biomass increase by the estimated value of fish per kilogram, indicated that treatment S (34018) had the highest value followed by treatment SL (24748), B (20878), BL (16198) and L (15658) respectively. With the highest value for treatment S with a high production cost, producing same value for other treatments may increase production cost respectively. Thus, narrowing profit margin of other treatments to treatment S.

The feeding of *C. gariepinus* on diets S, B, SL, BL and L resulted in a profit index of 1.1, 1.2, 1.7, 1.7 and 2.1, respectively (Figure 14).

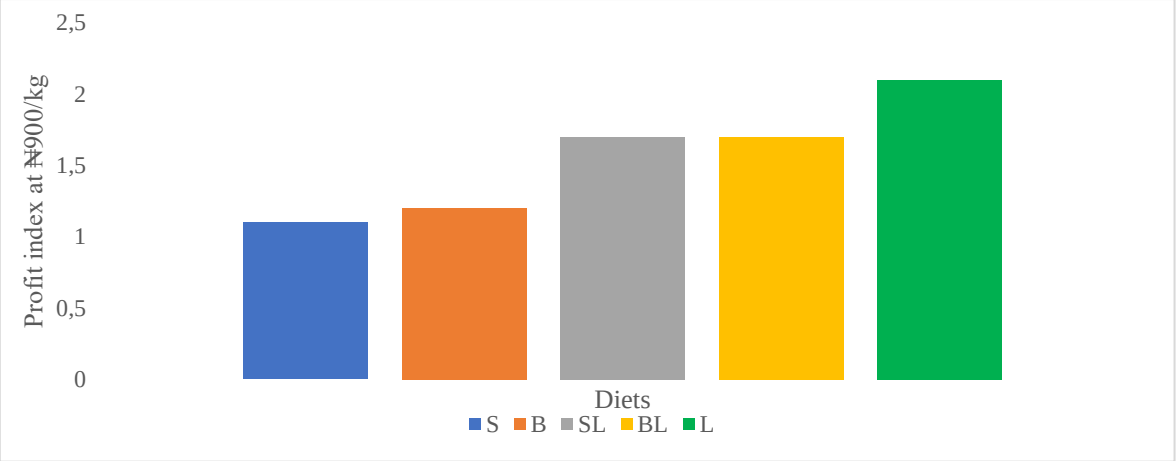

Figure 14: The profit index for production of *C. gariepinus* using commercial, combined and local diets during the study. The product value is set as ₦900/kg

The profit index for *C. gariepinus* on all the diets showed that the cost of feed affects both growth and profitability in catfish culture and is an important factor to consider. It can be deduced that the use of commercial feed only for fish production is less profitable due to the high cost of the feed. Also, this cost of commercial diets, influenced the profit index of the combined treatments SL and BL respectively. Though, diet S posed a well nutritional diet which generated more fish biomass and reflected in the combined diet SL. The high cost of the feed (S) was not of advantage to its profit index. A well nutritional formulated local diet may be more profitable and economically viable in the culture of *C. gariepinus* than the combined diets. Furthermore, the economic conversion ratio, which relates the cost of diet and FCR (table 8), was higher in treatment S compared to treatment B, BL, SL and L in the order. Even though the FCR of the treatment S (1.35) was lower than B (1.97), SL (1.97), BL (2.65) and L (2.81) respectively, using diets S and B entirely in catfish production may not be economically reasonable. The combined diet SL seems to be promising compared to the combined diet BL.

6 CONCLUSION

The current price on commercial diets for catfish production limits the development of catfish farming. The combined diets may also be adopted in the culture of African catfish to reduce feed cost compared to the commercial diets. Economically, there is a need to encourage feed manufacturers and catfish farmers to continue to improve the formulation of local diet that are mostly produced on farms because of cheaper raw materials, no importation cost and reduced processing cost. This will facilitate a more developed, sustainable and productive aquaculture sector. This study showed that the local diet may have a potential for catfish culture at reduced cost. The study indicates more room for improvement in the development of local feed formulation to the recommended nutritional needs of the African catfish.

7 RECOMMENDATION

Under the present conditions, fisheries stakeholders should equip fish farmers in Nigeria with the knowledge to formulate quality fish feed with available, less expensive local ingredients for better growth and more profit. Research into other animal-based protein like insect meal should be encouraged to alleviate dependency on fish meal.

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