Effect of Gum Arabic (*Acacia senegal*) on Growth Performance, Carcass Quality and Health of *Clarias gariepinus* Juveniles

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Abstract

The effect of Gum Arabic (GA) on growth, carcass quality, blood parameters, gut morphometry, and organ histology of African catfish *Clarias gariepinus* was studied. Five isonitrogenous diets with inclusion levels of GA at 0 g/100 g (GA_0; control), 5 g/100 g (GA_5), 10 g/100 g (GA_{10}), 15 g/100 g (GA_{15}), and 20 g/100 g (GA_{20}) were formulated in a 40% crude protein diet. Juveniles of *C. gariepinus* with average weight (7.35±0.48 g/fish) were stocked at 13 fish/25 L of water for 12 weeks in a completely randomized design and fed at 3% body weight daily. Growth indices showed GA_{10} improved the mean weight gain (69.88±8.89 g) and specific growth rate (2.76±0.14 %/day) while at (GA_{15}); (GA_{20}) growth was depressed. Carcass quality revealed dietary levels were superior to control with GA_{10} significantly different ($p < 0.05$) amongst treatments in protein and fat content. Hematological profile showed variations; erythrocyte indices compared to control, while plasma chemistry of aspartate aminotransferase, alkaline phosphatase, and alanine aminotransferase showed no difference ($p > 0.05$). Gut morphometrics varied with no particular pattern. At inclusion above GA_5 the gill, liver, and kidney were affected histologically with no changes in the intestines of all treatments. Diet supplemented with gum arabic at 10 g/100 g improved indices of performance of *C. gariepinus* juveniles in this study.

Keywords: feed additive, gum arabic, gut morphology, phytogenic, probiotic

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INTRODUCTION

The African catfish (*Clarias gariepinus*) inhabits a freshwater habitat (Bbosa *et al*., 2017). Its adaptability to different environments and its fast growth rate (Wachira *et al*., 2015) makes it cultured as a fish protein food source and for income by commercial and small-scale fish farmers in tropical countries (Asthana *et al*., 2019). In response to the wide cultivation that necessitates the use of chemical substances as non-nutrient additives and growth promoters in catfish diets, scientists are studying the effect of naturally occurring substances in the farming of fish. Phytogenic utilization is gaining due to its pharmacological effects on the sustenance of health on body metabolism in farmed animals while trying to discourage the use of chemically synthesized products that can bio-magnify leading to health disorders. Phytobiotics are plant-based materials that enhance the productivity and quality of fed animals by improving immune response to adverse effects of feed and environmental factors (Al-Baadani *et al*., 2021; Fikri *et al*., 2022). Phytobiotic additives have received the attention of fish nutritionists and pathologists due to their activity on the internal physiology of fish (Ji *et al*., 2007; Chakraborty and Hanez, 2011). Gum Arabic (GA) from the *Acacia Senegal* tree acts as a prebiotic (Calame *et al*., 2008). The edible exudate of GA is from the stem and branches of the tree and it is important as an emulsifier in drugs and food manufacture (Ali *et al*., 2013; Nasir *et al*., 2013). Various methods of use in the feed are proposed at a range of 10–900 g as binders, granulating agents, as emulsifiers, stabilizers, and carriers. It is a non-starchy polysaccharide of organic binders that possess complex polymers of carbohydrates useful in the food industry (Paolucci *et al*., 2012; Fikri *et al*., 2023). Characteristics of GA have been noted in

the immune response system due to anti-oxidant properties (Minzanova *et al*., 2018). The fermentation of GA takes place in the colon of animals to form fatty acids with short chains, which are easily assimilated as it is not digested in the stomach (Phillips and Phillips, 2011). Intake of GA metabolizes the fat in broiler chicken (Ali *et al*., 2009) and has been used as a prophylactic immune-stimulant in aquaculture (Kumari and Sahoo, 2006), while the similar hematological study on propolis in fish diet was noted to influenced fish health status (Cuesta *et al*., 2005; Talas and Gulham 2009; Yonar *et al*., 2012; Safira *et al*., 2023). Studies have documented the use of GA in land animals (Abdalla *et al*., 2015; Abd-Razig *et al*., 2010; Ali *et al*., 2013) and on fish of different species (Akrami *et al*., 2012; Faggio *et al*., 2015; Denji *et al*., 2015; El-Faki 2016; Gelibolu *et al*., 2018; Naiel *et al*., 2022). Also, safe limits have been established for GA in chicken (0.28 g), turkey (0.38 g), rabbit (0.40 g), piglet (0.50 g), pigs (0.60 g), cattle (1.10 g), calves/salmonids (1.25 g), and ornamental fish (4.89 g). The use of GA as an additive in feed ingredients with a re-evaluation of its usage in livestock is inevitable. This study was premised on El-Faki (2016) recommendation for the use of GA in the diet of other fish species while also studying its effect on the internal physiology of the cultured species. The utilization of polysaccharides has attracted attention to boost systemic production of probiotics in the gut of cultured fish. The dietary application of GA powder is identified as a promising growth promoter. However, information is lacking on its growth enhancement potential on *C. gariepinus*, a commercially important cultured species. Therefore, the effect of graded levels of GA on growth, blood profile, gut morphology, and histology of *C. gariepinus* juveniles was investigated.

MATERIALS AND METHODS

Ethical Approval

This study did not require ethical approval because there was no treatment of animals.

Study Period and Location

Experimental duration was 12 weeks, conducted at the Fisheries Laboratory, Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria.

Experimental Diet

An experimental diet with 40% crude protein content (Table 1) was formulated according to the Pearson Square Method. The gum arabic powder was added to the feed ingredients at 5 g/100 g (GA_5), 10 g/100 g (GA_{10}), 15 g/100 g (GA_{15}), and 20 g/100 g (GA_{20}) dietary levels with control diet (GA_0). All dry ingredients were thoroughly mixed and forced through a 2 mm size pellet mill.

Experimental Design

Acclimatization of *C. gariepinus* juveniles with average weight (7.35±0.48 g/fish) was for 14 days in rectangular plastic tanks (26 × 46 × 20 cm^3) filled to a water volume of 25 L/each. After the acclimatization period, fish were divided into five groups. Thirteen fish were randomly distributed in each tank as treatments in triplicate. The five experimental diets were fed at 3% body weight daily at 8:00–9:00 and 16:00–17:00 for 12 weeks. Measurements of weight changes were performed forth nightly using an electronic weighing scale (SF-400: 3 kg × 0.5 g) followed by feed adjustment accordingly. According to AOAC (2005) all five diets, initial and final fish were analyzed. The following growth indices e.g. final weight (FW), initial weight (IW), feed intake (FI), weight gain (WG), daily feed intake (DFI), average daily weight gain (ADWG), protein intake (PI), percentage weight gain (%WG), specific growth rate (SGR), feed conversion ratio (FCR), feed efficiency ratio (FER), and protein efficiency ratio (PER) were calculated from forthnight weight data.

$$\text{WG} = \text{Mean FW} - \text{Mean IW}$$

$$\text{DFI} = \frac{\text{FI (dry matter)}}{(\text{IW} + \text{FW}) \times \text{days}} \times 100$$

$$\text{ADWG} = \frac{\text{Daily weight gain}}{\text{Experimental period}}$$

$$\text{PI} = \text{FI} \times \%\text{ of protein in diet}$$

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

$$\%\text{WG} = \frac{(\text{FW} - \text{IW}) \times 100}{\text{IW}}$$

$$\text{SGR} = \frac{(\text{Log FW} - \text{Log IW}) \times 100}{\text{Time}}$$

$$\text{FCR} = \frac{\text{Feed Consumed (g)}}{\text{WG (g)}}$$

$$\text{FER} = \frac{(\text{FW} - \text{IW}) \times 100}{\text{FI (g)}}$$

$$\text{PER} = \frac{\text{Mean weight gain (g)}}{\text{Mean protein intake (mg)}}$$

Hematological Analysis

The blood of five fish was collected in triplicate from each treatment by caudal puncture of the blood vessel into an EDTA bottle for full blood count hematology analysis. The following variables e.g. Mean Cell Haemogblobin (MCH), Mean Cell Haemogblobin Concentration (MCHC), and Mean Cell Volume (MCV) were calculated.

$$\text{MCV (pg)} = \frac{\text{PCV} \times 10}{\text{Er}}$$

$$\text{MCHC (g/dL)} = \frac{\text{Hb} \times 100}{\text{PCV}}$$

$$\text{MCH (fl)} = \frac{\text{Hb} \times 10^2}{\text{Er}}$$

Meanwhile, serum biochemistry of aspartate aminotransferase (AST), alkaline phosphatase (ALP), and alanine aminotransferase (ALT) was determined according to Osuigwe *et al*., (2005).

Determination of Gut Morphometry

Gut morphology was determined using standard methods. The gut was prepared on slides based on Culling (1974) for the organs and tissues. Measurement of villus length (VL, µm), depth of crypt (DC, µm), villus width (VW, µm), and area of absorption (AA, μm^2) was taken using a light microscope (Hex40) (Olympus CX21, Japan) in triplicates with a micrometer rule as described by Spadoni *et al*., (2005) and Eyarefe *et al*., (2008).

Histopathology of *C. gariepinus*

The appropriately labeled samples were brought to the laboratory and subjected to the following procedure. Dissected, and appropriately labeled, fixed in 10% neutral buffered formalin for further fixing before processed in an automatic tissue processor, embedded in paraffin wax, and sectioned at 5 microns on a rotary microtome mounted on glass slides. The stepwise protocol for the automatic tissue processor for the histological examination of slides was described by Winsor (1994) and Hopwood (1996). Photomicrographs were taken with the aid of a computerized digital camera (Amscope MU900).

Data Analysis

One-way analysis of variance was used for the computation of data and the result was subjected to the Duncan Multiple Range Test for difference among means using SPSS version 20.

RESULTS AND DISCUSSION

There was no difference in all proximate composition parameters measured for the experimental diet (Table 1). The proximate composition parameters (crude protein, ether extract, ash, fiber, and dry matter content of the formulated diet were not significantly different ($p > 0.05$). NRC (2011) stated the requirement for dietary protein in fish in warm water as 38-55%, and this was met in this study. Mohammed and Mohammed-Alfaddul (2015) supplemented GA at 3%, 6%, and 9%, while El-Faki (2016) supplemented up to 12% in the tilapia diet. The

parameters of composition varied according to Mohammed and Mohammed-Alfaddul (2015) and El-Faki (2016) due to the level of supplementation, the ingredients used in feed formulation, and the species difference for the nutritional requirements.

The fish responded to varying levels of GA powder with varying growth responses as shown in Table 2. The highest mean weight gain was in GA_{10} and compared with GA_0 and GA_5, while the lowest weight gain was in GA_{15} and GA_{20} with no significant difference. The FCR and SGR followed the same trend and were not significantly different in GA_{10}, GA_0, and GA_5.

The dietary supplementation of GA powder enhanced growth performance significantly in the GA_{10} diet concerning control. The final weight gain and specific growth rate were significantly different ($p < 0.05$) among the diet groups. However, the weight gain, SGR, and survival rate were in agreement with Jabir *et al*., (2012); Muin *et al*., (2014), and El-Faki, (2016). They reported improved growth indices and reduced survival rates in *O. niloticus* fingerlings fed a diet supplemented with *P. sajor caju*, *P. florida* stalk meal, and GA meal respectively. The result on survival corroborates the findings of El-Faki (2016) who reported a 63.33% least survival rate when GA was included in the diet of *O. niloticus*, while the rate followed a similar trend (9% > 0% and 3% > 6% > 12% for *O. niloticus*). Mohammed and Mohammed-Alfaddul (2015) also reported a decreasing trend in survival rate at 3% > 6% > 9% for *O. niloticus*. Ene *et al*., (2012) reported that 12% GA in the diet of Sea bream did not affect growth performance and survival. While Ramos *et al*., (2015) also reported that supplementation of 8 and 12% guar gum fed to *Mugil liza* significantly reduced weight gain and SGR. Mohammed and Mohammed-Alfaddul (2015) reported differential significance in SGR, WG, and FCR. Weight gain was improved at 6% GA inclusion which is a third treatment and similar to the GA_{10} in this study. El-Faki, (2016) reported that 12% GA improved growth parameters in tilapia. In a recent study, Naiel *et al*., (2022) fed GA at a low level (0.5–1%) in tilapia diet and PWG, WG, FCR, and final body weight was better with a postulate that 1% GA is optimally used by the species. Ali *et al*., (2013) and Kur *et al*., (2013) reported similar weight increases in poultry fed up to 15% GA inclusion, while Waldroup *et al*., (2003) noted that GA feed showed no difference in the performance of broilers. El-Sayed *et al*., (2015) reported reduced final weight with rat-fed GA 10% which differs with an increase for catfish (GA_{10}) used in this experiment.

The dietary supplementation of GA showed a decreased feed intake with increasing inclusion levels with the control (GA_0) exhibiting the highest intake of feed. This agreed with Ramos *et al*., (2015) who reported reduced feed intake by *M. liza* fed a diet supplemented with 8 and 12% guar gum. In obese rats feed intake was reduced when GA 10% (14 g/day/rat) was fed with more feed intake at GA 5% (15.34 g/day/rat), this is contrary to the result observed in this catfish experiment (El-Sayed *et al*., 2015; Safira *et al*., 2022). This may be due to the obesity disorder in the rat. The FCR in this study differs significantly ($p < 0.05$) among the diet groups. This may be an indication of enhanced absorption and digestion of nutrients as indicated in the nutrient utilization indices. Jabir *et al*., (2012) and Muin *et al*., (2014) also observed better FCR, when *O. niloticus* fingerlings were fed *P. sajor caju* stalk meal.

The analyzed proximate composition of the fish is presented in Table 3. The crude protein percentage ranges were not significantly different among dietary treatments. The ash and fat content were significantly compared among treatments with no difference.

Improvement in carcass quality is the ultimate aim of nutritional studies which will influence consumer acceptance of fish products. The findings on flesh composition revealed that the inclusion of gum Arabic in the catfish diet improved the nutritional quality of the fish.

Hematological characteristics of *C. gariepinus* fed experimental diets for 12 weeks showed that the GA-supplemented diet (Table 4) increased PCV, HB concentration, RBC, and WBC count in the treatment groups compared control diet. The erythrocyte-derived indices: MCV; MCHC and MCH of GA_0 did not differ (p

> 0.05) from that of the diet groups. The Platelets, monocytes (Mono), Basopils (Baso), Lymphocytes (Lym), Heterophil (Het), and Eosinophil (Eos) of the diet groups did not differ ($p > 0.05$) from the control.

Hematological indices are good pointers to the health of fish, feed assessment and the nutritional state of an organism. A significant increase in the blood parameters of the diet group except heterophils and eosinophils was observed. The erythrocyte indices: MCV, MCHC and MCH were also compared to the control. The result indicates that the utilization of GA as a supplement may increase erythropoiesis and increase oxygen availability to the tissues of the fish (Jawad, 2004). The increase in the erythrocytes in the GA-supplemented diet group may indicate a higher concentration of haemoglobin in the erythrocytes (RBC) and increase the oxygen-carrying capacity of the fish blood. The increase in the WBC of the diet treatment groups may indicate an increase in haemopoiesis and stimulate the humoral immunity of the fish to stress and infection (Sunmonu and Oloyede, 2008). The hematological values found in this study agreed with previous studies on dietary mannan oligosaccharide's ability to elevate blood parameters as documented by Hisano *et al*., (2007) for tilapia fed 2% dietary mannan oligosaccharide; Andrew *et al*., (2009) for rohu; Satheeshkumar *et al*., (2010) and Fazio *et al*., (2012) for M. cephalus administered oral GA at 12% for 15 days.

The serum biochemical metabolites of *C. gariepinus* juvenile in response to dietary GA powder (Table 5) showed serum levels of albumin and urea were different among the diet group. The other serum parameters of globulin, total protein and serum enzymes of other diets concerning the control were also not different among the diet treatment groups.

The plasma chemistry AST, ALP and ALT activities did not significantly differ ($p > 0.05$) in the serum of *C. gariepinus* fed dietary GA powder compared to the control. This result agreed with those of Hoseinifar *et al*., (2011); Denji *et al*., (2015); Gelibolu *et al*., (2018) and Akrami *et al*., (2012) who reported prebiotic oligo-fructose, DMO and inulin had no effects on ALT, ALP and ALT of *H. huso, O. mykiss* and *S. aurata*, respectively. Gamal El-Din *et al*., (2003) noted that GA usage decrease hepatotoxicity with a noticeable decrease in ALT and AST. However, our study showed mixed variations of increase and decrease concerning creatinine and urea. Suliman (2000) reported both urea and creatinine reduction in the blood plasma of patients with renal failure when placed on GA oral supplementation. El-Sayed *et al*., (2015) noticed that urea in obese rats was high at GA 5% and low at GA 10% which disagreed with this study. Ali *et al*., (2013) noted a decrease in creatinine when broiler chicken was fed GA range 5–7.5%. However, creatinine was high at GA 5% and low at GA 10% in obese rats (El-Sayed *et al*., 2015), which was similar to the observed level for the catfish studied.

Gut morphometry of experimental fish (Table 6) showed the changes in internal morphometrics of *C. gariepinus* fingerlings fed with diets supplemented with GA. The parameters of indices indicated varied responses of the diet on the villi, cryptal, muscle thickness, and area of absorption and were different ($p < 0.05$) in all diet groups. While histological examination of internal organs (liver, kidney, gills and intestines) of *C. gariepinus* showed varying degrees of difference between the organs of the fish fed 0.0 g/100 g GA powder and those fed 5.0 g/100 g, 10.0 g/100 g, 15.0 g/100 g, and 20.0 g/100 g as shown in the plates below.

Gut morphometry is useful in accessing the nutrient absorption in the intestine of an organism. The increase in the villi height indicates enhanced absorption surface and improved absorptive capability of the intestine which consequently enhanced the growth response in the GA groups in comparison to the control diet. There were changes in the cryptal depth of GA groups compared to the control treatment. This indicates enhanced digestion, as cryptal depth has been adduced by Bowen (2011) for regeneration of the villi tissues and electrolyte secretion. An elevated cryptal depth also signifies effective absorption and better digestion of

Table 1. Composition of experimental diets

Ingredients (g/100g)	GA_0	GA_5	GA_{10}	GA_{15}	GA_{20}
Fish meal	24.71	24.71	24.71	24.71	24.71
Soybean meal	49.42	49.42	49.42	49.42	49.42
Maize	2.01	2.01	2.01	2.01	2.01
Wheat bran	2.01	2.01	2.01	2.01	2.01
Starch	20.00	15.00	10.00	5.00	0.00
Premix	0.60	0.60	0.60	0.60	0.60
Salt	0.25	0.25	0.25	0.25	0.25
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00
Gum arabic powder	0.00	5.00	10.00	15.00	20.00
Total	100	100	100	100	100
Crude protein %	39.00	39.02	38.85	39.16	39.03
Ash %	8.30	8.60	8.40	8.25	7.90
Crude fat %	7.00	6.45	6.60	6.35	7.35
Crude fiber %	3.25	3.50	3.20	3.60	3.40
Moisture content %	9.78	11.76	10.14	11.15	9.61
Nitrogen Free Extract %	32.67	30.67	33.41	31.49	32.71

Table 2. Growth performance of *C. gariepinus* fed dietary levels of gum arabic powder

Parameters	GA_0	GA_5	GA_{10}	GA_{15}	GA_{20}
IW (g)	7.62±0.05	7.62±0.05	7.61±0.05	7.62±0.05	7.61±0.05
FW (g)	$74.85±12.33^a$	$72.59±15.40^a$	$77.49±8.90^a$	$51.41±8.73^b$	$50.86±5.34^b$
Mean WG (g)	$67.23±12.29^a$	$64.97±15.44^a$	$69.88±8.89^a$	$43.79±8.67^b$	$43.25±5.31^b$
%WG	$882.09±156.63^a$	$853.28±205.81^a$	$918.28±116.05^a$	$574.17±110.19^b$	$568.24±68.08^b$
FER	$1.53±0.38^a$	$1.85±0.42^a$	$1.45±0.15^a$	$1.02±0.15^b$	$1.10±0.18^b$
ADWG	$0.80±0.15^a$	$0.77±0.18^a$	$0.83±0.11^a$	$0.52±0.10^b$	$0.51±0.06^b$
FCR	0.69±0.20	0.70±0.23	0.69±0.08	1.00±0.15	0.93±0.14
SGR	2.71±0.20	2.66±0.28	2.76±0.14	2.26±0.20	2.26±0.12
PI (g)	27.44±1.11	28.02±1.07	26.24±0.65	27.36±1.04	25.63±0.67
PER	0.90±0.02	0.89±0.03	0.90±0.01	0.85±0.03	0.85±0.01
%Survival	$66.67±22.21^b$	$58.97±8.88^b$	$79.49±4.44^a$	$74.36±11.75^a$	$87.18±16.01^a$
Total FI (g)	44.49±3.66	43.15±2.08	45.03±1.41	42.74±2.63	39.57±1.41

Mean in the same row with the same superscript are not significantly different ($p > 0.05$).

Table 3. Proximate composition of fish fed dietary levels of gum arabic powder

Parameters	Initial	GA_0	GA_5	GA_{10}	GA_{15}	GA_{20}
Crude protein (%)	$62.29±0.40^b$	$66.30±0.39^a$	$68.26±0.35^a$	$71.10±0.37^a$	$70.90±0.17^a$	$68.82±0.28^a$
Ash (%)	8.80±0.10	10.30±0.10	9.60±0.10	8.75±0.15	9.20±0.10	8.55±0.10
Crude fat (%)	8.30±0.20	8.15±0.50	8.40±0.10	9.00±0.10	8.80±0.10	8.40±0.20

Mean in the same row with the same superscript are not significantly different ($p > 0.05$).

consumed feeds as improved activity of mucosal proliferation (Zhou *et al*., 2010). Adeniyi *et al*., (2021) parameters for villi height, cryptal depth, muscle thickness, and area of absorption differ as the guts were enhanced by GA than tamarind leaves. Due to GA stimulating properties in the diet, the observed gut morphometric results in *C. gariepinus* fed GA diet showed the benefits GA possesses in enhancing and maintaining the intestinal mucosa. Gamal El-Din *et al*., (2003) also observed that GA has an anti-inflammatory substance for intestinal mucosa, and this study inferred that GA has no adverse effect on gut morphology as it increases villi height, cryptal depth, and area of absorption in African catfish.

The effect of GA on intestinal histology at the expense of other organs responsible for feed metabolism has been widely investigated (Gao *et al*., 2019). This would have addressed the reduced growth reported at higher dosages of GA. The

Table 4. Hematological profile of *C. gariepinus* fed dietary levels of gum arabic powder

Parameters	GA_0	GA_5	GA_{10}	GA_{15}	GA_{20}
PCV (%)	22.50±0.05^c	29.50±0.50^b	28.37±0.37^b	34.50±0.50^a	32.63±0.63^a
Hb (g/dL)	7.00±0.50^b	9.20±0.50^a	8.90±0.10^a	11.19±0.50^a	10.53±0.22^a
Rbc ($\times10^{12}$/L)	1.80±0.50^b	2.81±0.50^a	3.15±0.11^a	2.93±0.50^a	3.26±0.11^a
Wbc ($\times10^3$/L)	14.59±0.50^b	16.55±0.50^a	15.35±0.87^a	17.25±0.50^a	14.66±0.37^b
Platelet ($\times10^3$/µL)	146.99±0.50	235.94±0.50	187.87±0.87	188.96±0.50	160.88±0.12
Lym ($\times10^9$/L)	63.50±0.50	71.50±0.50	68.12±1.12	74.50±0.50	73.37±0.37
Het ($\times10^9$/L)	28.50±0.50	22.50±0.50	24.38±0.63	16.50±0.50	18.38±0.63
Mono ($\times10^9$/L)	1.50±0.50	2.50±0.50	3.63±0.37	4.50±0.50	4.13±0.12
Eos ($\times10^9$/L)	4.50±0.50	2.50±0.50	3.63±0.37	2.50±0.50	3.35±0.88
Baso ($\times10^9$/L)	0.33±0.58	0.67±0.58	0.50±0.50	0.50±0.50	0.13±0.13
MCV (fl)	99.50±0.50	90.13±0.50	86.95±2.06	101.54±0.50	96.60±1.65
MCH (pg)	32.11±0.50	28.81±0.50	27.44±0.46	33.61±0.50	31.32±0.76
MCHC (g/dL)	32.11±0.50	32.83±0.50	31.53±0.10	32.93±0.50	32.38±0.18

Mean in the same row with the same superscript are not significantly different ($p > 0.05$).
PCV= packed cell volume; Hb= haemoglobin concentration; Rbc= red blood count; Wbc= white blood count; Mono= monocytes; Baso= basopils; Lym= lymphocytes; Het= heterophil; Eos= eosinophil; MCV= mean cell volume; MCH= mean cell haemogblobin; MCHC= mean cell haemogblobin concentration.

Table 5. Serum biochemistry of *C. gariepinus* fed dietary levels of gum arabic powder

Parameters	GA_0	GA_5	GA_{10}	GA_{15}	GA_{20}
TP g/dL	4.50±0.50	5.40±0.30	5.20±0.50	4.60±0.53	4.20±0.50
ALB g/dL	0.60±0.50^b	0.98±0.13^a	1.00±0.50^a	0.67±0.58^b	0.30±0.50^c
GLO g/dL	3.40±0.59	3.93±0.18	3.70±0.50	3.43±0.59	3.40±0.50
AST U/L	187.50±0.50	189.38±0.63	192.50±0.50	177.17±0.22	180.50±0.50
ALT U/L	47.50±0.50	53.13±1.86	51.50±0.50	43.50±3.07	49.50±0.50
ALP	309.50±0.50	318.87±3.12	318.50±0.50	299.16±7.93	295.50±0.50
Urea	5.00±0.50^b	5.90±0.30^a	6.30±0.50^a	6.17±0.63^a	5.20±0.50^b
Creatinine	0.60±0.10^a	0.68±0.03^a	0.50±0.20^b	0.58±0.03^a	0.50±0.10^b

Mean in the same row with the same superscript are not significantly different ($p > 0.05$).
TP= total protein; ALB= albumin; GLO= globulin; AST= aspartate aminotransferase; ALT= alanine aminotransferase; ALP= alkaline phosphatase.

Table 6. Gut morphometry of *C. gariepinus* fed dietary levels of gum arabic powder

Indices	GA_0	GA_5	GA_{10}	GA_{15}	GA_{20}
VH (µm)	1216.49±117.26^b	674.45±45.28^c	1288.23±38.37^b	1448.98±41.61^a	1273.91±115.29^b
VW (µm)	189.18±26.57^a	217.30±74.80^a	125.10±5.28^c	173.44±15.27^b	198.73±51.03^a
CD (µm)	371.89±45.46^a	184.70±23.26^c	363.28±10.37^a	452.43±39.84^a	352.80±20.74^b
CW (µm)	142.29±21.90^b	188.72±41.38^a	122.33±4.60^c	139.77±10.06^b	200.13±10.09^a
MT (µm)	177.37±28.33^c	233.29±45.12^b	193.35±20.82^b	271.80±28.83^a	273.18±11.44^a
AA (μm^2)	231205.15 ±45977.14^b	148052.28 ±55553.41^d	162425.18 ±11146.58^c	251725.57 ±29499.46^a	256600.45 ±88612.82^a

Mean in the same row with the same superscript are not significantly different ($p > 0.05$).

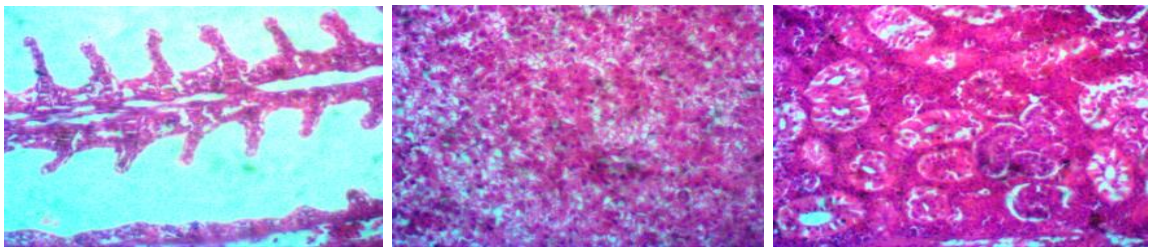

Figure 1. GA_0 group evaluation. No observable lesion in (a) gills, (b) liver, and (c) kidney. (H&E 400×)

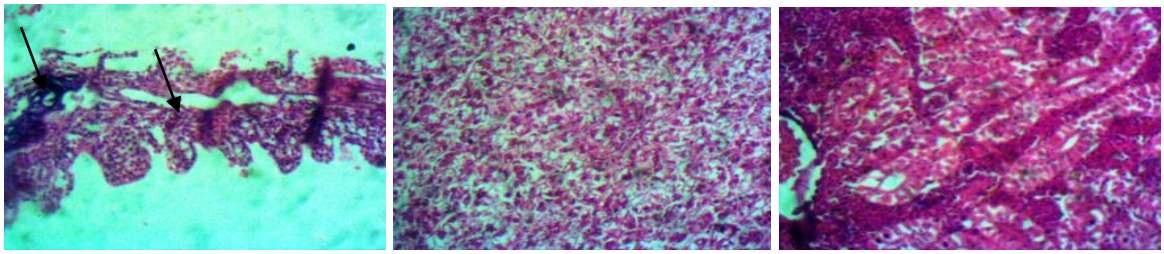

Figure 2. GA_5 group evaluation. (a) Capillary congestion in gills, no observable lesion in (b) liver and (c) kidney. (H&E 400×).

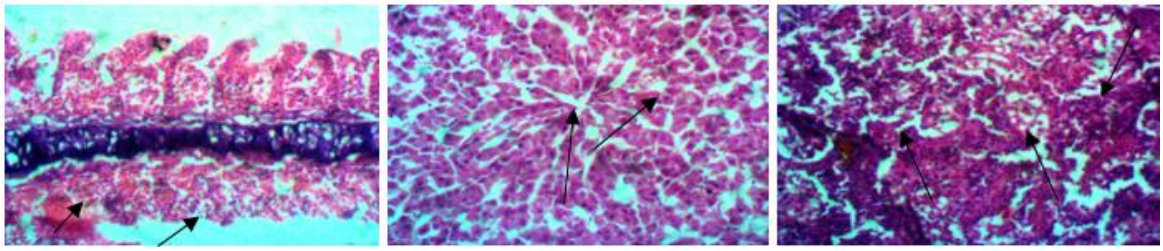

Figure 3. GA_{10} group evaluation. (a) Pillar congestion and lamellae hyperplasia in gills, (b) centrilobular hepatocellular atrophy in liver, (c) patchy tubular epithelial degeneration in kidney. (H&E 400×).

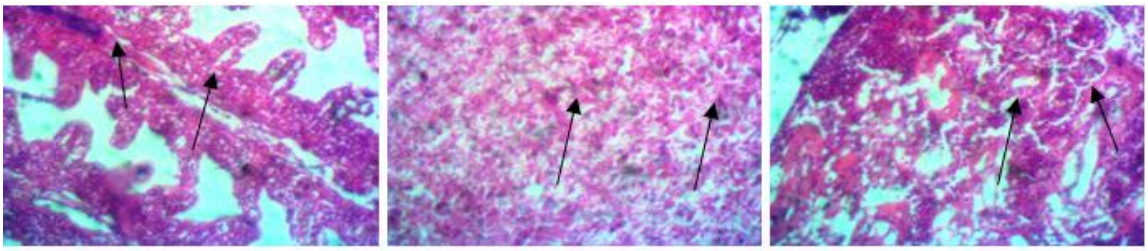

Figure 4. GA_{15} group evaluation. (a) Congestion of pillar capillaries in gills, (b) diffuse hepatocellular degeneration in liver, (c) tubular epithelial coagulation necrosis in kidney. (H&E 400×).

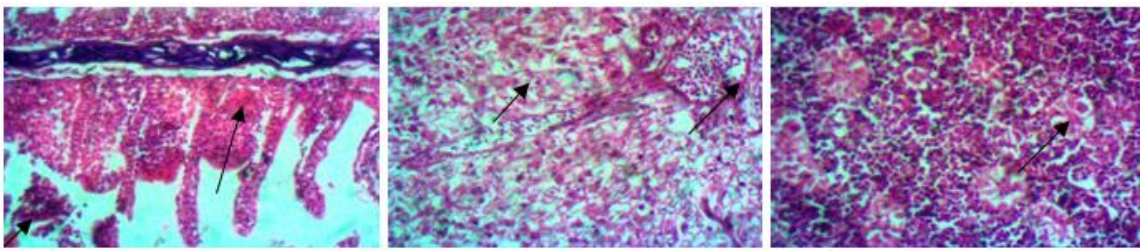

Figure 5. GA_{20} group evaluation. (a) Lamellae capillaries congestion in gills, (b) lamellar capillaries congestion and hepatocytes vacuolation in liver, (c) patchy tubular epithelial atrophy and degeneration in kidney. (H&E 400×).

binding effect of GA on feed (Storebakken, 1985) with a report of it being harmful to fish (Liu *et al*., 2022) may be the reason for changes in organs.

Histological alterations of *C. gariepinus* fed dietary levels of gum arabic powder showed that gum arabic affects fish organs at various inclusion levels except for the control diet. The changes in organ structure may result in adverse effects on fish health and increase susceptibility to secondary infections and lethality. Histological alterations of *C. gariepinus* range from a well-defined basement membrane, a well-defined nucleus on epithelial cells (Figure 1), a moderate to severe congestion of pillar (Figure 2) and lamellae capillaries of the gills (Figure 3, Figure 4, and Figure 5), lamellae hyperplasia, congestion of capillaries (Figures 2). Observation of the gills of the fish may affect the physiology of fish and later cause death. The control GA_0 showed no alteration and visible lesion, indicating diet purity (Figure 1). It was detected that gill, liver, and kidney alterations increased with dietary GA concentration increase. The alteration includes moderate, diffuse hepatocellular degeneration, moderate centrilobular hepatocellular atrophy, congestion of lamellar capillaries, and vacuolation of hepatocytes. Intestinal alterations were not observed in fish in this study compared to (Gao *et al*., 2019). Ibrahim *et al*., (2020) noted that the protection of cell cytology in organs by GA is due to the anti-oxidative effects of dietary GA, which mitigated damage to kidney cells at low levels with damage not completely prevented to the kidney when dosage is increased.

This result agreed with the findings of Ramos *et al*., (2015) that GA supplemented diet in *M. liza* showed no intestinal alteration. While Gao *et al*., (2019) reported that 5% GA supplementation of the *C. gibelio* diet induced distal intestinal damage. This can be a result of species differences and the ability of intestinal microbiota to act on GA. The toxicological effect at 5 – 20 g GA at sub-chronic administration with the highest dose not inducing effect on mice and rats. A low level of 1.25 g, 2.5 g, 3.75 g, and 7.5 g tested for carcinogenic effect on mice and rats for 103 weeks showed no response, also with no effect on reproduction in rats at 10.65 g. Liu *et al*., (2022) reported induced liver damage and poor intestinal health at increased levels of GA in Largemouth bass, which was attributed to changes in liver enzyme activity. The adverse effect on organs is a result of the viscosity of the GA at increased dosage which impacts distortions in fish organs. Non-starch polysaccharide (NSP) nature of GA could be responsible for physiological effects noticed in fish as fish lack endogenous enzymes capable of degrading NSP. Although the exertion of beneficial and detrimental effects are dose-dependent, the type of NSP and characteristics of NSP. These histological changes did not affect the survival rate in this study as GA diets showed improved survival than the control diet.

CONCLUSION

This study advocates for the use of gum Arabic in the African catfish diet at 10%, as it best improves the weight, percent weight gain, feed conversion, carcass protein, and survival rate at this optimal level. Although increasing gum arabic treatment did not affect intestinal organ damage, it did have a little immuno-stimulatory effect, as evidenced by the increased number of thrombocytes in the fish which demonstrated that the immuno-stimulatory effect of gum arabic is dose-dependent.

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AUTHORS' CONTRIBUTIONS

AEF: Conceptualized the study. AA: Conducted the experiment and performed the data analysis. SOS: Formulated the feed, wrote, and reviewed the draft. All authors approved the final manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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