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Can varying photoperiod regimes alter the growth response, behaviour and physiology of *Clarias gariepinus*?

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ABSTRACT

To understand the welfare implication of photoperiod manipulation on *Clarias gariepinus*, fingerlings (n = 108) and juveniles (n = 108) of *C. gariepinus* with a mean weight of 3.75±0.03 g and 21.7±2.88 g were exposed to zero light (0L:24D)-T1, average light (12L:12D)-T2 and continuous light (24L:0D)-T3 in triplicates for 35 days. The highest mortality rate was recorded in T2 and T3 for the fingerlings (13.9%) and juveniles (22.2%). T1 recorded a significantly higher (p = 0.03) weekly growth rate and mean weight gain (MWG). Specific Growth Rate (SGR) and Feed Conversion Ratio (FCR) were highest in T1 for both fingerlings and juveniles. Lowest average swimming rate was observed in T1 while the highest aggressive act, bruises, and scars were recorded in T3 for fingerlings and juveniles. The highest (58.6 mg/dl and 56.9 mg/dl) plasma glucose was found in T3 for both fish categories. There were no significant differences (p = 0.11) among the average cortisol levels of both categories of fish at the different photoperiod regimes. Fingerlings and juveniles exposed to 24-hour darkness had a higher MWG, survival rate, SGR and FCR without any physiological stress. A photoperiod regime of 24-hour darkness is recommended for the culture of fingerlings and juveniles of *C. gariepinus* to boost fish production in the Aquaculture sector.

Keywords: African catfish; fish behaviour; fish growth; fish physiology; photoperiod manipulation

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Introduction

Globally, the world is occupied with over seven billion people, and it has been projected to increase to above nine billion by 2050 (UN-DESA, 2017); which is a challenge to the attainment of fish food security and the process of curbing malnutrition in society. Moreover, Anderson *et al.* (2017) reported a rapid increase in the consumption rate of fish products driven by increased awareness of the nutritional and health benefits of these aquatic products which necessitate attempts to boost the rate of fish production in the Aquaculture sector. The sector provides reliable fish food for the populace; the sector represents a potentially sustainable solution to bridging the gap

between the demands and supply of fish and its products for the growing world population (Dauda *et al*., 2018). Meanwhile, the Food and Agriculture Organization stated that global aquaculture production has increased over the past six decades (FAO, 2016). Thus the sector is designated as the fastest-growing food production sector in the supply of animal protein to the diet of the populace (FAO, 2016; 2017).

Animal protein is the most deficient or undersupplied nutrient in man's diet (Mekonnen & Lemma, 2011); however, the World Bank (2016) categorised fish as the most affordable and accessible source of protein. It is an important source of energy and protein, comparable to or better than many terrestrial types of meat (USDA, 2016). Its consumption has various health, environmental, social and nutritional advantages essential to cognitive and physical development, especially in children (FAO, 2014). It is important to note that catfish farming mostly dominates the Aquaculture sector in Nigeria (Adebayo, 2018), and the most favoured species is *Clarias gariepinus* (Adewumi & Olaleye, 2011; Megbowon *et al.*, 2014; Ojelade *et al.*, 2022). Aquaculturists mostly prefer the species due to its resistance to diseases, hardiness and fast growth rate for increasing fish production. Thus, commercial catfish farmers are in need of cheap, practical, and highly reliable methods of improving the quality and quantity of this fish species (Oresegun *et al*., 2007) to meet the continuous increase in fish demand.

Photoperiod manipulation has been successfully used to improve the growth of some fish species (Mustapha *et al.,* 2012). Adewolu *et al.* (2008) reported higher feed utilisation and growth response of *C. gariepinus* at different photoperiods. In addition, Mustapha *et al.* (2012) categorised photoperiod manipulation as one of the simple, low-cost techniques that can obtain faster growth during intense production of *C. gariepinus*. Samuel *et al.* (2021) affirmed the positive effect of photoperiod manipulation on the growth performance of *Heterobranchus bidorsalis*. In addition, Türker & Yıldırım (2011) proposed the application of photoperiod manipulation in aquaculture. This is to increase fish farming efficiency and to raise fish to commercial weight at the earliest possible time. Interestingly, most previous studies focused on the use of photoperiod manipulation to boost the growth rate of fish species without considering the effect of photoperiod manipulation on the behaviour, physiology and welfare of the cultured fish species which necessitated this study.

Meanwhile, Almazan-Reuda *et al.* (2005) stated that the alteration of photoperiod could impose stress, suppress immune functions, which could compromise the welfare of aquatic fish species. Environmental alterations such as photoperiod manipulation are potential sources of stress to aquatic organisms; it could lead to hormone changes or modification in the presence of favourable physiological parameters (Malini *et al*., 2018). Loss of appetite, slowed growth and increased glucose, or cortisol are documented indicators of stress response in teleosts (Bruce, 2002). Therefore, it is necessary to consider the behaviour and physiological needs of this cultured fish species at different photoperiod regimes before its application to boost growth rate or otherwise in aquaculture practices. Thus, this experiment was conducted to evaluate the physiological or behavioural response of fingerlings and juveniles of *C. gariepinus* to different photoperiod regimes under laboratory conditions.

Materials and Methods

Experimental site

This research was carried out at the fish hatchery complex of the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. It lies on latitude $7^0$10' N and longitude $3^0$2' E. At 76 m above sea level, in the tropics with an average temperature of 28.6°C.

Experimental fish collection and management

The research was conducted in accordance with the guidelines of the Animal Ethics Committee of the Federal University of Agriculture, Abeokuta, Nigeria. All the fish samples were given adequate care to eliminate all forms of stress and discomfort. The ethical approval number for the experiment was FUNAAB/AEWC/2021/0024.

A total of 216 samples of fingerlings (n = 108) and juveniles (n = 108) of *Clarias gariepinus* were purchased from a reputable fish farm and transported to the fish hatchery complex of the Federal University of Agriculture, Abeokuta, Nigeria at about 07:00 hours of the day. The fish were acclimatised in a circular tank with a capacity of 350 m^3 filled with water to two-thirds of its capacity for a week at a normal daylight photoperiod regime of 12 Light (L) and 12 Darkness (D). A flow-through system at 6.0 L/hr was maintained during the acclimatisation period, while a partial water exchange of half of the volume of water in the tanks was carried out every other day. The experimental fish were fed at 5% of their body weight with a commercial diet (45% C.P.; 3,100 kcal digestible energy) at 08:00 and 17:00 hours daily (Fawole *et al.* 2020).

Experimental setup and photoperiod manipulation

The weight of the experimental fish at the start of the experiment was measured with a sensitive Metler weighing balance (Model 1106) to the nearest 0.01 g. 12 healthy specimens of fingerlings and juveniles with an average weight of 3.75±0.03 g and 21.7±2.88 g respectively were stocked per tank in triplicates. Each tank was randomly assigned to each of the three photoperiod regimes as described by Turker & Yildrim (2011) under laboratory conditions. 18 plastic tanks (nine tanks each for the fingerlings and juveniles) each of dimensions of 1.7×1.2×1.0 m were constructed in a flow-through system at a flow rate of 6.0 L of water per hour, while a partial water exchange of half of the volume of water in the plastic tank was done every other day. Six aquarium compressors (H.P.-200, 30 GPH) with three outlets each were installed to complement the flow-through system to maintain good water quality throughout the experimental period.

To examine the effect of the different photoperiod regimes on the welfare of the cultured *C. gariepinus*, each of the 18 culture tanks was randomly subjected to one of the three light treatment regimes for a 35-day culture period as described in Carlos *et al.* (2015). Tanks in T1 (0L:24D) were placed in a simulated dark room within the hatchery to prevent light penetration from normal daylight while T2 (12L:12D), which also serves as the control, was exposed to the usual darkness and lighting of the day under laboratory conditions. A 40 W fluorescent lamp was used for illuminating the tanks in T3 (24L:0D) at a distance of 100 cm from the surface of the water throughout the study period (Mustapha *et al.*, 2012).

Feeding of experimental fish species

The response of the cultured fingerlings and juveniles of *C. gariepinus* to feed was estimated using the method described by Zworykin (2017). The total number of pellets consumed per ration was estimated during each feeding time. All uneaten feeds were removed 10 minutes post-feeding to prevent impairment of water quality.

Growth Performance Estimation

All fish samples from each tank were weighed weekly to the nearest 0.01 g to note their weight gain and to re-estimate their quantity of feed with respect to their weight gain. Growth parameters were estimated according to Fawole *et al.* (2020) as follows:

Survival rate (%): (INF – FNF)/INF*100 ---1

Mean weight gain (g): FW – IW ----------2

Specific Growth Rate (g/day)

$$\left[\frac{(\ln FW - \ln IW)}{t}\right] * 100 \text{----------3}$$

Feed Conversion Ratio (FCR): FI /BWG------4

Where,

INF = Initial number of fish stocked

FNF = Final number of fish stocked

FW = Final mean weight gain

IW = Initial mean weight

t = Duration of the experiment

ln FW = Natural logarithm of the final weight of fish

ln IW = Natural logarithm of the initial weight of fish

FI = Feed Fed (g)

BWG = Body weight gain (g)

Fish behaviour

The behavioural traits of the experimental fish were assessed by direct observation of the behavioural attributes displayed by the stocked fingerlings and juveniles at the three photoperiod regimes for 10-minutes per scan sampling during feeding time (8 am and 5 pm) twice per week (day 2 and 5 of each week) throughout the experimental period as described by Pablo *et al*. (2003). Sidewalls of experimental aquaria were shaded with opaque black material from the outside to avoid disturbance during direct observation. Stopwatches were used for time countdown to observe the period of active swimming and resting. The frequency of aggressive acts and escape attempts was recorded and the number of fresh bruises and scars per specimen and treatment was also recorded during the water exchange. The description of the behavioural traits measured is given in the ethogram in Table 1.

TABLE 1

Ethogram of the measured behavioural variables

Behavioural traits	**Description**
Active swimming	The duration of the continuous movement of the fish within 600 seconds
Resting time	The duration of staying on a spot/lying motionless at the bottom of the tank
Aggressive acts	The Frequency of instances of chasing that leads to contact between the mouth and body of a fish to inflict a mark or injury
Escape attempts	A strive to jump out of the culture tank
Bruises and scars	The number of tender injuries on skin/marks left after healing of an injury

Blood sampling and measurement of physiological parameters

Blood samples were collected after the 35-day culture period to determine the physiological effect of the applied photoperiod regimes. Fingerlings and juveniles of *C. gariepinus* were starved 24hours prior to blood sampling. Blood samples were collected between 07:00 and 09:00 hours. Sampled fish species (n = 6) per treatment were netted from the experimental tanks and anaesthetised with MS222 in a 20 litres bucket of water; blood samples were collected at the caudal vein using a 2.5 ml heparinised syringe with 22Gx1½" according to the method of Di Marco *et al.* (2007). Collected blood was gently pushed into a sterilized microfuge tube containing anticoagulant (20m MEDTA). The whole blood withdrawal process took less than three minutes to prevent discomfort. The samples were analysed at the central Biotechnology Laboratory of the Federal University of Agriculture Abeokuta using the spectrophotometric method (Brown *et al*. 2004).

Data collection and analysis

Normality and homogeneity of all obtained data were done using the Shapiro Wilk test. Non-parametric analysis was done for data set that were not normally distributed, while a generalised linear model was used for data set that were normally distributed. A one-way analysis of variance (ANOVA) was carried out to test the effect of the treatments on the experimental fish species at a 95% (0.05) confidence limit. Obtained results were expressed as means ± Standard Error (S.E.). Statistical analyses were performed using SPSS Statistical Package 23.0 (IBM 2021, Chicago, USA).

Results and Discussion

Table 2 summarizes the mean values of the water quality parameters obtained at the different photoperiod regimes. The highest (6.46±0.32 mgl^{-1}) mean dissolved oxygen and least (28.49±0.65°C) temperature average was recorded in African catfish exposed to 24-hour darkness (Table 2). The survival rate of fingerlings and juveniles of *Clarias gariepinus* exposed to different photoperiod regimes varied across the three treatments. Fish exposed to 24-hour darkness (T1) had the highest (100%) survival rates for the fingerlings and juveniles catfish, while the least (86.1% and 77.8%) was recorded in fingerlings exposed to 24-hour light (T3) and 24-hour darkness (T1) for both fingerlings and juveniles, respectively (Table 3).

The weekly growth rates of *C. gariepinus* fluctuated throughout the experimental period with the highest weekly weight gain consistently found in the photoperiod regime of total darkness for both the fingerlings and juveniles, respectively (Figure 1). After the 35 days culture period, there were no significant differences (p = 0.08) in the feed responses of fingerlings and juveniles exposed to the various levels of photoperiod regimes. However, the highest (p = 0.02) feed response for both groups was observed in T1 while the least (p = 0.03) was found in T3 (Table 4). There were no significant differences (p = 0.21) in the weekly growth response between T2 and T3 for the fingerlings as well as between T1 and T2 for the juveniles of the cultured *C. gariepinus*. Mean Weight Gain (MWG) and Specific Growth Rate (SGR) were significantly higher (p = 0.01) for the fingerlings and juveniles exposed to no period

of light (T1) than those exposed to a normal-day light (T2) photoperiod regime. The best (p = 0.00) Feed Conversion Ratio (FCR) for the fingerlings and juveniles of *Clarias gariepinus* was found in the fish species exposed to no period of light (T1) regardless of size (Table 4).

The non-invasive method used to assess the behavioural traits and welfare of the fish species at different photoperiod regimes is presented in Figure 2. The fingerlings and juveniles exposed to a photoperiod regime of total darkness (0L:24D) had the least (6 min, 47 secs & 6 min, 39secs) swimming period for both sizes of fish throughout the study period. On the contrary, fingerlings and juveniles exposed to a photoperiod of no darkness (24L:0D) displayed the highest (76.3% and 78.9%) level of swimming time, aggressive act with a corresponding escape attempt and increased number of bruises and scars.

Physiologically, a higher (58.6 mg/dl and 56.9 mg/dl) plasma glucose level was obtained in T3 for both the fingerlings and the juveniles of *C. gariepinus*. There were significant differences (p = 0.02) in the levels of plasma glucose recorded for the fingerlings and the juveniles among all treatments (Figure 3). The highest (121.06±1.32 ng/ml and 107.51±1.04 ng/ml) average cortisol level was recorded in T3 for both fingerlings and juveniles respectively. There were no significant differences (p = 0.11) in cortisol levels for the two size groups among all treatments (Figure 4).

TABLE 2

Mean water quality parameters of C. gariepinus exposed to 0L:24D, 12L:12D and 24L:0D photoperiod regimes

Photoperiod regime	**Temperature (°C)**	**pH**	**Dissolved Oxygen (mg/l)**
0L:24D	28.49±0.65	6.74±0.03	6.46±0.32
12L:12D	28.65±0.69	6.86±0.05	6.42±0.25
24L:0D	28.97±0.73	6.91±0.10	6.32±0.18

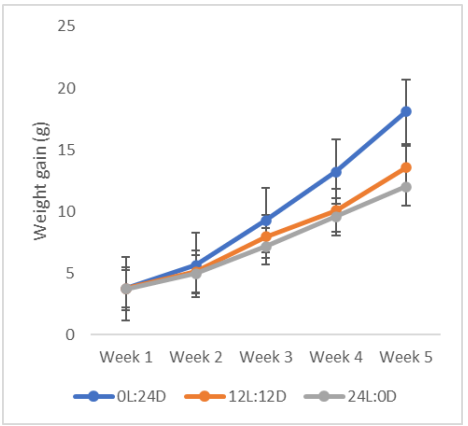
TABLE 3

Survival rate of fingerlings and juveniles of Clarias gariepinus exposed to different photoperiod regimes under laboratory conditions for 35 days

		Fingerlings			Juveniles		
T	Photoperiod	INS	NMR	PSR	INS	NMR	PSR
T1	0L:24D	36	0	100	36	0	100
T2	12L:12D	36	5	86.1	36	6	83.3
T3	24L:0D	36	3	91.7	36	8	77.8

L = Light, D = Darkness, INS = Initial number stocked, NMR = Number of mortality recorded, PSR = Percentage survival rate, T = Treatment

a



b

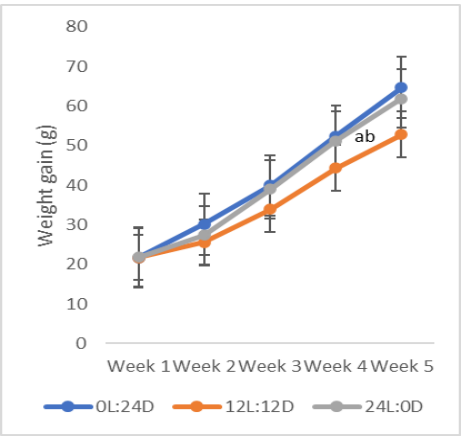


Fig. 1: Weekly growth curves (mean ± S.E) of a) fingerlings and b) juveniles of *Clarias gariepinus* reared at different photoperiod regimes. Values at the same point with different

TABLE 4

Growth indicators of fingerlings and juveniles of Clarias gariepinus exposed to (0L: 24D, 12L:12D; 24L:0D) photoperiod regimes

	0L:24D (T1)	12L:12D (T2)	24L:0D (T3)
Fingerlings			
Feed intake (g)	29.5±2.6^{a}	28.6±2.1^{a}	27.9±2.0^{a}
Initial body weight (g)	3.76±0.6^{a}	3.75±0.2^{a}	3.73±0.5^{a}
Final body weight (g)	18.09±1.5^{a}	13.56±0.4^{bc}	12.01±0.6^{b}
Mean weight gain (g)	14.33±1.09^{a}	9.81±0.64^{b}	8.28±0.98^{c}
Specific growth rate (g/day)	1.67±0.0^{a}	1.26±0.03^{b}	1.09±0.01^{c}
Feed conversion ratio	1.51±1.03^{a}	1.19±0.61^{b}	1.37±0.83^{c}
Juveniles			
Feed intake (g)	65.7±5.32^{a}	64.9±3.9^{a}	63.8±3.63^{a}
Initial body weight (g)	21.7±2.88^{a}	21.6±2.80^{a}	21.8±2.91^{a}
Final body weight (g)	64.7±6.13^{a}	52.8±4.23^{c}	61.9±5.64^{b}
Mean weight gain (g)	42.9±3.11^{a}	31.0±2.56^{c}	40.1±2.98^{ab}
Specific growth rate (g)	1.59±0.81^{a}	1.27±0.03^{bc}	1.30±0.06^{b}
Feed conversion ratio	1.42±0.08^{a}	1.14±0.03^{b}	1.13±0.06^{bc}

(0L:24D) = 0-hour light and 24-hour darkness, 12L:12D = 12-hour light and 12-hour darkness 24L:0D = 24hours light and 0-hour darkness; Values (mean±S.E.) in the same row with different superscripts are different at a 95% confidence limit

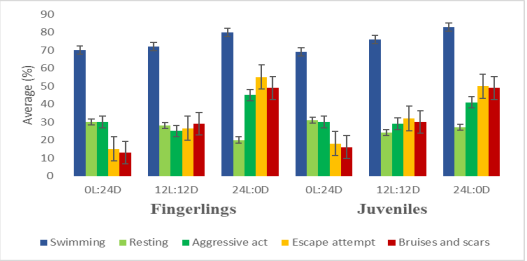


Fig. 2: Behavioural attributes of fingerlings and juveniles of *Clarias gariepinus* at (0L: 24D, 12L:12D; 24L:0D) photoperiod regimes

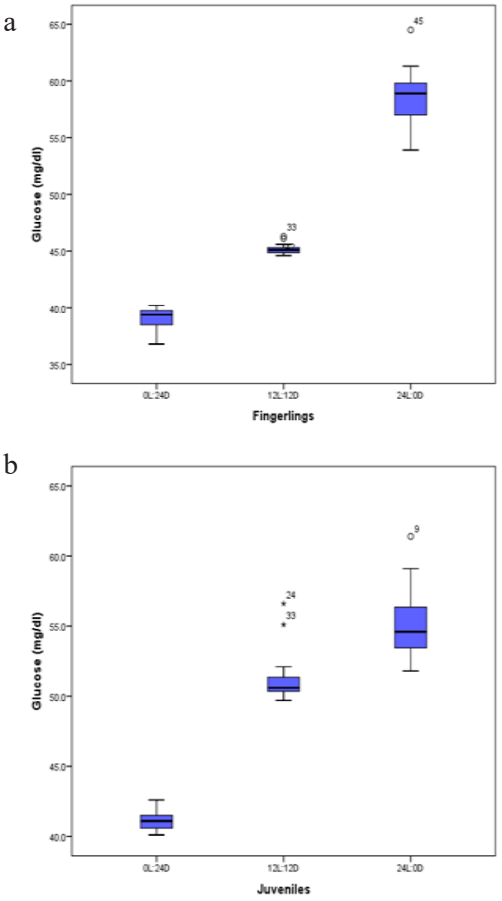


Fig. 3: Average plasma glucose in a) fingerlings and b) juveniles of *Clarias gariepinus* exposed to 0L:24D, 12L:12D, 24L:0D photoperiod regimes

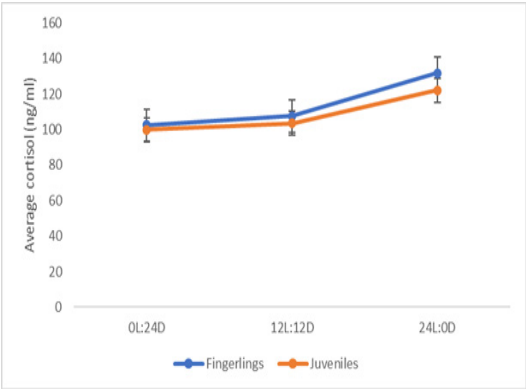


Fig. 4: Average cortisol (ng/ml) of fingerlings and juveniles of *Clarias gariepinus* exposed to 0L:24D, 12L:12D, and 24L:0D photoperiod regimes. Means with different superscripts are significantly different at $p < 0.05$

All living organisms, including aquatic species, respond to the cyclic changes of environmental factors called circadian rhythm (Carr *et al*., 2006). This rhythm influences the biochemical, physical, behavioural, and physiological attributes of fish species and they are ultimately determined by the daily and annual photoperiod regime (Falcon *et al.*, 2009). However, photoperiod manipulation has been used to increase fish farming efficiency to get the cultured fish species to an average weight of 27.39±0.16 g at the earliest possible time (Turker & Yildrim, 2011); without research on the implication of manipulation of photoperiod regime on the welfare and or physiology of these aquatic species.

The highest mean dissolved oxygen and least temperature found in this study at a photoperiod regime of 24-hour darkness are similar to the findings of Mustapha *et al.* (2012), who reported a similar range of water quality parameters in juvenile African catfish exposed to a photoperiod regime of continuous

darkness. This study found the highest survival rate at a photoperiod regime of total darkness for the fingerlings and juveniles of *Clarias gariepinus*. The highest survival rates obtained in this study at a photoperiod regime of total darkness are similar to the findings of Mustapha *et al.* (2014) and Bazeera *et al.* (2008) who also reported the highest survival rates in juveniles of *C. gariepinus* with an average weight of 76.8±1.0 g and fingerlings of *O. niloticus* with a mean size of 3.1±0.058 g exposed to continuous darkness in their study respectively.

On the contrary, the lowest survival rate was recorded in fingerlings of *C. gariepinus* with a mean size of 3.75±0.03 g cultured at 24-hour of continuous light. The level of mortality observed in this study at a photoperiod regime of continuous light could have resulted from the stressful effects of light, which increased the swimming rate, aggression, physical attack, injury and mortality in the African catfish. This result corroborates the findings of Mino *et al*. (2008) who reported a high level of mortality rate in fingerlings of *Clarias macrocephalus* exposed to a continuous light photoperiod regime.

In addition, Appelbaum & Kamler (2000) reported that continuous exposure of larvae of *Clarias gariepinus* with a mean size of 2.15±0.12 g to 24-hour light increased mortality, while Solomon & Okomoda (2012) linked increased mortality of juveniles of *C. gariepinus* exposed to a 24-hour light regime to a higher incidence of light. Therefore, it could be deduced that continuous exposure of *C. gariepinus* to 24-hour, 40 watts fluorescent light might reduce the survival rate, which invariably depends on the physical and chemical quality of the water in their rearing tanks, and the adaptation of the fingerlings or juveniles African catfish to those conditions (Oresegun *et al*., 2007).

The slightly higher feed response recorded for fingerlings and juveniles of *C. gariepinus* in this study at a photoperiod regime of 24-hour darkness showed that light availability reduced the feed intake of *C. gariepinus*. The observed highest response to feed at a photoperiod regime of 24-hour darkness further confirms that African catfish is a non-visual feeder that does not depend on light availability for sourcing or locating its food (Hossain *et al*., 2001). These findings are in line with the assertion of Adewolu *et al*. (2008), who stated that photoperiod manipulation to a period of 24-hour darkness enhanced the feed utilisation of *C. gariepinus* during the study period. Photoperiod manipulation to a period of 24-hour darkness is an acceptable method of boosting the feed response and the growth rate of fish species under laboratory conditions (Lundova *et al*., 2019).

In the current study, fingerlings and juveniles of *C. gariepinus* cultured at a photoperiod regime of continuous darkness had the best growth parameters compared to other photoperiod regimes. This could have resulted from better food conversion efficiency (Almazan-Rueda *et al*., 2005) and the conversion of energy gained from metabolic activities to body growth (Mustapha *et al*., 2014). These findings are similar to the report of Appelbaum & Kamler (2000) and Adewolu *et al*. (2008), who reported an increase in growth of *C. gariepinus* exposed to total darkness (0L:24D), which was attributed to high feeding activity and complete utilisation of the consumed feed. In contrast, Turker & Yildrim (2011) reported a higher growth rate and better utilisation of feed in juveniles of rainbow trout with a mean size of 27.39±0.16 g exposed to a 24-hour light photoperiods regime. This observed difference in growth

performance could be attributed to variations in fish species used and the geographical location of the studies. Groups exposed to artificial continuous light regimes in this study had the least mean weight gain. This observed low weight gain in the photoperiod regime of 24-hour light could be because they expend the energy gained in trying to maintain homeostasis in their modified rearing enclosure (Villamizar *et al*., 2011).

In addition, the highest specific growth rate recorded under total darkness might be a result of the slightly higher feed intake as a nocturnal animal in a dark environment and the fact that most of the energy gained was converted to growth and not expended on increased metabolic activities. Moreover, the positive effect of photoperiod manipulation to total darkness on the growth performance of *C.gariepinus* in this study could further be attributed to the fact that its growth is affected by day length with fish performing better under short-day photoperiods (Mustapha *et al*., 2014). Thus, prolonged light exposure upto 24-hour per day could reduce the feeding intake of fish which could invariably inhibit growth in the presence of other favourable environmental conditions such as good quality and quantity of water, adequate feed availability among others (Taylor *et al*., 2006; Shahjahan *et al*., 2020).

The non-invasive welfare indicators used in this work showed that both the fingerlings and juveniles African catfish thrived well at a photoperiod regime of continuous darkness with a reduced swimming rate throughout the 5-week experimental period. This implies that photoperiod manipulation to total darkness did not alter or compromise the welfare of the cultured *C. gariepinus.* These findings is in line with the assertion of Almazán-Rueda *et al.* (2005), who reported similar behavioural traits in *C. gariepinus* at a photoperiod regime of continuous darkness. The findings of this study also corroborate the assertion of Appelbaum & Kamler (2000) who concluded that the behaviour of African catfish and their welfare are dependent on their life stages.

Highest plasma glucose level was recorded at the photoperiod regime of 24-hour light for the fingerlings and juveniles of *C. gariepinus*. These findings contradict the report of Biswas *et al.* (2004), who obtained higher plasma glucose and cortisol in Nile Tilapia fish samples cultured at a normal (12L:12D) photoperiod compared to a 24-hour light photoperiod regime. However, the higher level of glucose found at 24-hour light compared to a photoperiod regime of 12-hour light and zero-hour light fell within the normal range of 109.8 to 127.8 mg/dl reported by Jana *et al.* (2016). This could be a result of the hyperactive lifestyle of the African catfish species in the process of fighting against their nocturnal nature. The recorded low level of glucose at a photoperiod regime of 24-hour darkness compared to the 12-hour light regime is in line with the result of Mustapha *et al.* (2014), who reported a lower glucose level in juveniles of *C. gariepinus* exposed to 24-hour darkness compared to the African catfish exposed to 24-hour light. Since there were no significant differences in the levels of cortisol in the blood samples of *C. gariepinus* in this study, photoperiod manipulation did not compromise the welfare of the fish under laboratory conditions.

Conclusion and Recommendation

Modifying the rearing enclosures of fingerlings and juveniles of *C. gariepinus* to a photoperiod regime of total darkness greatly enhanced the survival rates, feed responses and mean growth rates of *Clarias gariepinus* under

laboratory conditions. Also, a photoperiod regime of 24-hour darkness gave the best growth indices, reduced aggressiveness and number of bruises and scars compared to the fingerlings and juveniles cultured in other photoperiod regimes. In addition, the lowest stress (glucose) level was found in the photoperiod regime of 24-hour darkness. The results of this study provides an insight into the significance of photperiod manipulation to improve the production efficiency of the fingerlings and juveniles of *C. gariepinus*. This study recommends that the modification of the rearing enclosures of fingerlings and juveniles of *C. gariepinus* to a photoperiod regime of total darkness could be applied in the commercial settings to increase the production rate and reduce the aggressiveness of *Clarias gariepinus* for improved fish food security and sustainability.

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