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POTENTIAL OF CATTLE HAIR MEAL BASED DIET AS FISHMEAL REPLACER ON PHYSIOLOGY OF *Clarias gariepinus* JUVENILES

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ABSTRACT

The Cattle hair meal (CHM) has the potential of usage as a dietary protein source in fish nutrition due to the qualitative nutrients present in it and the enormous quantity generated at abattoirs worldwide. This study investigated the inclusion of CHM in diet of *Clarias gariepinus* as fishmeal replacement. Catfish juveniles with average weight of 5.86±0.14g were stocked in 15 plastic tanks at 21fish/tank in completely randomized design. The experimental fish were fed with 40% crude protein diet at 0%, 25%, 50%, 75% and 100% inclusion of CHM at 3% body weight for duration of 8 weeks. Growth performance, carcass quality, haematology, digestive enzymes, gut morphology and histology of *C. gariepinus* were assessed. Growth parameters differed significantly ($P<0.05$) among treatments with similar responses in carcass composition. The blood parameters, digestive enzymes and intestinal morphology also showed variations among treatments. Histological observation revealed that only diet with 25% CHM inclusion showed no alteration in tissues of kidney, liver and intestine. This study recommends usage of CHM up to 25% as replacement for fishmeal in *C. gariepinus* diet.

Keywords: Cattle, fishmeal, hair meal, digestive enzymes, gut morphology.

INTRODUCTION

Slaughtered cattle in Nigeria have been on the increase to over 3 million heads in 2016 (Sule, 2022) and inedible animal by-products are generated from the slaughter in the form of hair, wool, horn and hooves. Onifade *et al.* (1998) advocated for the use of keratin as nutrient rich feedstuff for livestock with the aid of biotechnology. This has opened new vista for research into keratin. Zoccola *et al.* (2009) noted that wool generated from butchery waste, can be used in extracting keratin rich products (Zoccola *et al.*, 2012) which can be used in improving

nitrogen content in soil (Zoccola *et al.,* 2015) These materials have been categorized as low risk when treated and used in different forms after valorization (DEFRA/APHA, 2014). Animal hair falls within the category 3 material of European Commission for inedible product (Kornilłowicz-Kowalska and Bohacz, 2011) and can be degraded (Tarun *et al.,* 2018) for use in different industries. Gohl (1981); Coward-Kelly *et al.* (2006) and Gau *et al.* (2021) reported the nutritional content of hair meal to be high while it is deficient in some amino acids. Investigation into the use of hair keratin has been documented (Eslahi *et al.,* 2013). Fermentation of wool by keratinase enzyme yielded valuable product for industries (Fang *et al.,* 2013), while alkaline hydrolysis of wool to improve soil nutrient was justified by Gousterova (2003). The ability by aquaculture species to digest keratin-based feed has been documented Chen *et al.,* (2022). Keratin from abattoir is been considered in recent times due to the high nutritional content of the product (Falaye and Sule 2020a; Sule *et al.,* 2020a; 2020b; Said *et al.,* 2022). The amount of non-conventional waste generated at the abattoir which needs valorization necessitated this baseline research in the use of cattle hair meal. The effect of cattle hair meal diet as fishmeal replacer was studied on *Clarias gariepinus* juveniles.

MATERIALS AND METHODS

Experimental Location

The experiment was conducted at Fish Nutrition Laboratory, Department of Forestry, Wildlife and Fisheries, Faculty of Agricultural Production and Renewable Resources, College of Agricultural Sciences, Olabisi Onabanjo University, Nigeria. *C. gariepinus* juveniles with average weight of 5.86±0.14g were stocked in rectangular plastic tank of 54 litres (0.6m X 0.3m X 0.3m) at 21/fish/tank in a completely randomized experimental design. The experimental water was changed every two days and the experiment lasted for 8 weeks.

Processing of Samples

Samples of cattle hair were collected from the Slaughter house. Sand sediments were washed off and 10% sodium carbonate was added for 72hours (AFRIS/Feedipedia, 2012). The cattle hair was autoclaved at 125^0C in an autoclave (YX-280A) at 100 psi, oven dried at 50^oC (Sule *et al.,* 2020a) and blended into meal. The cattle hair meal was mixed with other feed ingredients to compound the experimental feed. Fish diet was formulated to contain 40% crude protein (Table 1) at five inclusion levels of 0 % (CHM), 25 % (CHM), 50 % (CHM), 75 % (CHM), 100 % (CHM) and fed at 3% body weight for 56 days. The feed and fish were analyzed for nutritive value (AOAC, 2005).

Table 1: Composition of cattle hair diets fed to *Clarias gariepinus* juveniles

Ingredients	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
Fishmeal	26.71	21.88	16.96	12.09	0
Cattle hair meal	0	4.88	9.75	14.62	26.71
Groundnut Cake Meal	26.71	26.71	26.71	26.71	26.71
Soybean Meal	26.71	26.71	26.71	26.71	26.71
Maize	17.01	17.01	17.01	17.01	17.01
Bone	1.5	1.5	1.5	1.5	1.5
Premix	0.5	0.5	0.5	0.5	0.5
Oyster Shell	2	2	2	2	2
Salt	0.25	0.25	0.25	0.25	0.25

Growth Indices of the Experimental Fish

Specific Growth Rate (SGR) (%/day) = $\frac{\text{Ln } W_2 - \text{Ln } W_1}{T_2 - T_1} \times 100$

Ln = natural logarithm.

W_1 = Initial weight (g) of fish at time T_1(beginning of the experiment)

W_2 = final weight (g) of fish at time T_2 (end of the experiment)

T = time in days

Mean Weight Gain = $W_2 - W_1$

Food Conversion Ratio = $\frac{\text{Feed intake (g)}}{\text{weight gain (g)}}$

Feed efficiency Ratio = $\frac{\text{body weight gain (g)}}{\text{weight of feed fed (g)}} \times 100$

Protein Intake of Feed = feed intake x % protein in the diet

Protein Efficiency Ratio = $\frac{\text{Mean weight gain of fish (g)}}{\text{Protein intake}}$

Survival Rate (%) = $\frac{\text{initial no. of fish stocked} - \text{mortality}}{\text{initial no. of fish stocked}} \times 100$

Percentage Weight Gain = $\frac{\text{Mean weight gain}}{\text{Initial weight}} \times 100$

Haematology Assay

Samples for haematological examination were obtained by collecting blood from fish (n=3 per treatment) deprived of feed for 24hs using syringe and needle. The needle was introduced on the ventral midline between the anal opening and the beginning of the anal fin to access the cardinal vein beneath the vertebral column. The blood samples collected were preserved in an EDTA bottle before being taken to the laboratory for further examination. The procedures were determined using standard methods of Ajani (2009) and Oluwaniyi *et al.* (2001).

Intestinal Morphology

Three numbers of *C. gariepinus* were randomly selected from each treatment and disserted for intestinal histo-morphometry. Tissue samples for morphological measurement were rinsed in physiological

saline. Morphological analysis was performed on formalin-fixed intestinal samples. The samples were embedded in paraffin, sectioned and stained with hematoxylin and eosin. The sections were visualized using a light microscope. Villus height and crypts depth were measured and analyzed using Image-ProPlus 7.0 software, and 5 well-oriented villi and crypts from each sample were selected for measuring villus height and crypt depth.

Histological Assay

Samples for histological examination were taken from fish (n = 3 per treatment). Fish were dissected and samples of liver, kidney and intestines taken and preserved in Bouin's fluid. For microscopy examination, samples were dehydrated in graded ethanol prior to embedding in paraffin wax. From each wax block, multiple sections (5µm thick) were cut with a microtome and then mounted on glass slides. Multiple sets of sections were stained with haematoxylin and eosin. Tissue structures of the samples were examined under light microscope and images captured with a digital camera. For the intestines, the images were further analyzed to assess intestinal villi height, villi width and muscle thickness (Adesina *et al.,* 2016)

Statistical Analysis

Completely Randomized Design was used while data collected were subjected to one-way ANOVA statistical analysis using SPSS 20.0. Determination of significant difference among individual means was determined at P = 0.05 means compared by Duncan's multiple range tests

RESULTS

The results in Table 2 showed no significant differences in the protein content of compounded diets. The composition of other nutrients in cattle hair meal diet are also presented.

Table 2: Nutritional composition of cattle hair feed

Parameters	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
Crude protein	39.77	39.61	39.71	39.87	39.89
Fat	4.99	4.82	4.12	3.21	3.47
Crude fibre	4.12	5.06	5.02	6.17	5.06
Ash	8.43	9.59	9.66	10.12	9.56
Moisture content	10.63	9.75	9.23	9.56	9.63

Table 3 showed variations in the growth performances of *C. gariepinus* among dietary treatments. The parameters of the growth performances all revealed a decreasing trend with increased inclusion of CHM in diet. The FCR was least in control diet and highest in T5.

Table 3: Growth performance of *C. gariepinus* fed cattle hair meal-based diets

Indices	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
IWT	137.33±2.73^{a}	128.00±3.51^{ab}	124.00±2.51^{bc}	113.67±6.33^{c}	113.33±3.84^{c}
FWT	524.67±17.03^{a}	365.67±54.19^{b}	308.33±57.74^{bc}	217.67±22.84^{cd}	164.67±21.22^{d}
WG	387.33±19.13^{a}	237.67±51.29^{b}	184.33±60.15^{bc}	104.00±19.00^{cd}	51.33±23.79^{d}
MWG	19.74±1.24^{a}	13.25±2.27^{b}	9.30±2.55^{bc}	5.57±0.55^{cd}	2.64±1.27^{d}
TF	442.52±9.02^{a}	368.68±17.25^{b}	320.62±9.76^{c}	292.98±19.39^{c}	225.77±4.12^{d}
SGR	2.68±0.01^{a}	2.52±0.06^{ab}	2.44±0.09^{bc}	2.29±0.05^{cd}	2.17±0.05^{d}
FCR	0.85±0.04^{a}	1.04±0.10^{ab}	1.12±0.20^{ab}	1.37±0.11^{b}	1.42±0.18^{b}
PI	1.77±0.04^{a}	1.48±0.07^{b}	1.28±0.04^{c}	1.17±0.08^{c}	0.90±0.02^{d}
PER	11.19±0.94^{a}	8.88±1.09^{ab}	7.18±1.89^{ab}	4.75±0.39^{bc}	2.96±1.45^{c}
PWG	282.72±19.07^{a}	184.13±36.03^{b}	150.63±50.82^{bc}	91.09±15.69^{d}	46.39±22.26^{e}
SR	93.65±3.18^{a}	84.13±4.19^{a}	90.48±7.27^{a}	87.30±8.39^{a}	93.65±3.18^{a}

^{abcd} means on the same row with different superscript are significantly different ($p<0.05$) IWT; initial weight, FWT; final weight, WG; wight gain; MWG; mean weight gain, TF; total feed, SGR: specific growth rate, FCR: feed conversion ratio, PI: protein intake, PER: protein efficiency ratio, PWG: percentage weight gain, SR; survival rate.

The bi-weekly growth rate in Figure 1 revealed the superiority of control diet over other dietary treatments with declined growth rate from T2, T3, T4 and T5 respectively. The visual presentation showed that at higher inclusion of CHM fish weight declined.

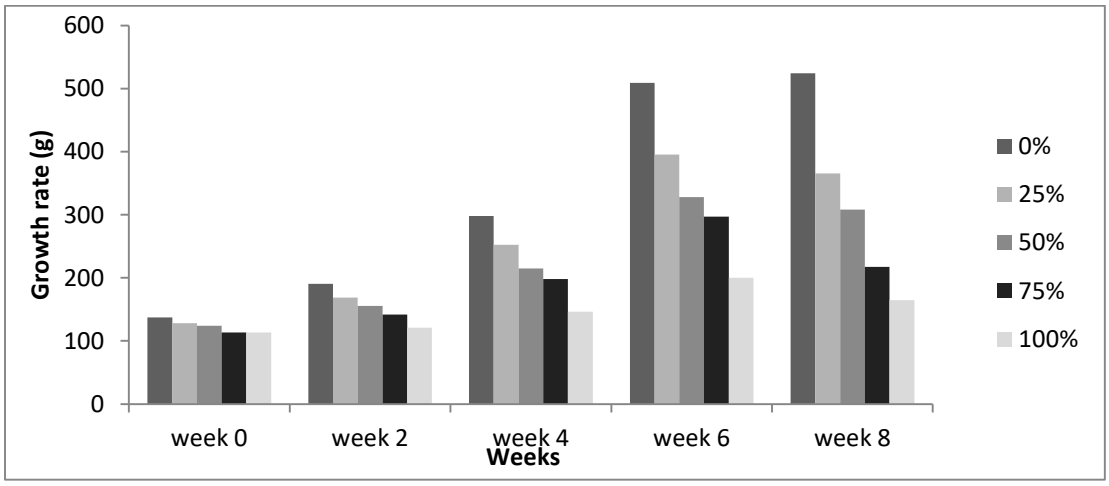


Figure 1: Bi-weekly growth rate of *C. gariepinus* juveniles fed cattle hair meal-based diets

The initial carcass quality of the experimental fish (Table 4) was improved by the control diet and dietary treatments. This showed that up to 75% inclusion of CHM protein in fish is improved while total replacement of fishmeal increased the ash content and also reduced the fat content of fish.

Table 4: Carcass composition of *C. gariepinus* juveniles fed cattle hair meal-based diets

Indices	Initial fish	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
Protein	40.80±1.63^{a}	71.03±1.52^{a}	70.15±1.72^{bc}	62.08±0.53^{c}	60.57±0.74^{c}	59.15±0.40^{c}
Fat	6.38±0.33^{a}	8.58±0.90^{b}	9.27±0.47^{bc}	6.36±0.64^{cd}	5.26±0.72^{d}	5.20±1.52^{d}
Ash	5.31±0.03^{a}	8.67±0.09^{b}	6.28±0.58^{bc}	10.12±0.36^{cd}	10.09±1.09^{d}	10.19±1.19^{d}
Moisture	8.63±1.54^{a}	8.75±1.17^{b}	9.28±1.13^{bc}	8.19±1.65^{cd}	10.62±2.71^{d}	10.53±1.87^{d}

^{abc} means on the same row with different superscript are significantly different ($p<0.05$)

In Table 5 the haematological parameters of PCV, HB, RBC, WBC and LYM in T4 showed significant difference when compared to other treatments in the experiment. While MCV and MCH of T2 and T1 are significantly compared with slight variation.

Table 5: Haematological parameters of *C. gariepinus* juveniles fed cattle hair meal-based diets

Indices	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
PCV %	20.00±0.62^{f}	22.00±1.02^{c}	29.00±0.00^{a}	30.00±1.61^{a}	26.00±0.85^{b}
HB g/dL	6.50±0.19^{c}	7.00±0.04^{c}	8.90±0.33^{a}	9.70±1.12^{a}	8.40±0.00^{b}
RBC x10µL	1.54±0.12^{b}	1.66±0.50^{b}	2.76±0.34^{a}	2.83±0.41^{a}	2.61±0.22^{a}
WBC μL^{-1}	11300±260.0^{d}	10500±600.13^{e}	13250±750.28^{c}	13850±860.45^{a}	13600±800.5^{b}
MCV fl	12.99±3.91^{a}	13.25±2.44^{a}	10.51±7.42^{b}	10.60±6.88^{b}	9.96±7.55^{b}
MCH pg	4.22±0.11^{a}	4.22±0.14^{a}	3.23±0.05^{c}	3.43±0.03^{b}	3.22±0.21^{c}
MCHC %	0.33±0.03^{a}	0.32±0.61^{b}	0.31±0.51^{c}	0.32±0.48^{b}	0.32±0.44^{b}
LYM %	50.00±0.23^{d}	53.00±0.65^{c}	58.00±1.33^{b}	66.00±3.22^{a}	54.00±2.11^{c}
HET %	43.00±0.00^{a}	40.00±0.22^{b}	37.00±0.41^{d}	28.00±0.34^{e}	39.00±0.74^{c}
MON %	5.00±0.00^{a}	2.00±0.00^{d}	2.00±0.00^{d}	3.00±0.00^{c}	4.00±0.00^{b}
EOS %	2.00±0.00^{c}	4.00±0.00^{a}	4.00±0.00^{a}	3.00±0.00^{b}	3.00±0.00^{b}
BAS %	0.00±0.00	1.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

^{abc} means on the same row with different superscript are significantly different ($p<0.05$). PCV: packed cell volume, HB: haemoglobin, RBC: red blood cells, WBC: white blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular volume, MCHC: mean corpuscular haemoglobin concentration, LYM: lymphocytes, HET: heterophil, MON: monocytes, EOS: eosinophil, BAS: basophil.

Treatment T2 in Table 6 differed significantly in most of the biochemical analytes while control treatment showed least readings in total protein, albumin, creatinine, BUN and AST respectively.

Table 6: Biochemical blood parameters of *C. gariepinus* juveniles fed cattle hair meal-based diets

Indices	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
Total Protein (g/dL)	4.00±0.71^{d}	5.70±0.35^{a}	5.20±0.56^{b}	4.80±0.17^{c}	4.50±0.33^{c}
Albumin (g/dL)	0.50±0.10^{e}	1.20±0.32^{a}	1.10±0.24^{b}	0.90±0.51^{c}	0.80±0.19^{d}
Cholesterol (g/dL)	167.00±22.0^{c}	170.00±15.9^{a}	167.00±10.5^{c}	168.00±25.8^{b}	167.00±12.65^{c}
Triglyceride(g/dL)	45.00±1.25^{d}	62.00±0.98^{a}	50.00±1.51^{b}	45.00±1.01^{d}	47.00±0.77^{c}
Glucose (mg/dL)	297.00±9.88^{c}	302.00±15.61^{a}	300.00±17.44^{b}	297.00±10.85^{c}	297.00±7.66^{c}
Creatinine (m.mol/L)	0.50±0.11^{e}	0.60±0.42^{b}	0.63±0.26^{a}	0.51±0.40^{d}	0.53±0.05^{c}
BUN (mg/dL)	5.30±0.23^{e}	6.40±0.53^{a}	6.00±0.09^{b}	5.50±0.62^{d}	5.60±0.41^{c}
AST (iu/L)	54.30±0.51^{d}	62.20±0.37^{a}	56.90±0.66^{c}	60.00±0.72^{b}	59.50±0.88^{c}
ALT (iu/L)	15.00±1.25^{b}	16.00±0.89^{a}	15.00±0.49^{b}	15.00±1.12^{b}	16.00±1.01^{a}
ALP (iu/L)	177.20±41.02^{b}	184.00±22.12^{a}	170.00±15.02^{d}	175.50±20.22^{c}	170.20±10.52^{d}

^{abc} means on the same row with different superscript are significantly different ($p<0.05$)
BUN: blood urea nitrogen, AST: aspartate transaminase, ALT: alanine transaminase, ALP: alkaline phosphate.

There was mixed variation in the indices of intestinal morphology of catfish fed CHM (Table 7) which did not follow a defined pattern. The fish responded to treatment diets differently resulting in the variations.

Table 7: Intestinal morphology of *C. gariepinus* juveniles fed cattle hair meal-based diets

Indices	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
Villi height	1583.16±27.45^{a}	1174.45±31.82^{b}	1021.56±34.82^{c}	1215.65±51.50^{b}	1107.25±53.16^{bc}
Villi width	189.18±15.34^{b}	217.30±43.19^{a}	126.00±3.05^{c}	173.44±8.82^{b}	165.39±2.88^{b}
CD	338.55±7.16^{a}	184.70±13.43^{c}	263.28±8.69^{b}	252.43±23.00^{b}	352.79±11.97^{a}
CW	205.62±6.34^{a}	188.72±23.89^{b}	122.33±2.65^{c}	149.77±6.12^{bc}	177.00±8.80^{b}
MT	194.03±7.07^{b}	233.29±26.05^{ab}	193.35±12.02^{b}	271.78±16.64^{a}	273.18±6.61^{a}

^{abc} means on the same row with different superscript are significantly different ($p<0.05$) CD: cryptal depth, CW: cryptal width, MT: muscle thickness.

In Table 8 amylase, sucrase and lipase digestive enzymes were predominantly significant in T5 which did not translate to improve growth from digestion process. The maltase and pepsin enzyme acted on fish digestive systems in T1, while in T2 chymotrypsin could be responsible for the improved growth noticed in the treatment.

Table 8: Digestive enzymes of *C. gariepinus* juveniles fed cattle hair meal-based diets

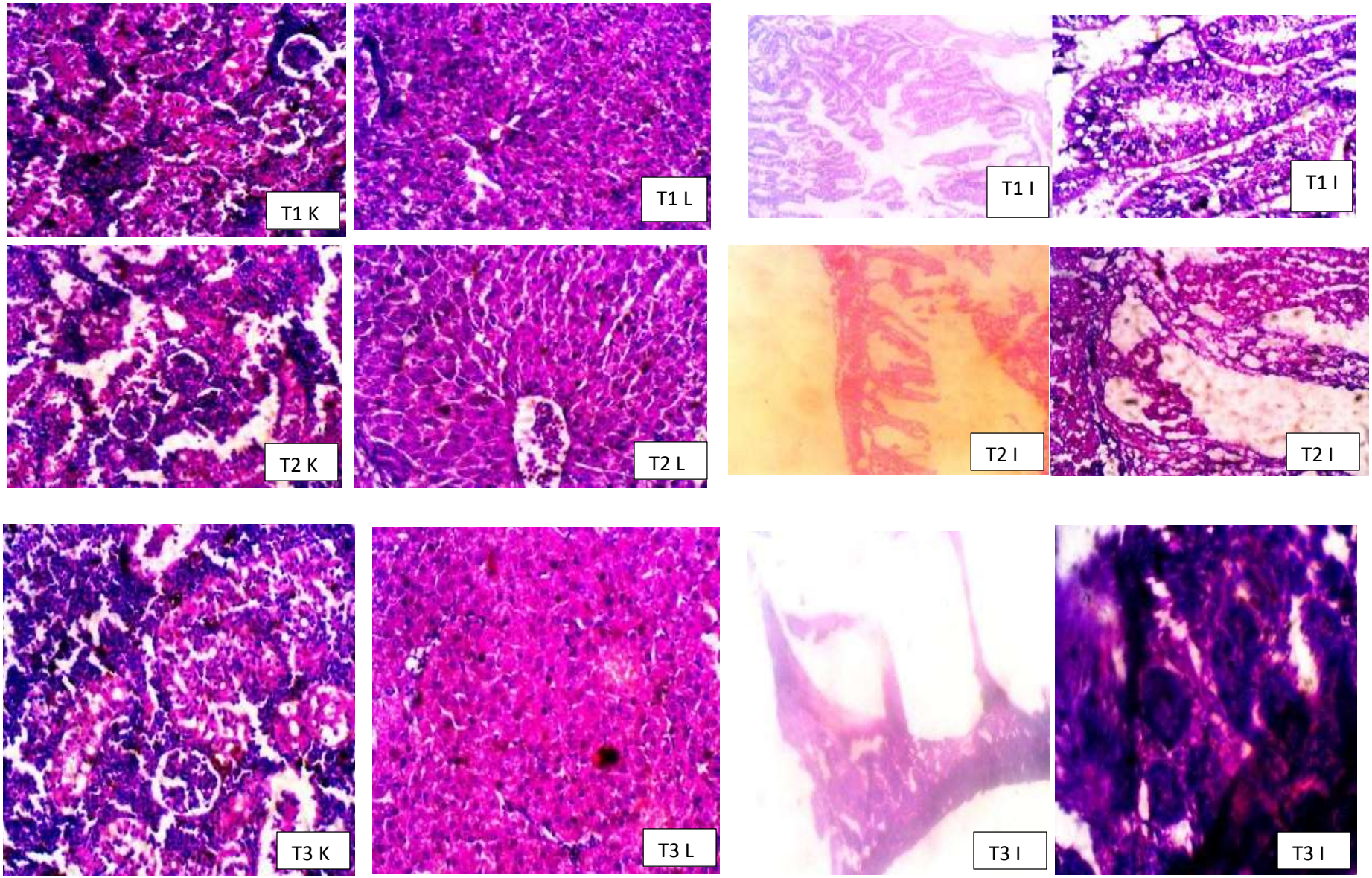
Parameters	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)
Amylase	3.11±0.11^{c}	3.02±0.47^{c}	5.01±0.66^{b}	4.12±0.06^{bc}	8.73±50.15^{a}
Sucrase	1.40±0.15^{b}	1.51±0.29^{b}	1.63±0.12^{b}	0.52±0.28^{c}	2.59±0.03^{a}
Maltase	0.75±0.08^{a}	0.47±0.19^{c}	0.40±0.82^{c}	0.44±0.12^{c}	0.65±0.06^{b}
Chymotrypsin	1.40±0.40^{b}	7.07±1.13^{a}	1.17±0.97^{b}	0.17±0.11^{c}	0.33±0.28^{c}
Pepsin	1.81±0.17^{a}	0.61±0.07^{d}	1.06±0.27^{c}	1.74±0.93^{b}	0.59±0.09^{d}
Lipase	39.49±0.45^{b}	47.98±2.55^{a}	24.55±1.31^{c}	38.07±2.84^{b}	47.19±0.96^{a}

^{abc} means on the same row with different superscript are significantly different ($p<0.05$).

The response of the intestinal organs to CHM in Table 9 showed that the kidney in T2 and T5 and liver, intestine in T2 were not affected by the inclusion levels. However, histological alterations were noticed above 25% inclusion levels of CHM. Further illustration of the histomorphological alterations are presented in Figure 2.

Table 9: Organ histology of *C. gariepinus* juveniles fed cattle hair diets

Treatments	Kidney	Liver	Intestine
T1 (0%)	No observable lesions	No observable lesions	Goblet cell hyperplasia
T2 (25%)	No observable lesions	No observable lesions	No observable lesions
T3 (50%)	Tubular epithelial degeneration	Random hepatocellular coagulation necrosis	Atrophy of villi and moderate hyperplasia of crypts
T4 (75%)	Patchy tubular epithelial degeneration	Centrilobullar atrophy and degeneration	Atrophy of villi and sloughing of enterocytes
T5 (100%)	No observable lesions	Severe diffuse hepatocellular degeneration	Severe atrophy of villi


T1 K
T1 L
T1 I
T1 I
T2 K
T2 L
T2 I
T2 I
T3 K
T3 L
T3 I
T3 I

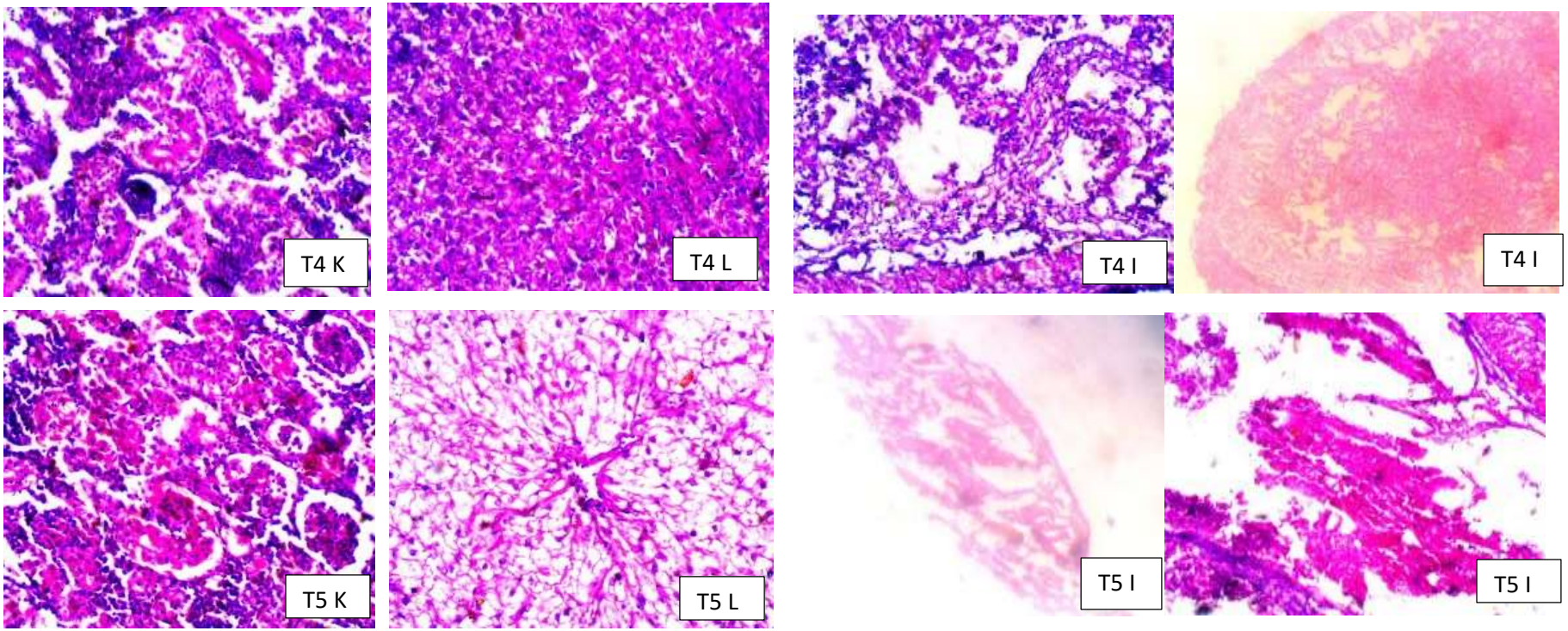


Figure 2. Histomorphological illustration of *C. gariepinus* juveniles fed cattle hair diets

T1: Kidney- There is no observable lesion. T1: Liver- There is no observable lesion. T1: Intestine- There is goblet cell hyperplasia. HE x400. T2: Kidney- There is no observable lesion. T2: Liver- There is no observable lesion. T2: Intestine- There is no observable lesion (autolysis) HE. x400. T3: Kidney- There is tubular epithelial degeneration. T3: Liver – there is random hepatocellular coagulation necrosis. T3: Intestine- There is atrophy of villi and moderate hyperplasia of crypts. HEx100, 400. T4: Kidney- There is patchy tubular epithelial degeneration. T4: Liver- there is centrilobular atrophy and degeneration. T4: Intestine- There is atrophy of villi and sloughing of enterocytes. HE x400. T5: Kidney- There is no observable lesion. T5: Liver- There is severe diffuse hepatocellular degeneration. T5: Intestine- There is severe atrophy of villi. HE x400.

DISCUSSION

The protein content of compounded diets was within the protein diet range recommended for catfish (Faturoti, 2000). The studies of Coward-Kelly *et al.,* (2006) and Gau *et al.,* (2021) reported cattle hair to be a rich protein feedstuff. This may be responsible for the balanced diet composition of the treated cattle hair as feedstuff. The feeding of CHM at low level of inclusion was in line with the findings of Oh *et al.,* (2018) when 10% pig hair inclusion improved percent egg production and egg weight with reduced feed conversion ratio. Falaye and Sule (2020b; 2022); Yusuf *et al.,* (2022) and Sule *et al.,* (2023b) also reported treated cattle hoof and horn to be well digested with improved growth of *C. gariepinus* between 25% - 30%. Said *et al.,* (2022) used CHM in poultry nutrition and reported its use at 0-6% in quail diet, due to its low digestibility. However, keratin feedstuff of cattle and pig have been reported by Sule (2022); Sule *et al.,* (2022a; 2022b) and Sule *et al.,* (2023a) to improve growth up to 75% when the keratin were processed by alkaline and degraded by enzyme. The findings of Oh *et al.,* (2018); Said *et al.,* (2022) and Yusuf *et al.,* (2022) corroborated that higher inclusion of CHM depressed growth performance of animals as noticed in this study. Sule (2022) and Falaye and Sule (2022) reported carcass composition improvement when cattle horn and hoof were fed to *C. gariepinus*, over initial fish which indicated that nutritional quality can be improved with hair meal also, which was evident in this study.

Haematological analyses are used in monitoring response of fish to new diets. These have been used in assessing the implication of feeding new feedstuff on normal physiology of fish. Higher WBC above 25% was not able to improve immunity of catfish against organ disorder. This was not in line with Falaye and Sule (2022) when high diet keratin meal improved blood parameters and reduced stress of catfish. Liver enzyme activities are noted for indicating pathological effects of diets, especially when the feed does not meet the nutritional requirement of the species in question. Increased liver enzyme activities across treatment were responsible for tissue damage which indicates toxicity of feed ingredients at higher levels of inclusion. Similar results on liver enzyme activities have been reported by Sule (2022) when cattle keratin was feed to *C. gariepinus* juveniles. The changes in the cryptal depth and muscle thickness of the diet treatment groups compared to the control signified enhanced digestion as cryptal depth is responsible for the regeneration of the villi and secretion of electrolytes which enhances water secretion into the intestinal lumen for the purpose of digestion (Bowen, 2019) which translate to stress on the intestine and the inability to digest CHM. Higher cryptal depth denotes efficient digestibility and absorption of diet (Zhou *et al.,* 2010). However, Chen *et al.* (2022) reported that the immune response in both the intestine and liver of hybrid tilapia fed with hydrolyzed feather meal indicated feather to be an excellent alternative protein source, which is at variance with this study.

Digestive enzymes have been implicated for the various catabolic reactions of diets in gut of fish. These reactions have been able to digest complex dietary molecules for easy absorption in fish gut which allows the intestinal morphometrics to absorb the nutrients in the diet for growth of the fish cells for flesh deposition. The high values of digestive enzymes were within the range reported by Kareem *et al.,* (2021). However, these

values did not translate to growth performance above 25% indicating that processing of hair meal needs to be achieved by other methods to break the disulphide bond further for easy utilization of the embedded protein in hair meal. Nutritional studies will be incomplete without the pathological effects of diets on organs that catabolize and metabolize the diets for ease of absorption. These effects are initially noticed in elevated levels of liver enzymes, which eventually translate into mild and severe reactions to organs. Rastovic *et al.* (2011) reported that liver alteration still allowed fish to grow, which was at abeyance with this study. According to Karapanagiotidis (2016) alterations was not noticed in fish gut fed feather meal above 75%. However, liver alteration was recorded at 75%, which also differed with CHM in diets. Psofakis *et al.* (2016) noted that total replacement of feather meal altered liver of seabream. Sule (2022) reported that organs of *C. gariepinus* juveniles fed cattle horn and cattle hoof showed similar alterations, with composite cattle horn and hoof diets having no effect on the fish.

CONCLUSION

Cattle hair can be used in the diet of catfish at low levels of inclusion without significant impact on the fish physiology. Utilization at higher levels should however be discouraged. This study revealed that hair keratin waste materials from cattle can serve as fishmeal replacer if well processed.

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