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Evaluation of carcass composition, serum biochemical indices and intestinal histology in *clarias gariepinus* fed sesame seed meal as replacer for soybean meal

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Abstract
The study examined the whole body composition, biochemical parameters and intestinal histology of *C. gariepinus* fed Sesame seed meal (SSM). One hundred and fifty healthy *C. gariepinus* juveniles of mean weight 34.35 ± 3.05g were used in the study. Proximate analyses of the experimental diets and whole body composition of the fish was conducted using the standard method. Selected biochemical parameters of the experimental fish was also analyses using a commercial kit, VetTest Biochemical Analyzer (Idexx Lab., USA). The intestine of the fish were removed, fixed, stained, sectioned and viewed using standard procedure. The result of proximate composition of the experimental diets revealed that protein decrease from 53.52 to 50.06% while lipid content increase from 5.41 to 7.10% as the replacement of SBM with SSM increased in the diets. The whole body composition also showed the highest protein level of 18.32% and the least lipid level of 4.05% recorded in fish fed the control diet (0% SSM). The levels of protein and lipid in both the experimental diets and whole body composition of *C. gariepinus* were not significant (p>0.05). Elevated levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP), 53.49 – 59.29U/L, 65.38 – 73.26U/L and 73.67 – 77.75U/L respectively were recorded although not statistically significant (p> 0.05). Serum total protein (45.19 – 42.99mg/dL) and cholesterol (59.63 – 57.54mg/dL) decreased in fish fed increased SSM diets. Slight increase in glucose, urea, calcium and phosphorus was also observed. Slight alterations in the high of the villi and mildly eroded and infiltrated by inflammatory cells was observed in fish fed 45 and 60% SSM diets respectively The present study revealed that C. gariepinus can tolerate up to 60% replacement level of soybean without any adverse effects on the body composition, physiological disruption and cellular alteration. Hence suggest it could be nutritionally and economically viable means of developing a cost – effective feed to maximize fish growth.

Keywords: Sesame seeds, carcass composition, serum biochemistry, intestinal histology and *Clarias gariepinus*

1. Introduction
Aquaculture has been identified as the fastest growing food sector in the world especially in the last 10 – 15 years (FAO, 2020) [22]. The fish feed production industries that largely depend on the use of fishmeal find a great challenge its use as a cost-effective source of animal protein in their feed. Fishmeal which as the major protein feedstuff is in excessive demand by other feed agriculture sector leading to increase demand and price. Feed formulation is becoming increasingly expensive and difficult to obtain in many countries practicing aquaculture due to a high price and a drop in fishmeal production making the industry economically unviable (Acar and Turker 2018) [1]. According to Boserup, (2017), 68% of fishmeal production is used in aquaculture which has negatively affected the sustainable development of the sector especially in sub Saharan Africa. High cost, fluctuating quality and availability of fish meal have led to the need to identify alternative protein sources for fish feed production. Researchers have reported that plant- based protein foodstuffs can be used to replace fishmeal in the diets with a view of reducing the cost of fish feeds. Fagbenro *et al.* (2003) [21] reported that seeds from leguminous plants could serve as a good replacer of ever expensive and scare fishmeal.

Soybean products have been used to replace a significant portion of fishmeal in fish feed with nutritional, environmental and economic benefits. According to Storebakken *et al.*, (2000) [48] soybean meal (SBM) have been reported to have the capacity to replace fishmeal component without any detrimental effects on the fish due to its high nutrient content. Utilization and availability of this conventional source as protein for fish feed is limited by increasing demand for human consumption and other livestock industries thus making it unsustainable for the sustenance of aquaculture industry (Siddhuraju and Becker, 2001). This has resulted to the need to find alternative to soybean meal in the fish feed industries capable of comparing favourably with nutritional qualities of soybean meal, cheap, readily available, ecofriendly and economically sustainable. Studies have shown that plant protein sources have high potentials for supplying fish with required protein needed for their maximum productivity (Ozovehe and Nzeh, 2013) [41].

Protein plays important role in supporting fish growth and inadequate supply in a diet results in reduction or cessation of growth and loss of weight due to lack of essential amino acids needed for the functioning of vital tissues and organs in the fish (Ahmed and Maqbool, 2017) [4]. Complete replacement of animal protein sources with that of plant sources in the diets of cultured fish species have recorded little successes due to the presence of anti-nutritional factors and inadequate amino acids (Ovie and Ovie 2007) [40]. According to Lim and Dominy (1990) [36] improper balance of essentials nutrients such as amino acids, fatty acids, energy, minerals, high fibre, decrease palatability of the feed and reduction of pellet qualities, which are the observable effects of plant protein substitution. The search for alternatives to soybean is important for the sustenance of aquaculture industry and its profitability.

Sesame seed contain 41-58% oil, 18-25% protein, 13-17% carbohydrate, essential fatty acids (Linoleic and Linolenic), amino acids (methionine and lysine), suphur and calcium (Lee *et al.*, 2003) [35]. The seeds are classified as oil seeds because of the high composition of oils and is use for making soup for human consumption and reported to promote good health. According to Conney *et al.* (2001) consumption of sesame seed increase plasma gamma tocopherol which prevents cancer and heart diseases. Lipids (oils) are highly digestible sources of energy and concentrated energy and contain about 2.25 times as much as equivalent amount of carbohydrate and protein (Robison *et al*., 2001; Sotolu, 2010) [44, 47]. It can be utilized to spare protein in aquaculture feed and can minimize the use of protein which is more expensive as energy source (Solomon *et al.* 2012) [46]. Diets containing high levels of lipids affects growth negatively due to excessive fat deposition in the liver hence reducing market quality (Craig, 2009) [14]. The replacement of soybean meal with sesame seed up to 16% in the diet of Nile tilapia, *Orechromis niloticus* is reported to have no negative effects on the growth performance of the fish. Ochang *et al.* (2014) [39] recommended 25% inclusion in *Clarias gariepinus* juveniles without any negative effects on growth and haematology. However 75 – 100% replacement with sesame seed meal (SSM) have been reported to have negative effects on the weight gain of Nile tilapia. Improved growth performance and carcass crude protein deposition in *C. gariepinus* fed 25-50% sesame seed is an indication that this meal could be viable in improving the cost of fish feeding (Jimoh and Aroyehun 2010) [20]. Increased total protein and body lipid in African catfish fed Sesame seed and Bambara seed meals was as a result of higher fat content in SSM (Enyidi *et al.* 2014) [19]. Dienye and Olumuji (2014) [16] reported a significant elevation in AST, ALT and ALP in *C. gariepinus* fingerlings fed varying levels of *Moringa oleifera* leaves diets. Significantly higher levels of ALT, AST and ALP enzymes in the serum are suggestive of liver and tissue damage leading to the leakage into the circulatory system (Mousa *et al.*, 2008) [37]. Kurmar *et al.* (2011) [34] who reported a decrease in total protein and cholesterol in Rainbow trout fed diet replacing fishmeal with *Jathropha curcas* kernel. Histological changes in the intestine due to dietary intake of plant protein have been reported to reduce growth performance in fish (Wang *et al*., 2006; Heikkinen *et al*., 2006) [51, 27]. Progressive alterations in the normal architecture of the intestinal mocusa of *Clarias gariepinus* fed increased *Morinda lucida* leaves meal (Raimi *et al*., 2021) [43]. Effects on growth and histological structure of liver and intestine have also been reported in fish fed diets replacing fishmeal with soybean meal and non-animal ingredients (Boonyaratpalin *et al*., 1999; Uran *et al*., 2009; Ye *et al.*, 2011; Markovic *et al.* 2012) [12, 49, 53]. The partial replacement of soybean with sesame seed although reported to be promising, studies on oil extracted SSM on the carcass composition and some biochemical parameters still need to be investigated. Therefore this study aimed to investigating the replacement of highly competitive and costly soybean meal (SBM) with cheap and less competitive sesame seed meal (SSM) on some biochemical parameters and intestinal histology of *C. gariepinus*.

Materials and Methods

Experimental site

The study was carried out in the wet laboratory of the Department of Fisheries and Aquatic Science, Cross River University of Technology (CRUTECH), Obubra Campus.

Experimental Fish

Three hundred and fifty apparently healthy juveniles of *C. gariepinus* were procured from Farmosas family farm in Calabar, Cross River State, Nigeria. They were put in 20 litres jerry cans and transported by Car to the wet laboratory, Department of Fisheries and Aquatic Science. They were batch weighed and put in aquaria, acclimated for two weeks before the commencement of the research. During the period of acclimation the fish were fed at 5% body weight with top feed with a crude protein of 40% twice daily and discontinuous 24 hours prior to commencement of the experiment. This was done to eliminate variation in weight due to residual food in their gut, prepare the gastrointestinal tract for the experimental diets and to increase the appetite of the fish.

Collection and preparation of sesame seed meal (SSM)

The sesame seed was purchased from Adun market, Ofodua, Obubra Local Government Area of Cross River State. The sesame seed was sieved to remove dirt and sand, washed and sun dried for 3 days. The seed was ground with a hammer mill and the oil removed using a catalyst n- hexane as recommeneded by Enujiugha and Akanbi (2005) [18].

Preparation of experimental diets

The isonitrogenous diets of 51.88% crude protein were formulated using the Pearson's square method. The sesame seed meal was included to replace varying quantities of soybean in the diets Table 1. The feed ingredients were ground separately to fine powder using the hammer mill. Each ingredient was weighed into a bowl and all were mixed properly. Boiled water was then added to the mixture and stirred to obtain a consistent dough which was passed through a pelleting machine to produce a 0.5 mm pellets. Thereafter, the feed was sundried for 4 days, then stored in an airtight plastic container and kept until the time for use.

Table 1: Ingredients composition of formulated diets (% Dry weight) and proximate of experimental diets.

Ingredient (g/100g)	D1 (0%)	D2 (15%)	D3 (30%)	D4 (45%)	D5 (60%)
Blood meal (80% CP)	10	10	10	10	10
Fishmeal (64%CP)	25	25	25	25	25
Soybean meal (42%CP)	30	25.5	21	16.5	12
Sesame seed meal (28%CP)	0	4.5	9	13.5	18
Maize (11%CP)	27	27	27	27	27
Soybean oil	3	3	3	3	3
Vit/min premix	2.5	2.5	2.5	2.5	2.5
Lysine	0.3	0.3	0.3	0.3	0.3
Methionine	0.2	0.2	0.2	0.2	0.2
Binder	2	2	2	2	2
Total (%)	100	100	100	100	100

Experimental design and procedure

A completely randomized design (CRD) with five treatments in three replicates (5 x 3) was used. The 15 labelled aquaria were randomly allocated with 20 fish each on the five treatment diets (D1, D2, D3, D4 and D5) in triplicate. Feeding was carried out twice daily, 8:00 – 8:30am, and 5:00 – 5:30pm for 56 days.

Proximate analysis

Samples of the experimental diets and the whole fish (before and after the experiment) in all the treatments were analyzed for proximate composition. Moisture content was determined by oven-drying to a constant weight, crude fat and protein were determined using soxhlet extraction and micro-Kjeldahl method, respectively. Total ash and crude fiber were analyzed using muffle furnace combustion and trichloroacetic acid method, respectively. The carbohydrate was determined by 100 – (% moisture +%ash +%fat +%protein +% fiber) according to Henken *et al.* (1986) and Effiong *et al.* (2019) [17]. The nitrogen free extract (NFE %) was determined by%DM (100) - (% moisture +% CL +% CP +% ash +% CF) Where: DM = dry matter, CL = lipid, CP = crude protein CF = crude fibre according to Effiong *et al.* (2019) [17].

Biochemical Parameter.

The clotted blood was centrifuged for 15 minutes at 3500 revolutions per minute (rpm). A clear fluid which is the serum was pipetted out into clean sterilize bottle for further analysis. The stored serum was used for the analysis of some enzymes, metabolites and electrolytes using a commercial kit, VetTest Biochemical Analyzer (Idexx Lab., USA). The enzymes were alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) while metabolites determined were glucose (Gluc), protein (Prt), cholesterol (Chol), urea (Urea) and triacylglycerols (Trgly). Serum electrolytes determined were Calcium (Ca) and Phosphorus (P).

Histological procedures:

Four (4) fish each whose serum was sampled for biochemical analysis were sacrificed and the intestine removed and preserved in 10% formaldehyde for proper fixation for 4 days. The tissues were then removed from the fixative and rinsed in tap water for 5 minutes, dehydrated in ascending ethanol concentrations (70%, 80% and 90% alcohol) for 2 minutes. Thereafter the tissues were infiltrated in a wax miscible agent (xylene) for 2 minutes and then embedded in paraffin using standard protocols according to Bernet *et al.* (1999) [10]. The fish tissues were then cut into sections of 6µm thickness using a rotary microtome (Leica RM 2235 Germany). The sections were oven-dried, de-waxed, rehydrated through descending concentrations of ethanol (90%, 80% and 70% alcohol) for 2 minutes. The tissues were stained in haematoxylin solution and aqueous eosin for 3 minutes, then mounted on a slide for histopathological examination using digital binocular compound LED microscope with a digital camera (Nikon 9000) according to Bancroft and Cook (1994) [8]. Photomicrographs of the sections showing the effects of SSM diets on the cell structure of the intestine were made at x100, and x400 magnifications.

Data Analysis

The data obtained from the experiment were subjected to multivariate analysis using a statistical software SPSS version 25 to compute for the mean value of the variables proximate and biochemical parameters. The differences among the means were compared using Turkey's multiple comparison test at 5% significance level.

Results

Proximate composition of experimental diets

The result of the proximate composition of the experimental diets fed to *C. gariepinus* is presented in table 2. The moisture content (7.18 – 8.19%), crude lipid (5.41 – 7.10%) and ash (5.33 – 6.95%) were increasing while crude protein (53.52 – 50.06%), and NFE (28.56 – 27.25%) decreased as the level of SSM% in the diets increased. The highest moisture level of 8.19% was recorded in fish fed D5 while the lower value of 7.18% was obtained in fish fed the control diet (D1). Similar trend of 7.10 and 5.41% lipid was recorded for fish fed D5 and D1 diets respectively. The highest protein level of 53.52% was recorded in fish fed the control diet while the least value of 50.06% was in those fed D5 with the highest level of SSM replacement (60%). The changes in all the parameters in the various diets were not significantly different ($p > 0.05$) from that fed the control diet.

Whole body composition of *C. gariepinus* juveniles

The result of the initial and final mean values of whole body composition (%) of moisture, protein, lipid, ash and nitrogen free extract (NFE) contents is presented in Table 3. The initial values of 71.65, 16.50, 3.38, 4.84 and 3.63% were recorded for moisture, protein, lipid, ash and nitrogen free extract respectively. The initial values of protein and lipid were lower while those of total ash and NFE were higher than those of the experimental diets. The result also showed increase in moisture (71.65-72.59%) and crude lipid (3.38-6.80%) with decrease in crude protein (18.55-17.05%), ash (3.76-2.50%) and NFE (2.06-1.08%) as the level of SSM in the diets increases. The highest value of moisture content (72.59%) was recorded in fish fed 60%SSM diets although was not significant ($p > 0.05$) from the least value of 71.63% recorded for the control diet. Similar increase in the crude lipid deposition of 6.68 and 4.05% for fish fed 60 and 0% SS Mdiets respectively was significant at ($p < 0.05$). The highest level of crude protein (18.55%) was recorded in fish fed the control SSM diets and was not significant ($p > 0.05$) from the least value of 17.05% obtained from fish 60% SSM diets. The values of total ash and nitrogen free extract of fish fed the various levels of SSM diets were not significantly lower ($p > 0.05$) than those fed the control diets.

Table 2: Proximate composition of experimental diets fed to *C. gariepinus* Juveniles

Parameter (%)	Diets				
	D1	**D2**	**D3**	**D4**	**D5**
Moisture	7.18 ± 1.23^{ab}	7.23 ± 0.37^{a}	7.40 ± 1.05^{a}	7.64 ±1.16^{a}	8.19 ± 1.50^{a}
Protein	53.52 ± 1.05^{a}	52.81 ± 1.20^{a}	51.62 ± 0.55^{ab}	51.40 ±1.25^{ab}	50.06 ± 0.55^{ab}
Lipid	5.41 ±0.50^{ab}	5.82 ±0.80^{ab}	6.14 ± 0.55^{a}	6.55 ± 1.50^{a}	7.10 ± 1.05^{a}
Ash	5.33 ± 0.40^{ab}	5.76 ± 0.70^{ab}	6.04 ± 0.58^{a}	6.35 ±1.05^{a}	6.95 ± 1.50^{a}
Nitrogen Free Extract	28.56 ± 2.80^{a}	28.38 ± 1.90^{a}	28.80 ±0.80^{a}	27.56 ± 0.90^{ab}	27.25 ± 1.45^{ab}

Means with the same superscript are not significant at $p > 0.05$

Table 3: Whole body composition (%) of *C. gariepinus* before and after treatment

Parameter (%)		Diets				
	Initial	**D1**	**D2**	**D3**	**D4**	**D5**
Moisture	71.65±0.54^{ab}	71.63±0.26^{ab}	71.67±0.37^{ab}	71.82±0.05^{ab}	72.10 ±0.16^{a}	72.59 ±0.58^{a}
Protein	16.50±1.08^{ab}	18.55 ±1.58^{a}	18.32 ±1.15^{a}	18.06 ±1.22^{a}	17.55±1.45^{ab}	17.05 ±1.25^{ab}
Lipid	3.38 ±0.42^{b}	4.05 ±0.15^{ab}	4.62 ±0.28^{ab}	5.04 ±0.21^{ab}	6.15 ±0.35^{a}	6.80 ±0.05^{a}
Ash	4.84 ±0.16^{a}	3.76 ±0.22^{ab}	3.53 ±0.30^{ab}	3.28 ±0.38^{ab}	2.85 ±0.25^{b}	2.50 ±0.50^{b}
Nitrogen Free extract	3.63 ±0.85^{a}	2.06 ±0.80^{ab}	1.86 ±0.90^{b}	1.80 ±0.55^{b}	1.35 ±0.60^{b}	1.06 ± 0.45^{b}

Means with the same superscript are not significant at $p > 0.05$

Biochemical parameters

Result of selected enzymes, (AST, ALT and ALP) metabolites (TP, Glu, Cho, Trgly and Ure) and electrolytes (Ca and P) of *C. gariepinus* fed SSM diets is presented in Table 2. The result showed an increase in plasma enzymes as the level of SSM in the diets increased. Alanine aminotransferase (ALT) showed that fish fed 60% had the highest value of 73.26U/L while the control diet (0%) had the lowest (65.38U/L). Similar trend was recorded for AST and ALP in fish fed 60% and control diets respectively. The result of ANOVA shows that the mean values of all the enzymes in fish fed the various SSM diets were not significant ($p > 0.05$) from those of the control (SSM0%). Total protein (TP) and Cho decrease from 45.19 – 42.99 and 59.63 – 57.54 while Trgly, Glu and Ure increase from 64.43 – 67.02, 25.94 – 28.31 and 26.48 – 27.90 respectively as the level of SSM in the diets increases. The mean values of TP of fish fed the control diet, 45.19 was not significant (p <0.05) from those fed various SSM diets. Similar trend of non-significant changes (p<0.05) was recorded for Cholesterol, triglyceride, glucose and urea from the fish fed control diet. The mean values of Ca in fish fed the various diets were not significant from that of the control diet while the value of P of fish fed 15 and 30% SSM diets were not significantly different (p<0.05) from the control but however, different from those fed 45 and 60% SSM diets.

Table 4: Selected biochemical parameters of *C. gariepinus* fed SSM diets

Parameter	Diets				
	D1	D2	D3	D4	D5
ALT (U/L)	65.38± 0.45^{ab}	65.78 ±0.15^{ab}	67.38 ±0.16^{ab}	70.69 ± 0.69^{a}	73.26± 0.66^{a}
AST (U/L)	53.49 ± 0.50^{ab}	54.62 ±0.37^{ab}	55.3 ±1 0.33^{ab}	56.53 ± 0.25^{ab}	59.29 ± 0.29^{a}
ALP (U/L)	73.67 ±0.31^{ab}	74.82 ±0.12^{ab}	75.08 ±0.20^{ab}	76.73 ±0.46^{a}	77.95 ±0.15^{a}
TP (mg/dL)	45.19 ±0.20^{a}	44.40 ±0.20^{a}	43.77 ± 0.10^{ab}	43.30 ±0.54^{ab}	42.99 ±0.63^{ab}
CHO (mg/dL)	59.63 ± 0.39^{a}	59.63 ± 0.39^{a}	58.55 ±0.13^{a}	57.73 ± 0.08^{ab}	57.54 ±0.26^{ab}
TRIG (mg/dL)	64.43 ±0.21^{ab}	64.76 ±0.40^{ab}	65.52 ± 0.84^{ab}	67.02 ±0.48^{a}	67.02 ±0.48^{a}
GLU (mg/dl)	25.94 ±0.11^{ab}	26.14 ±0.24^{ab}	26.33 ±0.3^{ab}	26.76 ±0.35^{ab}	28.31 ±0.30^{a}
URE (mg/dL)	26.48± 0.18^{ab}	26.76 ± 0.19^{a}	27.02 ±0.07a	27.61 ±0.16^{a}	27.90 ±0.18a
Ca (mmol/dL)	16.45 ±0.42^{ab}	16.91 ±0.24^{ab}	17.07 ±0.04^{a}	18.55 ±0.64^{a}	19.04 ±0.07^{a}
P (mmol/dL)	6.81 ±0.05^{ab}	7.14 ±0.16^{ab}	7.47 ±0.37^{ab}	9.00 ±0.13^{a}	10.17 ±0.18^{a}

Means with the same superscript are not significant at $p > 0.05$

Intestinal histology

The result of the intestinal histology of *C.gariepinus* fed varying SSM diets is shown in plates 1 – 5. The photomicrograph of the fish fed control diets reveals normal structure of the mocusa with villi lined by simple columnar epithelia filled with gland (Plate 1). Slight alterations in the morphology of the villus and lamina propria was observed in fish fed 45% SSM and appeared midly eroded and infiltrated by inflammatory cells in those fed 60% SSM diets.

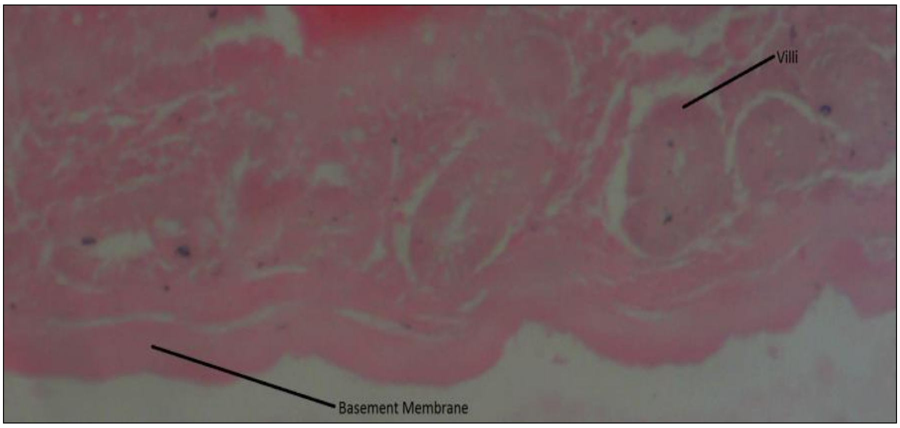

Plate 1: Photomicrograph (x 200) of intestinal section of fish fed 0% SSM diet showing normal intestinal mucosa with villi lined by simple columnar epithelia with glands. The basement membrane comprising of the submucosa and muscularis were normal without any inflammation.

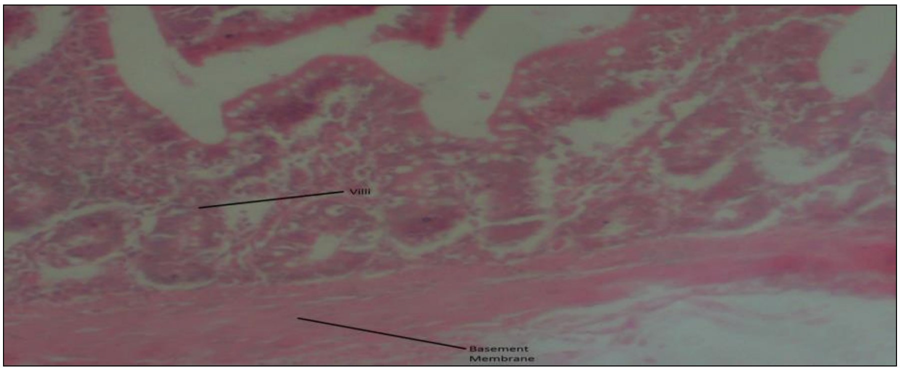

Plate 2: Photomicrograph (x 400) of intestinal section of fish fed 15% SSM diet showing normal histology with the villi lined by simple columnar epithelium. No visible effect on the submucosa and lamina propria.

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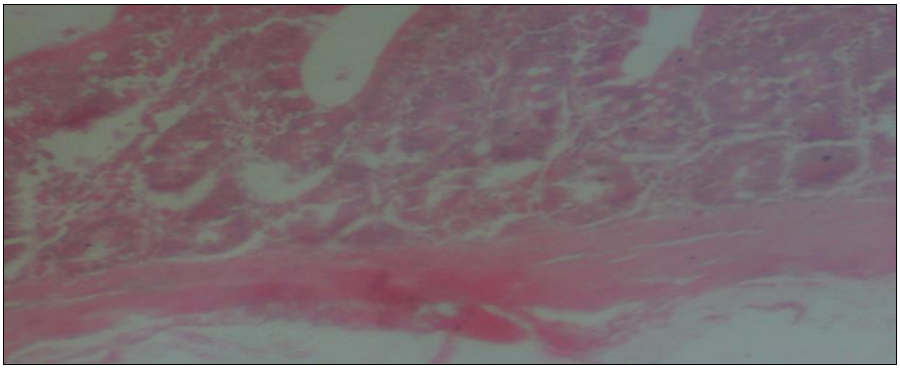

Plate 3: Photomicrograph (x 400) of intestinal section of fish fed 30% SSM diet showing fairly normal villi with mildly infiltrated inflammatory cells.

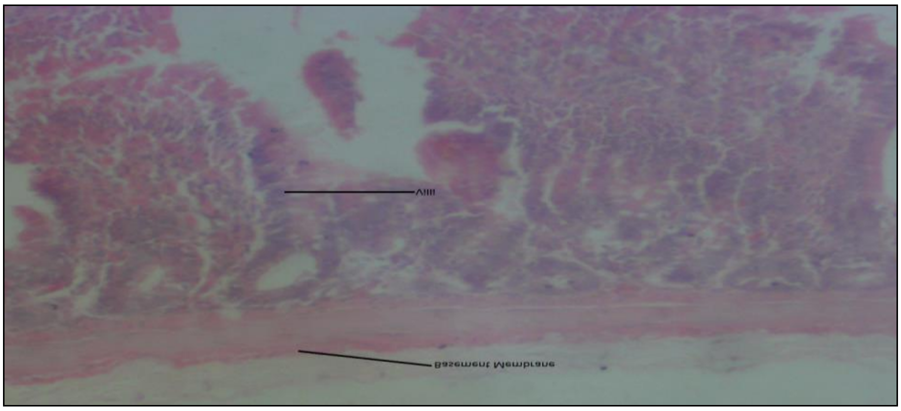

Plate 4: Photomicrograph of intestinal section of fish fed 45% SSM diet showing moderately eroded and reduction in the high of the villi. The submucosa and lamina propria showed no visible effects.

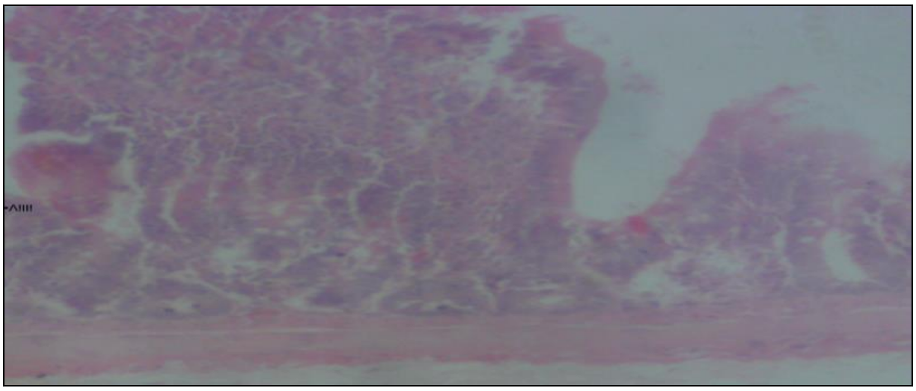

Plate 5: Photomicrograph (x 400) of intestinal section of fish fed 60% SSM diet showing reduction in the height of villi with higher number of inflammatory cells.

Proximate composition of diet and fish carcass

Nutrition indices such as moisture, crude protein, lipid, ash and nitrogen free extracts (NFE) plays a great role in diet formulation and spoilage (Ogbuebume *et al.* 2021). Knowledge of proximate analysis of diet helps in the development of cost – effective feed that provides balanced diet to maximize fish growth rate (NRC, 2011) [38]. Carcass composition measures the growth and quality of protein, lipid, ash and its utilization in fishes (Ahmed and Maqbool, 2017) [4]. According to Degani *et al*. (1989), Ali and Jauncey (2005), the optimum protein requirement for African catfish, *C. gariepinus* ranged between 40 – 45%. In this study the ranged of 50.06 – 53.52% protein was higher the optimum requirement and the 41.09 – 41.54 in Sesame seed meal by Ochang *et al.* (2014) [39] but lower than the 60 – 62% reported for Moringa oleifera leaf meal by Ozovehe and Nzeh (2013) [41] and Agwu *et al.* (2017) [3]. The variations could be attributed to the different protein levels in the ingredients use for the experimental diets. The level of protein in the experimental diets decreased with increased in the percentage replacement with SSM. The higher protein level (53.52%) in the control diet (SSM 0%) may correspond to its higher level in the soybean meal than in sesame seed meal. Similar decrease in the level of protein from the control diets fed to *C. gariepinus*, *Moringa oleifera* leaf meal (Ozovehe, 2013) [41], sunflower and sesame seed (Fagbenro *et al.* 2010) [20] and *Sesame indicum* (Yakubu *et al.* 2020) [52]. Some researchers have reported lower protein level of 30 – 40% using various sources of plant based protein ingredients as replacement for soybean (Fatouri *et al.* 1986; Alatise *et al.* 2016; Ikwuemesi *et al.* 2017) [23, 6, 29]. The increase in the lipid content from 5.41 – 7.10% in the experimental diets in this study corroborates those of Jimoh and Aroyehum (2011) [31] in Sesame seed meal based diet fed to *C. gariepinus* and Acar and Turker (2018) [1] in Peanut meal (PNM) diet fed to Rainbow trout. A decrease fromf 5.05 – 4.15% lipid content was reported for *Moringa oleifera* leaf meal fed to *C. gariepinus* (Ozovehe and Nzeh, 2013) [41]. This is because Sesame seed contains more oil than moringa oleifera leaves. The protein and lipid requirement for *C. gariepinus* was met by the quantity provided in the diets making it sustainable feedstuff required for growth of the fish. Uys and Hecht (1985) [50] reported that the best growth rate and feed conversion efficiency in juveniles and sub-adult are achieved with diets containing 38-42% crude protein and lipid content of 5-10%. The decrease in ash content in the control diets in this study was in line with those of other researchers who used plant based protein sources to replace fish meal (Fagbenro *et al.* 2010; Acar and Turker, 2018) [20, 1].

The decrease in crude protein with an increase in lipid content of whole body composition of *C. gariepinus* fed varying percentage of SSM diets corroborates the findings of Jimoh and Aroyehum (2011) [31] and Yakubu *et al.* (2020) [52]. The highest level of crude protein obtained in the carcass of fish fed the control diets may correspond to its highest level in the soybean than sesame seed. Similar decrease in the carcass crude protein and increase in lipid content from the control in *C. gariepinus* fed sunflower and sesame seed diets have been reported by Fagbenro *et al.* (2010) [20]. The elevated body lipid in African catfish fed Sesame seed and Bambara seed meals was as a result of higher fat content in SSM (Enyidi *et al.* 2014) [19]. Jimoh and Aroyehum (2011) [31] also reported a significant increase in the lipid content of *C. gariepinus* carcass fed SSM diets greater than 50% of soybean replacement. Detary lipid content have been reported to directly affect body lipid (Lee and Lee, 2005) [35]. The tissues of African catfish with high lipid deposition have been reported to contain low levels of lysine a very important amino acid (Ozorio *et al.* 2002). Lysine is one of the most essential amino acids requirement for optimal functioning enzymes, maximum growth and development in fish (Ahmed and Maqbool 2017) [4]. The whole body crude ash and nitrogen free extract did not show any significant difference among the treatment except the initial where there were higher. Similar observation was reported in *C. gariepinus* using sunflower and sesame seed diets (Fagbenro *et al.* 2010) [20], *C. gariepinus* on Chrysophyllum albidium diets (Jimoh *et al.* 2014) [32] and Cyprinus carpio fed various dietary protein level (Ahmed and Maqbool 2017) [4]. The non – significant changes in the whole body protein and fat suggest that replacement of SBM with 60%SSM in the diet of *C. gariepinus* could be nutritionally and economically viable means of developing a cost –effective feed to maximize fish growth.

Biochemical parameters

Biochemical parameters have frequently been use as indicators of nutritional, stress condition and health status in fish (Wagner and Congleton 2004; Fazio, 2018; Jimoh *et al.*, 2020) [24]. According to Patti and Kulkarni (1993), serum enzymes are used to diagnose tissues and liver damaged. Elavated levels of ALT, AST and ALP was recorded as the levels of SSM increased in the diets although not significant ($p > 0.05$) in this study. This contradicts the findings of Dienye and Olumuji (2014) [16] who reported a significant elevation in AST, ALT and ALP in *C. gariepinus* fingerlings fed varying levels of *Moringa oleifera* leaves diets. Adesina (2017) [2] had also reported a significant increase in the levels of these enzymes in *C. gariepinus* juveniles fed graded levels of sunflower seed meal diets. These findings however contradicts that of Okey *et al.* (2020) who reported a decrease in ALP and ALT in *C. gariepinus* juveniles treated with clove powder anaesthestics. Alanine amino transferase (ALT) mobilizes L- amino acid for gluconeogenesis and functions as a link between carbohydrate and protein metabolism under altered physiological, pathological and induce environmental condition (Sastry and Subhadra, 1985). According to Mousa *et al.* 2008) [37] significantly higher levels of ALT, AST and ALP enzymes in the serum are suggestive of liver and tissue damage leading to the leakage into the circulatory system. The non – significant changes is this study is an indication that there was no adverse effect on the liver and other tissues.

Serum protein, cholesterol and triglyceride are among the main energy sources and play essential role in maintaining the blood glucose level (Shwetha *et al.* 2012) [45]. In this study the observed decrease in serum protein and cholesterol was in agreement with the finding of Kurmar *et al.* (2011) [34] who reported a non – significant decrease in total protein and cholesterol in Rainbow trout fed diet replacing fishmeal with *Jathropha curcas* kernel. However a significant decrease in serum total protein and cholesterol have been recorded in *C. gariepinus* fed dried *Moringa oleifera* leaves (Bamidele *et al.* 2015) [7] and *Luffa cylindrical* seed meal (Jimoh *et al.*, 2020). Significant decrease in protein reported in fish is attributed to the disturbances in protein synthesis within the liver and also a physiological strategy to adapt to alterations in their metabolic systems (Das and Mukharjee, 2000; Jee *et al.*, 2005; Adesina, 2017) [30, 15, 2]. The decrease in cholesterol was inline the findings of many researchers who fed fish with plant based protein sources (Acar and Turker 2018; Jimoh *et al.* 2020) [1]. According to Kurmar *et al.* (2011) [34] the cholesterol lowering effects of plant protein sources is because they inhibit the absorption of cholesterol from the intestine by increasing the excretion of bile salt from the body. The serum triglycerides, GLU, URE, Ca and P all increased with the replacement of SSM in the di*et al*.though not significant ($p>0.05$). Similar increase in these parameters have been reported in fishes fed various plant based protein diets (Hosseni and Khajopour, 2011; Adesina 2017; Acar and Turker 2008) [1, 2]. Increase in the mean values of triglyceride in this study compliments the increase in crude lipid in the diets and whole body composition. Previous studies have reported increase in triglyceride, glucose and urea on Tilapia (Akinleye, 2012) [5], Rainbow trout (Kurmar *et al.* 2011) [34], *C. gariepinus* (Jimoh *et al.* 2020). Jahanbakshi *et al.* (2013) reported significant increase in glucose in sturgeon fish, *Huso huso* fed diets of fishmeal substituted with Sesame oil cake and corn meal. Rapid increase in serum glucose is an indicative of acute stress (Barton, 2002) [9] and L – amino acid mobilized to produce glucose under stress condition. The non –significant changes in glucose recorded in this study showed the fish were not stress and L – amino acid was not mobilized since the fish was not in any adverse condition.

Intestinal histology

Intestine and liver are organs important in digestion and absorption of food nutrients. In this study there was no marked effects in the mucosa, submucosa and muscular layers especially in fish fed diets of below 60% SSM. They were moderately eroded villi and mildly infiltrated inflammatory goblet cells in fish fed 60% SSM diets. Raimi *et al.* (2021) [43] reported a moderate alterations in the intestinal architecture of *C. gariepinus* fed 50% *Morinda lucida* leaf meal but with severe proliferation, degeneration and necrosis of the villi, serosa, mucosa and submucosa in fish fed 75 – 100% *M. lucida* diets. The replacement of soybean meal with fishmeal is reported to increase the intensity of enteritis in Atlantic salmon, *Salmo solar* (Krogdahl *et al.* 2003; Uran *et al.* 2009) [33, 49]. Some researchers have reported widening of the basement membrane and mucosal folding, increase infiltration of inflammatory cells in the lamina propria in fish fed higher levels of plant based protein (Refstie *et al.* 2000; Hlophe and Moyo, 2014) [28]. However, Estruch *et al.* (2015) reported no severe alterations in gut histology of gilthead seabream, *Sparus aurata* L fed with high plant protein based diets. Since there was no recognizable effects observed in the intestinal structure in this study, is implies that SSM can replace soybean up to 60%.

Conclusion

The proximate composition of the diets and fish did not show any significant changes ($p> 0.05$) from the control. Elevated level of serum AST, ALT and ALP were also not significant from those fed the control diets. Serum total protein and cholesterol level decrease as the SSM% in the diet increased. The slight alterations in the normal structure of the intestinal mucosa progresses with the increased in the level of SSM in the diets. The non – significant changes in the whole body protein, fat, biochemical parameters and with no any severe negative effects on the intestinal mucosa investigated in this study suggest that replacement of SBM with 60%SSM in the diet of *C. gariepinus* could be nutritionally and economically viable means of developing a cost – effective feed to maximize fish growth. This also provides information on the nutritional qualities of Sesame seed as feedstuff for replacing highly competitive and expensive soybean meal in the diet of *C. gariepinus*

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