Sumerianz Journal of Scientific Research, 2024, Vol. 7, No. 4, pp. 57-65
ISSN(e): 2617-6955, ISSN(p): 2617-765X
Website: https://www.sumerianz.com
DOI: https://doi.org/10.47752/sjsr.74.57.65

Original Article Open Access

Enhanced Growth, Haematological and Biochemical Performance in Hybrid Catfish of *Clarias gariepinus* x *Clarias cavernicola*

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Article History

Received: 20 October, 2024

Revised: 2 December, 2024

Accepted: 4 December, 2024

Published: 6 December, 2024

How to Cite

Ekerette E. Ekerette, Paul B. Ekpo, Owoidihe M. Etukudo, et al., 2024. Enhanced Growth, Haematological and Biochemical Performance in Hybrid Catfish of *Clarias gariepinus* x *Clarias cavernicola*. *Sumerianz Journal of Scientific Research, Vol. 7, No. 4, pp. 57-65.*

Abstract

This study evaluated the growth performance, haematological indices, and biochemical parameters of four catfish breeds, including two purebreds (*Clarias cavernicola* and *Clarias gariepinus*) and two hybrids (female *C. cavernicola* x male *C. gariepinus* and female *C. gariepinus* x male *C. cavernicola*). Over four months, growth was assessed by measuring body weight, total length, and standard length. Haematological and biochemical analyses were conducted to assess the health and immune status of the different breeds. The results indicated that the hybrid of female *C. cavernicola* x male *C.*

gariepinus exhibited the highest growth performance, with significant increases in body weight and length compared to the other breeds. This hybrid also demonstrated the highest white blood cell (WBC) and lymphocyte counts, suggesting a stronger immune response, which was statistically significant (p<0.05) compared to the purebreds. Granulocyte levels were consistent across all breeds, while red blood cell (RBC) and platelet counts showed no significant differences, indicating stability in these parameters. Biochemical analysis revealed that the female *C. cavernicola* x male *C. gariepinus* hybrid had the highest total protein and globulin levels, which are indicative of better health and immune function. Albumin levels were higher in both hybrids compared to the purebreds, while cholesterol, creatinine, and glucose levels were similar across all breeds. The alleles associated with better immunity are likely present in the maternal line of *C. cavernicola*, leading to the superior vigour observed in the *C. cavernicola* (female) x *C. gariepinus* (male) hybrid. This enhanced vigour results in improved growth, hematological, and biochemical profiles. Compared to purebred breeds, this hybrid demonstrates better health, increased disease resistance, and a higher potential for productivity in aquaculture.
Keywords: Biochemical; Growth; Haematology; Hybrid and resilient.

1. Introduction

In the dynamic world of aquaculture, the pursuit of optimal fish breeds that exhibit superior growth, health, and adaptability remains a critical challenge. The North African catfish (*Clarias gariepinus*) is particularly significant in Nigerian aquaculture due to its rapid growth and adaptability. It is the most cultivated fish in Nigeria [1] and has garnered substantial attention in the aquaculture industry because of its potential for a high return on investment. However, recent reports indicate a decline in the productivity of this breed, primarily due to reduced resilience in broodstock, which is largely attributed to inbreeding depression [2] and the repeated use of limited broodstock in hybridization [3]. If not properly addressed, inbreeding depression can have long-term detrimental effects on health and resilience, prompting urgent and sustainable action from stakeholders.

Enhancing the performance of African catfish is essential for optimizing aquaculture productivity and sustainability. Traditional breeding practices, which often involve repeated crosses of purebreds, can face challenges such as inbreeding depression, resulting in reduced genetic diversity, slower growth rates, and compromised health [2]. Hybridization offers a promising alternative by combining desirable traits from different parent breeds. Among various fish species, hybrids resulting from crossing genetically diverse strains have shown potential to improve aquaculture efficiency [3-6]. Hybrid fish play a significant role in enhancing aquaculture productivity and food security. Successful hybridization for genetic improvement requires the proper identification of purebreds, achieved through genetic mapping of quantitative trait loci associated with economic traits [7-11], followed by selection and utilization in breeding trials.

One potential candidate for hybridization is the blind catfish (*Clarias cavernicola*). Although this species is blind and lacks competitive feeding advantages, resulting in slower growth compared to other catfish, it is known to exhibit greater resilience to environmental stressors than *C. gariepinus* [3]. This resilience makes *C. cavernicola* a promising candidate for hybridization with *C. gariepinus*, potentially combining the fast growth rate of *C. gariepinus* with the high resilience of *C. cavernicola* to produce hybrids with superior vigour. Therefore, we hypothesize that hybrids created by crossing *C. cavernicola* with *C. gariepinus* can potentially demonstrate enhanced growth performance and resilience compared to purebreds.

Assessing the benefits of hybridization involves evaluating various parameters, including growth performance, haematological indices, and biochemical profiles. Fish growth, measured by weight and length, remains a fundamental approach for evaluating performance. Researchers have noted that fish growth is influenced by multiple factors, including genetics and environmental conditions [12-14], making accurate measurement important for assessing outcomes. Haematological indices, such as white blood cell (WBC) counts and lymphocyte percentages, are essential for evaluating immune function and overall health. These indices serve as bio-indicators of a fish's health, immune status, and physiological condition [15-19]. Similarly, biochemical parameters, including total protein, albumin, and globulin levels, provide insights into fish health and immune status [19-21]. Comparing these parameters among different catfish breeds, including hybrids and purebreds, we can determine whether hybrids offer improved growth and resilience. Although previous research has explored growth and health in purebred catfish [18, 22-26], there is a need for more detailed comparisons between hybrids and purebreds, specifically focusing on their growth rates, immune responses, and overall health. This study aims to evaluate the growth performance, haematological indices, and biochemical parameters of both purebred and hybrid catfish to determine the advantages of hybridization. Understanding these differences will contribute to more effective breeding strategies and improved aquaculture practices.

2. Materials and Methods

2.1. Study Area

The experiment was conducted at the Fish Hatchery Facilities of the Institute of Oceanography, University of Calabar Fish Farm (UCFF) in Calabar, Nigeria. Calabar is situated in Nigeria's south-south region, positioned between latitude 4.1504°N and longitude 8.120°E. The area experiences annual rainfall between 1260 and 1280 mm, with relative humidity ranging from 70% to 80%, and is located at an elevation of 99 meters above sea level.

2.2. Broodstock Sourcing

Broodstock of *Clarias gariepinus* (African catfish) was obtained from the University of Calabar Fish Farm in Calabar, while *Clarias cavernicola* (light-skinned catfish) broodstock came from Sebore Farms EPZ in Mayo Belwa, a well-regarded animal farm in Adamawa State, Nigeria. The *C. cavernicola* broodstock was placed in a 50-liter container with water and transported by bus to the experimental site. Each broodstock group consisted of two sexually mature males and two females, with each fish weighing at least 2 kg.

2.3. Mating Protocol

Mating was carried out in the following order:

Purebreed: *Clarias gariepinus* ♀ x *Clarias gariepinus* ♂ (Cg♀ x Cg♂)

Purebreed: *Clarias cavernicola* ♀ x *Clarias cavernicola* ♂ (Cc♀ x Cc♂)

Hybrid: *Clarias gariepinus* ♀ x *Clarias cavernicola* ♂ (Cg♀ x Cc♂)

Hybrid: *Clarias cavernicola*♀ x *Clarias gariepinus* ♂ (Cc♀ x Cg♂)

The different groups were raised in earthen ponds with a stocking density of 30 per pond.

2.4. Measurement of weight, total length, and standard length

Body weight (BW) was at the end of the experiment using a weighing balance. Total length (TL) and standard length (SL) were measured with a meter ruler.

2.5. Haematological Aanalysis

Blood samples were collected from 60 randomly selected individuals for haematological evaluation, with 15 samples from each fish breed. Blood was collected through caudal puncture using a hypodermic needle attached to a plastic syringe, extracting 5 ml per sample. The blood was quickly transferred into Eppendorf containing anticoagulant, Ethylene Diamine Tetra-Acetic Acid (EDTA). The puncture site was cleaned with tissue paper to avoid contamination with mucus, and the blood samples were gently rocked in the tubes to ensure thorough mixing with the anticoagulant. Haematological profiles, including White Blood Cells, Lymphocytes, Monocytes, Granulocytes, Haemoglobin, Haematocrit, Red Blood Cells, Mean Corpuscular Volume, Mean Corpuscular Hemoglobin, Mean Corpuscular Hemoglobin Concentration, Red Cell Distribution Width (Coefficient of Variation), Red Cell Distribution Width (Standard Deviation), Platelets, Mean Platelet Volume, Plateletcrit and Platelet Distribution Width were assessed for *C. gariepinus*, *C. cavernicola*, and their hybrids. The haematological analysis was performed at the Laboratory of the People's Specialist Hospital, IBB Road, Calabar, Cross River State.

2.6. Biochemical Analysis

The biochemical indices were evaluated using the serum samples from the same individuals used for the haematological analysis. A total of 5 ml of blood was collected from each sample using a hypodermic needle attached to a plastic syringe. The blood sample was placed into dry tubes and centrifuged at 3000 revolutions per minute for five minutes to separate the serum. This serum was then analyzed using colorimetric assays with LABKIT reagents (CHEMELEX, S.A.). The serum biochemical indices included glucose, total protein, albumin, globulin, creatin, and total cholesterol. The biochemical analysis was performed at the Laboratory of the People's Specialist Hospital, IBB Road, Calabar, Cross River State.

3.5. Statistical Analysis

All data were subjected to a one-way analysis of variance (ANOVA) to determine the presence of statistically significant differences among the breeds. Following the ANOVA, the Least Significant Difference (LSD) test was applied to separate and compare the means, identifying which specific pairs of breed means were significantly different. The significance level for all tests was set at 5% ($p < 0.05$). The statistical analysis was conducted using SPSS software, version 20.0.

4. Results

4.1. Weight, Total Length, And Standard Length

The growth performance of the four catfish breeds was compared and is presented in Table 1. The crossbreed of female *Clarias cavernicola* x male *Clarias gariepinus* consistently outperformed the others, exhibiting the highest body weight, total length, and standard length at each measurement point. Another crossbreed, female *Clarias gariepinus* x male *Clarias cavernicola*, also demonstrated superior growth compared to the pure breeds, though it was slightly lower than the female *Clarias cavernicola* x male *Clarias gariepinus* crossbreed. Both pure breeds, *C. gariepinus* and *C. cavernicola*, showed lower growth rates across all parameters. The results suggest that crossbreeding, particularly with a female *Clarias cavernicola* and a male *Clarias gariepinus*, may produce offspring with enhanced growth traits, indicating a potential hybrid vigor effect.

4.2. Evaluation of Haematological Indices

The study assessed various haematological indices in the different catfish breeds to understand their blood characteristics and differences among them. The findings in Table 2 revealed distinct variations in white blood cell (WBC) counts and lymphocyte percentages across the breeds. Among the catfish breeds evaluated, the hybrid of female *C. cavernicola* crossed with male *C. gariepinus* exhibited the highest WBC count. This result was statistically significant ($p<0.05$) compared to the other breeds. This hybrid also had the highest lymphocyte count, which was significantly higher than that of the purebred *C. gariepinus*. The purebred *C. cavernicola* showed lymphocyte levels similar to those of the female *C. cavernicola* x male *C. gariepinus* hybrid, while the purebred *C.*

gariepinus had the lowest WBC and lymphocyte counts among the breeds. Granulocyte levels did not show significant differences among the four breeds, indicating that this particular haematological component is relatively stable across different catfish breeds. The percentages of lymphocytes and granulocytes, provide further details on the distribution of these cells in the blood (Figures 1 and 2). Specifically, the percentage of lymphocytes was highest in the female *C. cavernicola* x male *C. gariepinus* hybrid and purebred *C. cavernicola* (92% and 95%, respectively). Conversely, the purebred *C. gariepinus* had the lowest lymphocyte percentage, a value that was statistically similar to the hybrid of female *C. gariepinus* x male *C. cavernicola*. Regarding red blood cells (RBC) and their components, no significant differences were observed among the four breeds ($p>0.05$), indicating that these parameters are consistent across the studied catfish breeds. Similarly, the blood platelet counts were statistically similar among all breeds.

4.3. Evaluation of Biochemical Indices

The biochemical assessment results of the four catfish breeds are presented in Table 3. Total protein content was highest in the female *C. cavernicola* x male *C. gariepinus* hybrid (4.68 g/dL) but was similar to that of the purebred *C. cavernicola* (4.00 g/dL). Albumin content in the two hybrids was higher than in the purebreds. Likewise, globulin levels were significantly higher in the female *C. cavernicola* x male *C. gariepinus* hybrid (3.33 g/dL), followed by the female *C. gariepinus* x male *C. cavernicola* hybrid (2.33 g/dL). The lowest globulin amount was recorded in the purebred *C. gariepinus*. Total cholesterol levels were statistically similar across the four catfish breeds, as were the creatinine and glucose levels.

5. Discussion

Fish growth is a composite trait measured through various indicators such as weight and length. In fish farming, weight is particularly important as it is a key economic trait, with consumers often attracted to fish based on their weight. Breeding fish with higher weight gain over a short period is therefore advantageous for farmers, offering a quicker return on investment. In our study, we observed significant variation in the growth rates of four catfish breeds raised over four months, assessed through body weight, total length, and standard length. Notably, body weight, total length, and standard length were consistently higher in the hybrid cross of female *C. cavernicola* x male *C. gariepinus*. By the fourth month, the two hybrids showed similar weight and standard length, both outperforming the two purebreds. These findings align with previous research that reported significantly higher growth characteristics in hybrid catfish compared to purebreds [3].

Haematological indices are valuable bio-indicators for assessing the health and physiological status of fish [27]. These parameters are crucial not only for diagnosing diseases but also for evaluating metabolic processes in fish across different ecological environments. They reflect internal changes within the fish, providing information on the overall health [28, 29]. Haematological parameters such as haematocrit (Hct), haemoglobin (Hb), and red blood cells (RBCs) are particularly useful in assessing the functional status of oxygen transport in the bloodstream. These indices help diagnose diseases and evaluate physiological changes in various ecological contexts.

In our study, the number of white blood cells (WBCs) was higher in the hybrid catfish involving the female *C. cavernicola* x male *C. gariepinus*, followed by the purebred *C. cavernicola*. This trend was also observed in other WBC components assessed in the study. WBCs are a critical part of an organism's defense mechanism. Lymphocytes, a type of WBC, are essential for identifying and combating pathogens such as bacteria, viruses, and parasites by recognizing and neutralizing them to prevent infectious diseases [30, 31]. Therefore, the higher lymphocyte count observed in the hybrid cross of female *C. cavernicola* x male *C. gariepinus* and the purebred *C. cavernicola* suggests a greater resistance to pathogens in these breeds compared to the other catfish breeds. WBCs continuously patrol the fish’s body, monitoring for signs of disease. Their ability to detect and respond to pathogens is crucial for maintaining health and preventing disease outbreaks in fish populations [32]. It has been noted that when fish are exposed to injuries or infections, WBCs are involved in the inflammatory response, which helps to isolate and remove harmful agents, promoting healing and restoring tissue function [33]. Granulocytes, another type of WBC, are essential for defending fish against infections, managing inflammation, and maintaining overall immune system function [34]. Their ability to respond quickly and effectively to a wide range of pathogens is crucial for the health and survival of fish. Therefore, the significantly higher granulocyte counts in the hybrid of female *C. cavernicola* x male *C. gariepinus* and the purebred *C. cavernicola* suggest a better ability to withstand pathogens. This implies that hybridization of the purebreds (*C. gariepinus* and *C. cavernicola*) may have combined and successfully transferred higher immune response traits to the hybrid catfish, particularly in the hybrid involving the female *C. cavernicola* x male *C. gariepinus*. Among the purebreds, our results suggest a higher immune response in *C. cavernicola* compared to *C. gariepinus*. The observed variations in WBC counts among the four catfish breeds indicate that they will respond differently to environmental changes, such as disease exposure.

We observed that RBC and platelet levels were similar across all fish breeds, consistent with Chand, *et al.* [17] who earlier observed that most of the haematological parameters did not differ significantly between *C. batrachus* and *C. gariepinus*. Sulem-Yong, *et al.* [26], also noted no significant variation in the blood platelets of *C. gariepinus* fed different commercial and farm-made feeds. Our findings also corroborate Abdel-Hay, *et al.* [23] that there were no significant differences in blood parameters between *C. gariepinus* fed various types of feed, except for white blood cells (WBCs), heterophil percentage, lymphocytes, and monocytes. Despite the observed variations in growth characteristics among the fish breeds, the levels of RBCs and platelets were consistent, implying that these two blood parameters may not be distinguishing factors between the breeds. Therefore, regarding haematological differences among the breeds, WBCs may serve as a more discriminating component. Considering the importance of

RBCs in oxygen transportation and platelets in blood clotting and wound repair, the levels quantified in the breeds are key to their overall performance.

Biochemical parameters in fish are important indicators of their health, physiological state, and overall well-being. Changes in biochemical indices can reflect environmental conditions such as water quality, temperature, or pollution [15]. Stress responses often manifest in altered levels of certain biochemical markers. Biochemical indices are generally useful for assessing growth rates and development in fish, providing insights into their overall fitness and potential for aquaculture [35, 36]. We observed high total protein levels in the hybrid of female *C. cavernicola* x male *C. gariepinus*, similar to those in the purebred *C. gariepinus*. Total proteins are essential in fish, as they can reflect immune status, given that some proteins, like immunoglobulins, are involved in the immune response. This finding corroborates the WBC results, which also indicated higher values in the hybrid of female *C. cavernicola* x male *C. gariepinus*, suggesting a stronger immune response in this hybrid catfish. Our results are consistent with earlier findings that reported significant variation in total protein levels of *C. gariepinus* at different feeding levels [26]. Similar submission was also made in Grass carp [19].

Albumin and globulin are important biochemical markers in fish. Albumin helps maintain osmotic pressure in the blood and tissues by exerting oncotic pressure, which regulates fluid balance between the blood and tissues, preventing excessive fluid loss or accumulation [37]. Albumin's roles in hormone transport, buffering capacity, binding, and detoxification of metabolic wastes have also been noted [37-39]. Conversely, many globulins act as antibodies, participate in immune surveillance, nutrient transport, blood clotting (coagulation factors), and regulation of osmotic pressure, and exhibit anti-inflammatory effects [40]. The levels of albumin and globulin in the fish breeds, especially in the hybrid of female *C. cavernicola* x male *C. gariepinus*, indicate their innate ability to combat diseases in their environment, reflecting their proper health status. Although this study did not directly measure the immune response of the fish breeds, the haematological data, especially WBC counts, and the biochemical indices suggest a higher immune status in the hybrid catfish of female *C. cavernicola* x male *C. gariepinus* compared to the other breeds. When comparing the two purebreds, *C. cavernicola* showed higher WBC and biochemical parameter levels, which could be linked to better immunity than *C. gariepinus*. Therefore, the hybrid resulting from the two purebred catfish can provide fish stock with greater environmental adaptability and production performance, offering farmers better investment returns.

Interestingly, the growth data indicated that the hybrid of female *C. cavernicola* x male *C. gariepinus* significantly outperformed the other fish breeds. This suggests that their enhanced immune system and better engagement with their environment, in terms of defense mechanisms, may have given them a competitive advantage for food over the other fish breeds. The superior growth performance of the hybrid *C. cavernicola* x *C. gariepinus* may be attributed to its enhanced immune status, as indicated by haematological and biochemical parameters. Higher WBC counts and total protein levels suggest better health and disease resistance, which could translate into more efficient growth and better adaptability to environmental conditions. This finding highlights the potential for hybrids to offer significant advantages in aquaculture, where improved immune responses can contribute to superior growth performance.

6. Conclusion

The results showed that hybridization, particularly between female *C. cavernicola* and male *C. gariepinus*, can lead to superior growth performance and enhanced immune function compared to the purebred breeds. The significant variation in growth traits, with the hybrid of female *C. cavernicola* x male *C. gariepinus* showing the highest body weight and length, suggests that this hybrid has a distinct advantage in terms of growth efficiency. This finding is particularly important for aquaculture, where faster growth rates translate into quicker returns on investment for farmers. The ability of this hybrid to outperform purebred counterparts in growth metrics emphasizes the potential benefits of selective breeding and hybridization in improving aquaculture production. Haematological analysis revealed that this hybrid had the highest white blood cell (WBC) and lymphocyte counts, indicating a stronger immune system and greater disease resistance. Biochemical assessments supported these findings, with higher total protein, globulin, and albumin levels in the hybrids, suggesting better overall health and resilience. The alleles linked to enhanced immunity are probably found in the maternal line of *C. cavernicola*, contributing to the greater vigour seen in the *C. cavernicola* (female) x *C. gariepinus* (male) hybrid. We demonstrate the benefits of hybridization for improving growth efficiency and potential immune function in catfish aquaculture.

Table-1. Body weight, total length, and standard length of four catfish breeds at four months

Breeds	BW (g)	TL (cm)	SL (cm)
Cg♀ x Cg♂	781.43 ± 62.45^{b}	48.18 ± 0.45^{c}	43.09 ± 1.34^{b}
Cc♀ x Cc♂	642.18 ± 10.23^{b}	44.40 ± 0.76^{d}	38.25 ± 0.76^{c}
Cg♀ x Cc♂	897.45 ± 49.51^{a}	52.14 ± 0.18^{b}	48.97 ± 0.76^{a}
Cc♀ x Cg♂	1016.20 ± 53.71^{a}	54.31 ± 0.76^{a}	51.22 ± 0.23^{a}

Results are presented in mean ± standard error; BW = Body weight; TL = Total length; SL = Standard length. Cg♀ x Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus*; Cc♀ x Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola;* Cg♀ x Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola;* Cc♀ x Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*

Table-2. Haematological indices in four breeds of catfish

Fish Breed	WBC ($10^3/\mu L$)	LYM ($10^3/\mu L$)	GRA ($10^3/\mu L$)	MON $10^3/\mu L$	RBC ($10^6/\mu L$)	HGB (g/dL)	HCT (%)	MCV (fL)	MCH (pg)	MCHC g/dL	RDW-CV (%)	RDW-SD (fL)	PLT ($10^3/\mu L$)	MPV (fL)	PCT (%)	PDW (fL)
Cg♀ x Cg♂	19.3 ± 2.52^{c}	4.33 ± 0.33^{b}	1.67 ± 0.33^{a}	0.00 ± 0.00	1.67 ± 0.33^{a}	9.00 ± 0.58^{a}	28.00 ± 1.73^{a}	147.67 ± 18.55^{a}	47.00 ± 8.39^{a}	36.33 ± 2.33^{a}	14.67 ± 4.67^{a}	129.67 ± 8.18^{a}	117.00 ± 13.52^{a}	9.33 ± 1.20^{a}	0.67 ± 0.33^{a}	3.33 ± 0.33^{a}
Cc♀ x Cc♂	25.3 ± 1.53^{b}	15.67 ± 0.67^{a}	1.67 ± 0.02^{a}	0.00 ± 0.00	1.67 ± 0.33^{a}	8.33 ± 0.33^{a}	25.33 ± 0.88^{a}	163.67 ± 12.20^{a}	53.33 ± 2.91^{a}	33.00 ± 1.00^{a}	12.33 ± 0.67^{a}	101.33 ± 3.84^{a}	82.67 ± 2.19^{a}	8.67 ± 0.67^{a}	0.00 ± 0.00^{a}	3.00 ± 0.001^{a}
Cg♀ x Cc♂	27.67 ± 0.33^{b}	4.33 ± 0.33^{b}	1.67 ± 0.33^{a}	0.00 ± 0.00	2.00 ± 0.00^{a}	9.67 ± 0.88^{a}	29.00 ± 2.08^{a}	145.33 ± 9.74^{a}	49.33 ± 4.81^{a}	33.67 ± 1.20^{a}	13.00 ± 1.52^{a}	96.00 ± 7.21^{a}	69.33 ± 7.34^{a}	10.33 ± 1.45^{a}	0.33 ± 0.02^{a}	3.00 ± 0.001^{a}
Cc♀ x Cg♂	33.0 ± 1.00^{a}	14.67 ± 0.33^{a}	1.00 ± 0.00^{a}	0.00 ± 0.00	2.00 ± 0.00^{a}	9.67 ± 0.88^{a}	28.33 ± 1.67^{a}	160.33 ± 5.93^{a}	57.00 ± 2.31^{a}	35.67 ± 0.88^{a}	11.33 ± 0.67^{a}	86.67 ± 6.07^{a}	76.67 ± 12.60^{a}	10.33 ± 0.88^{a}	0.33 ± 0.02^{a}	3.33 ± 0.33^{a}

Results are presented in mean ± standard error. Mean values with different superscripts along the same vertical axis differ significantly ($p<0.05$). Cg♀ x Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus*; Cc♀ x Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola;* Cg♀ x Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola;* Cc♀ x Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus,* WBC= white blood cells, LYM= lymphocytes; MON= monocytes; GRA= granulocytes; HGB= haemoglobin; HCT= haematocrit; RBC=red blood cells; MCV=mean corpuscular volume; MCH=mean corpuscular hemoglobin; MCHC=mean corpuscular hemoglobin concentration; RDW-CV= red cell distribution width-coefficient of variation; RDW-SD= red cell distribution width-standard deviation; PLT= platelets; MPV= mean platelet volume; PCT= plateletcrit; PDW= platelet distribution width.

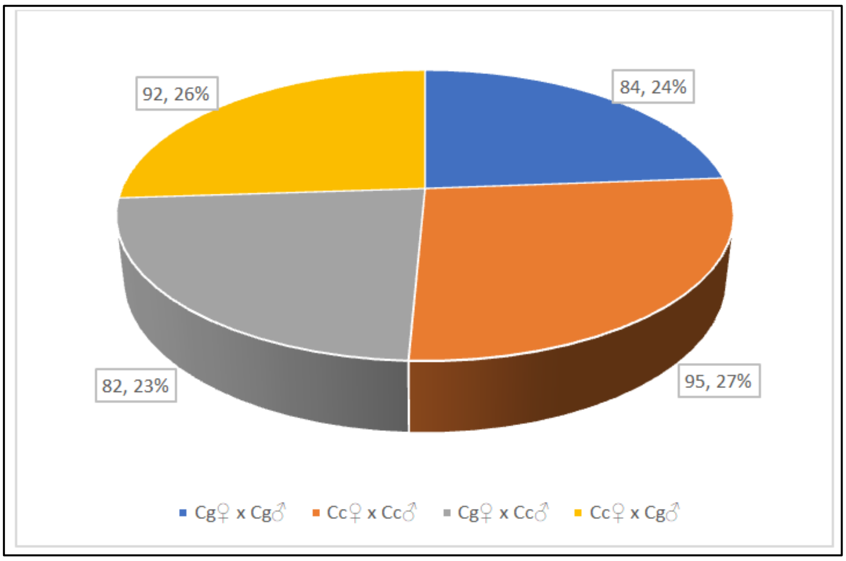

Figure-1. Percentage of lymphocytes in four catfish breeds

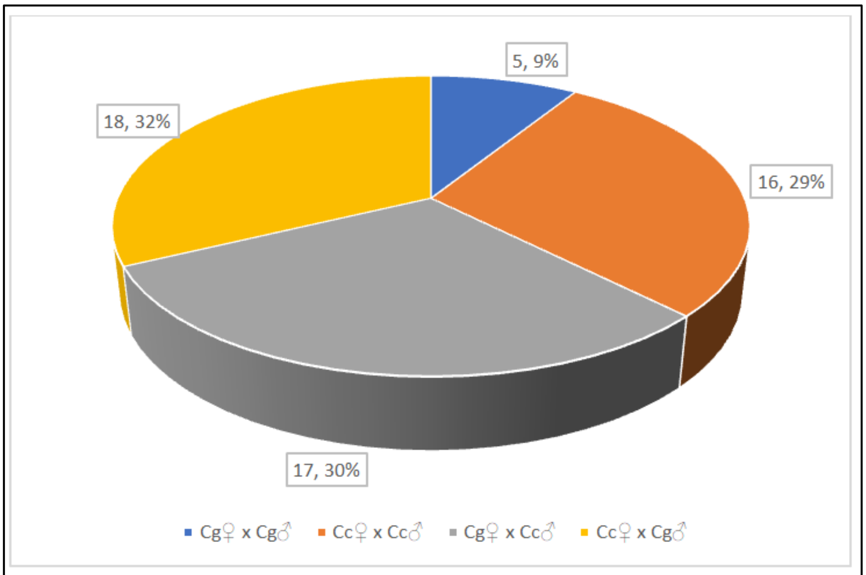

Figure-2. Percentage of granulocytes in four catfish breeds

Table-3. Biochemical profile of four breeds of catfish

Fish Breed	Total protein (g/dl)	Albumin (g/dl)	Globulin (g/dl)	TC (g/dl)	Creatin (mmol/L)	Glucose (mmol/L)
Cg♀ x Cg♂	4.00±0.00[a]	1.00±0.00[b]	1.33±0.33[c]	3.33±0.58[a]	50.67±4.81[a]	1.00±0.00[a]
Cc♀ x Cc♂	3.00±0.58[b]	1.00±0.00[b]	2.00±0.58[b]	2.33±0.58[a]	110.33±5.24[a]	0.67±0.33[a]
Cg♀ x Cc♂	3.00±0.58[b]	1.67±0.33[a]	2.33±0.33[ab]	2.33±0.58[a]	149.33±1.76[a]	0.67±0.33[a]
Cc♀ x Cg♂	4.68±0.33[a]	1.67±0.33[a]	3.33±0.33[a]	3.33±0.58[a]	89.33±8.29[a]	0.67±0.33[a]

TC = Total cholesterol; Cg♀ x Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus*; Cc♀ x Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola;* Cg♀ x Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola;* Cc♀ x Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*

Acknowledgment

The authors wish to express their appreciation to Unical Fish Farm, under the Institute of Oceanography, for providing the facilities necessary to conduct this experiment.

Funding

This research did not receive any funding from any source

Conflict of interest statement

Authors have no competing interest to declare

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