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The effects of diet and temperature on enzymes, hormones, and fecundity of the African Catfish *Clarias gariepinus* (Burchell 1822)

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ABSTRACT

The aim of this study was to check the effect of multiple temperatures and various protein diet formulas on liver enzymes, gonadotropins, and growth hormone (GH) using African catfish *Clarias gariepinus*. *C. gariepinus* was exposed to multiple temperatures (T_{24}°C, T_{28}°C, and T_{32}°C) and various protein diet formulas: D_1 (fishmeal-based diet), D_2 (soymeal-based diet), and D_3 (pea-meal based diet). Tilapia commercial feed (D_4) was used as reference diet. A total of 720 individuals with an average weight (101–104 g) were stocked at a density of 20 individual fish per tank in 12 tanks of three replicates. Liver enzymes, gonadotropins, GH, and fish fecundity were measured after 16 weeks. The results revealed that liver enzyme like glutamate-oxaloacetate transaminase was significantly ($P < 0.05$) lowered at T_{28}°C: D_2 diet, while glutamic pyruvic acid transaminase was lowered by T_{28}°C: D_4 diet. However, no effect was observed on creatinine ($P > 0.05$) at any experimental condition. Follicle-stimulating hormone and luteinizing hormone were significantly ($P < 0.05$) increased at T_{28}°C: D_1 diet and T_{32}°C: D_1 diet, respectively. GH was significantly ($P < 0.05$) increased by T_{28}°C: D_1. The relative weight of the ovary of *C. gariepinus* was significantly ($P < 0.05$) increase at T_{32}°C: D_1, while the testis relative weight was increased with T_{24}°C: D_3. The result from this study revealed that there is a direct relationship of temperature on fish fecundity, enzymes, and reproductive hormones in *C. gariepinus*. The temperature of 28°C along with fishmeal or soy-meal positively improved the fecundity and health of fish.

1. INTRODUCTION

Clarias gariepinus (the African catfish) is an important cultured fish in the tropical and subtropical areas [1]. *C. gariepinus* is a well-known fish for fast growth rate and resistance to adverse conditions such as handling, temperature fluctuation, low oxygen, deteriorated water quality, and high stocking density [2]. The aquaculture of African catfish expanded greatly in the 1970s and 1980s [3,4]. The aquaculture of *C. gariepinus* is suitable in developed and developing countries both biologically and economically [5].

Various fish diets were tested by researchers in the past to optimize the growth of fish without affecting the health of fish [6]. The fluctuation in temperature and nutrition could induce the stress which, in turn, could affect the fish in aquaculture system [7,8]. Optimum water temperature allows fish to grow faster and healthier. Water temperature and fish feeding rate are the most important factors that affect the growth of fish [9]. The fish metabolic rate is significantly affected by water temperature. The decrease in water temperature increases the activity of tissue enzyme [10,11]. Growth hormone (GH) would also influence by changing environmental conditions [12,13], fish nutrition [14], and feed ingredients [15].

Pituitary gonadotropins, follicle-stimulating hormone (FSH), and luteinizing hormone (LH) play a central role in regulating gametogenesis and gonadal hormones production which are required for the development of sexual behavior and secondary sex characters in all vertebrates [16,17]. Early developmental stages of the gonads such as vitellogenesis and spermatogenesis are stimulated by FSH, while later stages such as ovulation and spermiation are stimulated by LH [18].

Fish fecundity is an important tool of fishery biology; it has a direct effect on fish stock recruitment and management as well as fish production. Fish fecundity is defined as the number of eggs just before spawning [19].

In the present study, we have investigated the response of liver enzyme, reproductive parameters, GH, and fecundity of the fish by four different types of diets comprising of altered protein source at three different temperature conditions using African catfish *C. gariepinus*.

2. MATERIALS AND METHODS

2.1. Experimental Fish

African catfish *C. gariepinus* was obtained from the King Abdul Aziz City of Science and Technology research station. 720 fish with an

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average weight between 101 and 104 g were randomly selected and stocked in 12 tanks with three replicates at a density of six males and seven females per tank at Zoology Department, King Saud University, Kingdom of Saudi Arabia. 2 weeks before the start of the feeding trials, a commercial feed containing 36% crude protein was fed to fish twice a day at 2% of fish weight.

2.2. Fish Feed Formulation

The following feed having 36% crude protein was: Diet 1 (D_1) the control was formulated of fishmeal, wheat, vitamin, and mineral premix, and fat. Fishmeal was partially replaced with soybean meal in diet 2 (D_2) and Pea-meal in diet 3 (D_3), while D_4 was ARASCO commercial diet (36% crude protein) is used as a reference. Fish were fed 3% per body weight 3 times on a daily basis.

2.3. Water Quality

Water quality parameters such as temperature, pH, dissolved oxygen, ammonia, nitrite, and nitrate were monitored weekly throughout the study. The temperature was measured using a mercury-in-glass thermometer, while the dissolved oxygen and PH were measured using a dissolved oxygen meter HANNA-HI9142 model and HANNA-HI98107 model, respectively. Water temperature (T_2, T_2, and T_3) was controlled by heaters at three different levels for each diet as (T_{24}°C, T_{28}°C, and T_{32}°C), respectively.

2.4. Enzymes and Hormones

Blood was drawn from arterial caudalis with heparinized syringes to measure the level of glutamic pyruvic acid transaminase (GPT), glutamic oxaloacetic acid transaminase (GOT), and creatinine following the method as described previously [20]. LH, FSH, and GH were measured using blood serum using a commercial kit of enzyme immunoassay.

2.5. Sperm Morphometry

The abdominal cavity of each fish from different treatments was dissected and testis were removed and prepared for scanning electron microscopy using JSM-6380 LA scanning electron microscope by following the methods as described previously [21] at an accelerating voltage of 0.3–30 kV, Appendix V. The length and width of the sperm head, mid-piece, and tail were measured and recorded [Figure 1].

2.6. Fish and Gonadal Measurements

The weight of each fish (*C. gariepinus*) was measured with a digital balance at the start and end of the experiment. The length of each fish was measured before the beginning and at the end of the experiment using a ruler. The results were recorded. The ovaries and testis were removed from all of 120 individual fish from experimental and control group, and their relative weights were recorded.

2.7. Fecundity Determination

Fish fecundity was quantified by taking three samples of ovaries weighing 1 g each from each experimental and control group. The anterior, middle, and posterior regions of both ovaries from each fish were used to collect ovaries subsamples as described [22]. The subsamples were spread evenly on a counting slide with a few drops of water, and the number of mature ova was counted, and the average number of three areas was used to determine the fecundity using following formula.

$$\text{Fish fecundity} = \frac{\text{Number of ova in the subsample} \times \text{total o var y weight}}{\text{Weight of subsample}}$$

Eggs within each subsample were counted for both ovaries, and the mean number of eggs was used to calculate a number of eggs per gram of fish [23]. The fecundity of *C. gariepinus* related to fish weight and fish length was also measured.

2.8. Statistical Analysis

All values were recorded as a mean ± standard deviation and subjected to two-way analysisof variance using 95% confidence level to test for significant differencesbetween the various treatment means obtained for enzymes and hormones as described previously [24], using SPSS 10 for window software package. Regression analysis was used to measure the relationship between fecundity variables. The linear correlation coefficient (r) and the coefficient of determination (r^2) were calculated to evaluate the fit of the linear function to the imperial data. The significance of correlation coefficients for chosen relationships among the traits was subjected to the *t*-test [25].

3. RESULTS AND DISCUSSION

3.1. Glutamate-oxaloacetate Transaminase, Glutamic-pyruvic Transaminase, and Creatinine

The difference in concentration of GOT in *C. gariepinus* was statistically significant ($P < 0.05$) when the fish are exposed to various temperature levels and different diets. As shown in Table 1, the maximum concentrations of GOT were attained at T_{32} and D_4, as 129.8 µ/l and lowest at T_{28} and D_2 as 60.55 µ/l, respectively. Similarly, the concentration of GPT in *C. gariepinus* males and females was significantly different ($P < 0.05$), even though exposing them to the same treatments. The highest concentration of GPT was recorded as 64.5 µ/l at T_{28} and D_4 and the lowest was 36.95 µ/l which was recorded at T_{24} and D_4 [Table 2]. Surprisingly, the temperature or the diet alone has not affected the blood creatinine level significantly between control and treated fish; however, a significant difference ($P < 0.05$) was noted in blood creatinine level as a combined effect of temperature and diet. The maximum blood creatinine was recorded as 0.45 ± 0.05 mg at two experimental conditions (i) at T_{32} and D_3 and (ii) at T_{24} and D_4; on the other side, the lowest value of blood creatinine was 0.317 ± 0.04 mg, which was observed at T_{32} and D_1 and T_{28} and D_2, respectively, experimental conditions as shown in Table 3.

Quantification of various enzymes in an animal system is essential to gauge any change in the metabolic functions or predicting any pathological changes in tissues or organs [26]. Water temperature has a considerable effect on fish metabolism. The fluctuation of temperature from the optimum level changes the concentration of GOT and GPT which has induced a negative impact on the metabolic functions of *C. gariepinus*. The GOT and GPT enzymes are also biological markers to indicate pollutant toxicity [27]. Unfavorable and stressful environmental conditions increase GOT and GPT levels in the fish blood. It has been previously shown that the concentration of GOT and GPT increases in response to damages at the cellular level [28]. The water temperature which is lower than the optimal level could enhance the activity of tissue enzymes [10]. The fluctuation in water temperature from 27°C to 35°C promoted the change in tissue enzymes in *C. gariepinus* [11].

The optimal concentrations of GOT and GPT were observed at 28°C, while higher concentrations were recorded at 24°C and 32°C in this

study. The optimal production of these enzymes at 28°C indicates that the physiological status of *C. gariepinus* was at best at 28°C, while other temperatures induced a negative effect on the growth.

3.2. Sex and GH

The concentrations of LH in *C. gariepinus* were significantly different ($P < 0.05$) at different temperatures, diets, and their combinations. The highest concentration of LH was 0.854 ± 0.03 µ/l which was recorded at experimental conditions of T_{32} and D_1 and the concentration was lowest at the experimental condition of T_{24} and D_2 which was 0.431 ± 0.03 µ/l [Table 4]. The variability in temperature and diet also induced a significant difference in FSH concentration in *C. gariepins.* As shown in Table 5, the highest value of FSH was 0.789 ± 0.01 µ/l at the experimental condition of T_2 and D_1 and the lowest was 0.566 ± 0.02 µ/l at T_{32} and D_3. Similarly, the GH in *C. gariepinus* males and females also showed a significant difference ($P < 0.05$) at various temperatures, diets, and the combination of diets and temperature. The highest concentration was found to be 0.905 ng/ml at T_{28} and D_1,and the lowest value was 0.744 ng/ml at T_{32} and D_3 [Table 6].

Measurements of FSH and LH in *C. gariepinus* are reported to show some disruption in their activity when exerted to a sublethal concentration of 4-nonylphenol [29]. The reproductive activity of fish is regulated by the brain–pituitary–gonad axis. The vitellogenesis in female fish is regulated by FSH while; oocyte maturation is accomplished by LH [17]. In the present study, sex hormones were negatively affected

Table 1: Concentration of GOT µ/l in *C. gariepinus* males and females treated with different diets and temperatures at the end of the experiment

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	62.72±3.03	93.23±1.82	109±1.81	62.26±1.48	81.97±20.0
T_2	82.82±1.6	60.55±1.28	87.47±2.76	77.67±2.08	77.13±10.6
T_3	110.5±2.15	112.4±2.15	128.1±17	129.8±1.71	120.2±12.1
Overall mean	83.33±20.3	88.73±22.1	108.4±19.5	89.9±29.9	93.09±24.5

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

Table 2: Concentration of GPT µ/l in *C. gariepinus* males and females treated with different diets and temperatures at the end of the experiment

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	51.78±1.62	55.2±1.39	50.35±1.34	64.5±1.28	55.46±5.78
T_2	42.3±2.16	52.03±4.49	53.93±1.16	36.95±1.72	46.3±7.55
T_3	47.9±1.24	42.2±1.54	37.98±1.72	42.33±1.1	42.6±3.83
Overall mean	47.33±4.32	49.81±6.29	47.42±7.16	47.93±12.3	48.12±7.98

D_1, D_2, D_3, and D_4 referred to different diets, andT_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

Table 3: Concentration of Creatinine mg/dl in *C. gariepinus* males and females treated with different diets and temperatures at the end of the experiment

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	0.41±0.04	0.433±0.05	0.35±0.05	0.45±0.05	0.413±0.06
T_2	0.433±0.05	0.317±0.04	0.417±0.04	0.417±0.04	0.396±0.06
T_3	0.317±0.04	0.433±0.05	0.45±0.05	0.4±0.06	0.4±0.07
Overall mean	0.389±0.07	0.394±0.07	0.406±0.06	0.422±0.05	0.403±0.06

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

Table 4: Concentration of LH µ/l in female *C. gariepinus*

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	0.46±0.13	0.431±0.03	0.437±0.06	0.546±0.03	0.468±0.08
T_2	0.437±0.09	0.528±0.06	0.587±0.05	0.57±0.03	0.53±0.08
T_3	0.854±0.03	0.807±0.07	0.619±0.03	0.763±0.08	0.761±0.1
Overall mean	0.584±0.22	0.589±0.17	0.547±0.09	0.626±0.11	0.587±0.16

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

by temperature and diet. The concentration of LH positively increased with temperature from 24°C to 32°C. The highest concentration of LH was recorded in *C. gariepinus* with fishmeal-based diet (D_1) while soybean meal-based diet (D_2), reduced the concentration of LH in this study. The concentration of FSH reached at its maximum at 28°C then decreased with increasing temperature up to 32°C. The FSH and LH are important for better egg quality and successful fish reproduction. The fishmeal-based diet (D_1) produced the highest concentration of FSH while pea-meal based diet (D_3) produced the lowest concentration of FSH in this study. Water temperature regulates the level of GH. The best temperature for optimum production of GH in *C. gariepinus* was found to be 28°C in this study. The level of hormones increased from 24°C to 28°C then decreased at a higher temperature. Fish diet also has an essential role in GH regulation. It was observed in this study that fishmeal-based diet (D_1) increases the concentration of GH and pea-meal based diet reduces the concentration of GH in *C. gariepinus*.

3.3. Sperm Morphometries and Gonadal Weight

The effect of different diets and temperature and temperate and diet combinations on the sperm head, mid-piece, and tail of sperm of male fish of *C. gariepinus* is shown in Table 7. The sperm head length showed significant ($P < 0.05$) difference between variable diets and temperature and to different diet and temperature combinations. The highest length which was recorded was 2.348 ± 0.9 µm at T_{32} and D_4 and the lowest length was 1.395 ± 0.2 µm at T_{32} and D_2, respectively. The maximum length (2.348 ± 0.9 µm) of sperm head was found at the experimental condition of D_4 and T_3 while the minimum length (1.18 ± 0.03 µm) was found at T_{24} and D_2. The sperm head width showed a significant difference ($P < 0.05$) to diet as well as temperature. The length of sperm mid-piece showed a significant difference between all diets, temperature, and the combined effect of diet and temperature ($P < 0.05$). The maximum and minimum values are 425.00 ± 75.20 µm and 247.75 ± 73.11 µm at D_4 and T_3 and D_4 and T_1, respectively. The width of sperm mid-piece was statistically not significant at any temperature or diets, but the combined effect of diet and temperature showed significant ($P < 0.05$) difference in the width in the midpiece of sperm of *C. gariepinus*. The maximum width of sperm midpiece was 539.44 ± 34.67 µm at D_1 and T_1 and the minimum value was 292.13 ± 5.25 µm at T_{24} and D_4. The tail length of the sperms showed a significant difference between all diets, temperature, and their combinations. The highest and lowest values are 41.95 ± 6.99 µm and 9.09 ± 5.2 µm at T_{24} and D_2 and T_{32} and D_1, respectively. On the other hand, the width of the sperm tail was significantly different for diet and their combined effect ($P < 0.05$), but the temperature showed no significant difference on sperm tail length at $P < 0.05$. The highest and lowest values are 230.80 ± 36.90 µm and 155.75 ± 38.24 µm at T_{32} and D_4 and T_{28} and D_3, respectively. Sperm length determined the speed of the sperm which is important in fertilization success; a longer flagellum means a stronger propulsive force [30,31]. Various studies showed that there is no evidence of sperm morphology on sperm quality [32]. Other studies done in Salmon indicate that there is no influence of sperm morphology on the ejaculate longevity as well as no correlation between spermatocrit and sperm morphology [33].

Various combinations of temperature and diets showed a significant ($P < 0.05$) difference in the relative weight of testis of the male *C. gariepinus*. The highest and lower values were 0.935% ± 0.6% and 0.282% ± 0.13% at T_{24} and D_3 and T_{32} and D_4, respectively, shown in Tables 8.

The result showed that treatments with both temperature and diet gave significant differences between the average relative weight of the ovary of the catfish *C. gariepinus* ($P < 0.05$). D_1 and T_3 showed the highest relative weight of ovary as 17.266% ± 6.89% and the lower value at T_{24} and D_2 as 11.728% ± 5.33% as shown in Tables 9 and 10.

Unlike capture fisheries, the aquaculture involves human intervention in fish breeding to exceed the production and yield of the natural environment [34]. Temperature and diet management will improve gonadotropins and liver enzymes to achieve an effective development of fish sperms and ova to get successful egg fertilization and eventually maximize the fish number in the system. One of the most important problems of aquaculture development is the scarcity of fish fingerlings of the chosen species for culture [35]. We need to adjust temperature and diet quality to produce enough seeds for aquaculture development of the fish. This study indicates that the gonads or gonadosomatic index, quality of sperms, levels of gonadotropins, and liver enzymes

Table 5: Concentration of (FSH) µ/l in *C. gariepinus* males and females at the end of the experiment

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	0.737±0.03	0.7±0.04	0.742±0.03	0.755±0.03	0.733±0.04
T_2	0.789±0.01	0.759±0.04	0.738±0.01	0.713±0.03	0.75±0.04
T_3	0.609±0.03	0.57±0.02	0.566±0.02	0.597±0.04	0.585±0.03
Overall mean	0.712±0.08	0.676±0.09	0.682±0.09	0.688±0.08	0.689±0.08

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

Table 6: Concentration of GH ng/ml in the blood of *C. gariepinus* males and females at the end of the experiment

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	0.863±0.02	0.831±0.03	0.842±0.03	0.855±0.02	0.848±0.03
T_2	0.905±0.02	0.833±0.02	0.819±0.02	0.859±0.02	0.854±0.04
T_3	0.813±0.02	0.796±0.01	0.744±0.02	0.807±0.02	0.79±0.03
Overall mean	0.86±0.04	0.82±0.02	0.802±0.05	0.84±0.03	0.831±0.04

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

Table 7: Average morphometry (μm) of different parts of sperm of the *C. gariepinus* treated with different diets and temperature during the period of the experiment

Diet	Temperature	Descriptions					
		Head		Mid-piece		Tail	
		Length	Width	Length	Width	Length	Width
D_1	T_1	1.638±0.2	1.225±0.04	306.91±96.7	539.44±34.67	16.77±1.39	201.46±27.38
	T_2	1.88±0.5	1.54±0.5	78.55±59.41	335.64±66.35	19.65±8.03	176.82±32.33
	T_3	2.297±0.8	1.865±0.79	258.44±72.64	388.78±110.6	9.07±5.29	198.78±34.86
	Overall mean	1.94±0.6	1.54±0.6	282.77±78.1	423.36±115.1	15.55±6.99	191.94±32.45
D_2	T_1	1.457±0.1	1.18±0.03	312.72±38.82	385.72±20.66	41.95±2.85	181.08±28.38
	T_2	1.802±0.2	1.249±0.3	359.2±128.6	399±105.1	31.09±7.1	215.33±55.61
	T_3	1.395±0.1	1.202±0.1	352.9±76.34	416.7±73.81	11.44±6.86	188.78±20.6
	Overall mean	1.54±0.2	1.206±0.14	338.34±83.8	399.13±69.1	29.94±14	193.26±38.43
D_3	T_1	1.611±0.1	1.223±0.1	366.5±50.3	431.75±42.92	38.14±2.13	203.13±44.78
	T_2	1.735±0.2	1.203±0.1	349.5±93.71	522.38±110.4	25.95±1.36	155.75±38.24
	T_3	1.538±0.4	1.324±0.4	372.63±98.1	366±70.8	18.1±6.75	183.75±14.93
	Overall mean	1.63±0.3	1.25±0.24	362.88±80.42	440.04±100.4	27.48±9.31	180.88±38.96
D_4	T_1	1.613±0.2	1.2±0.04	247.75±73.11	292.13±77.19	20.13±1.68	211.25±22.75
	T_2	1.931±0.7	1.526±0.5	280±69.9	387.78±81.78	28.46±2.65	207.44±29.77
	T_3	2.348±0.9	2.102±1	452±75.2	537±149.5	32.59±15.4	230.8±36.9
	Overall mean	2.027±0.8	1.69±0.8	334±116	414.7±148.4	27.50±10.6	217.22±31.59

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

Table 8: Average testis/body weight % of African Catfish *C. gariepinus*

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	0.678±0.21	0.68±0.3	0.935±0.6	0.935±0.19	0.807±0.37
T_2	0.834±0.24	0.68±0.29	0.615±0.25	0.787±0.22	0.729±0.26
T_3	0.45±0.2	0.73±0.29	0.76±0.17	0.282±0.13	0.561±0.28
Overall mean	0.654±0.26	0.697±0.29	0.77±0.4	0.679±0.33	0.7±0.32

D_1, D_2, D_3, and D_4 referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment respectively

Table 9: Absolute and relative fecundity of *C. gariepinus*

Parameter	Length of fish (cm)	Weight of fish (g)	Absolute fecundity	Relative weight of testis (%)	Relative weight of ovary (%)
Range	27.80±2.06–34.00±1.23	169.20±8.12–277.85±11.31	54,060±489.06–294.315±1,987.63	0.935±0.60–0.282±0.13	11.728±5.33–11.728±5.33
Mean	31.13±3.97	217.51±10.98	125.178±607.72	0.7±0.32	14.684±4.86

cm: Centimeter, g: Gram

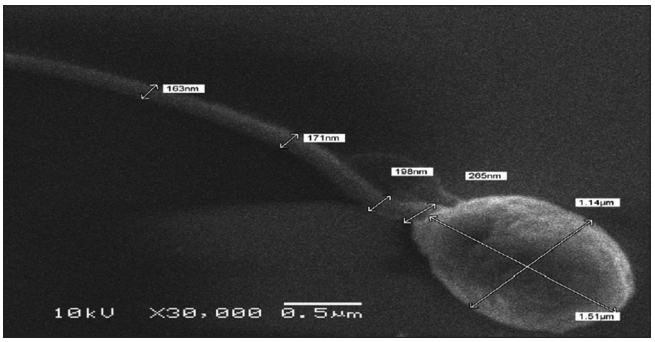

Figure 1: Scanning electron micrograph showing measurements of head, midpiece, and tail of *C. gariepinus* spermatozoa

showed the best performance at the temperature of 28°C and a diet of fishmeal and soy-meal. These parameters would provide the baseline to attain the best production for the aquaculture of *C. gariepinus* in future.

3.4. Fecundity

Fecundity is a very essential characteristic of fish culture because it gives an indication of the average reproductive feature of the fish [36]. The fecundity of *C. gariepinus* varied between 54,060 and 294,315 in this study; however, the absolute fecundity was calculated 125,178 ± 607.72 at T_{28} and D_2 [Table 9].

The regression analysis between fish fecundity and fish weight showed a high correlation coefficient (r^2) between the logarithm of fecundity and weight throughout the experimentation equal to 0.861 [Figure 2].

Table 10: Average relative weight % of ovary of African Catfish *C. gariepinusa* at the end of experimentation period

Parameter	Diet				Overall mean
	D_1	D_2	D_3	D_4	
Temperature					
T_1	15.864±4.58	11.7--28±5.33	13.89±3.1	12.126±2.17	13.402±4.2
T_2	16.98±6.45	14.287±4	12.892±4.4	14.605±3.7	14.693±4.84
T_3	17.266±6.89	16.612±6.72	15.584±3.62	14.364±2.48	15.957±5.24
Overall mean	16.706±5.91	14.209±5.68	14.122±3.81	13.698±3	14.684±4.86

D_1, D_2, D_3, and D_4referred to different diets, and T_1, T_2, and T_3 referred to temperatures T_{24}°C, T_{28}°C, and T_{32}°C that used for the experiment, respectively

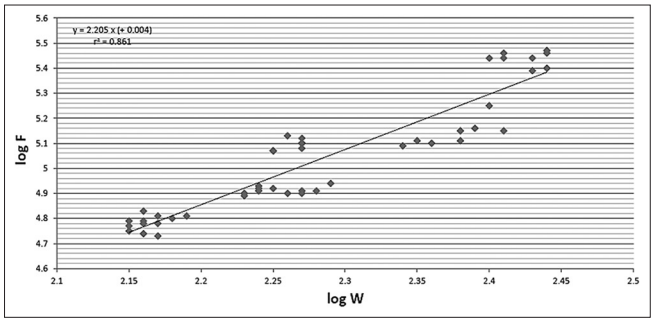

Figure 2: The relationship between log of fecundity and log of the weight of *C. gariepinus* tested with different diets and temperature for 4 months. Log = logarithm; F = fish fecundity; W = fish weight

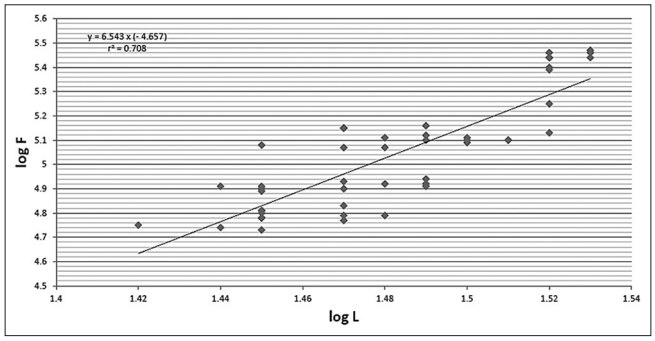

Figure 3: The relationship between logarithm of fecundity and total length of C gariepinus tested with different diets and temperature for 4 months. Log = logarithm; F = fish fecundity; L = fish length

The correlation coefficient (r^2) for the regression of logarithm of fecundity and total length also showed a similar result for *C. gariepinus* throughout the experimentation period with $r^2 = 0.708$ [Figure 3].

The total fecundity of fish is the total number of eggs of fish ovaries, while the relative fecundity is the amount of ovary egg per gram. Fish fecundity and egg qualities are important factors for fish breeding and the success of aquaculture. The present study revealed a high correlation between the logarithm of total fecundity and logarithm of both weight and length of the *C. gariepinus* with R^2 always >0.70, which mean that fecundity of *C. gariepinus* increased with weight and length of the fish. Similar kind of findings has also been reported in previous studies [35,37-39].

4. CONCLUSION

The effect of temperature and type of food on the growth, metabolism, and the physiological status of different species of fish has been studied previously [40-43]. The role of temperature and food type on fish growth and the performance of reproductive enzymes and hormones have been evaluated in *C. gariepinus* to achieve the successful aquaculture of this economically important catfish. The data in this study suggest an optimum temperate of 28°C for the best growth, fish fecundity and health of *C. gariepinus*. Moreover, the fishmeal and soymeal-based diets would be beneficial to attain the best growth and fecundity of this fish when combined with the optimum water temperature.

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