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Impact of the Color of Rearing Tank on Behavior and Growth of Nile Tilapia, *Oreochromis niloticus* (Linnaeus, 1758)

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Abstract

This study examined the impact of tank color (black, red, blue, green, and transparent) on the behavior (boldness and aggressiveness) and growth of Nile Tilapia over nine weeks (first, third, sixth, and ninth weeks). Boldness and aggression levels were assessed using open field and mirror image tests for individual Nile Tilapia (*Oreochromis niloticus*). Healthy Nile Tilapia, weighing 2.51g on average, were used in the experimental trials conducted in tanks of different colors. The findings indicated that red tanks appeared to foster the highest level of boldness ($p<0.05$). In contrast, fish in transparent tanks exhibited the highest level of aggressiveness compared to other tanks ($p<0.05$). Moreover, individuals in black tanks displayed the highest growth rate in terms of weight ($p<0.05$). This study suggests that *O. niloticus* can thrive better in black-rearing tanks, as the black tanks appear to enhance the growth rate of the fish, possibly through improvements in physiological processes.

INTRODUCTION

Behavior or personality traits differentiate one animal from another. These traits can include swimming performance, reproductive reactions, boldness, and aggression. Boldness and aggression are two specific behavioral traits that have garnered significant interest from behavioral ecologists (Ariyomo and Watt, 2015).

Boldness is the propensity of an animal to engage in risky behavior. The shy–bold axis of behavior has received increasing attention, especially from ecological researchers. Individual variation along this axis may have important consequences in many contexts across an individual's lifespan given that boldness may influence success in mating competition, feeding, adjusting to environmental change, and responding to predators, subsequently influencing individual fitness (Toms *et al.,* 2010).

Aggressive behavior plays an important role in reproduction and survival and can involve actual or potential harm to another individual (Ariyomo and Watt, 2015). It also refers to a negative attitude displayed toward another by applying physical contact or force. According to Reebs (2008), the most aggressive, usually the fastest-eating animal occupies the best shelter and gets most of the food available in the environment, consequently influencing the growth rate of individuals within an

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ecosystem. Therefore, aggressive display is necessary for the survival of some fish species in their environment.

Growth is the permanent increase in the size of an organism. The increase may be through body length, girth, and weight that occur when an animal is given adequate food, water, and shelter. The growth rate of fish populations is related to environmental conditions (Khan and Khan, 2014), such as temperature, oxygen, the wavelength of light (color), etc. The environmental color appears to be important to fish as some colors have been shown to influence the physiology, stress response, growth, feeding, and reproduction of different fish species. The effect of environmental color on animal physiology and behavior is a developing field. In nature where water bodies have great depth when light enters the water, the light rays with shorter wavelengths (e.g. blue, violet, and green) penetrate deeper than those with longer wavelengths (e.g. red) (Ruchin, 2004), therefore, in the natural environment, blue, green and infrared are common (Elnwishy *et al*., 2012).

However, in enclosed spaces such as in the laboratories and indoor facilities used in aquaculture, the spectrum of the simulated lights used (which have fewer blue photons than red) is different from the sun's spectrum (Robinson, 2012). Moreover, in the laboratories and indoor facilities used in aquaculture, the depths are shallower and less turbid than in nature, hence, the absorption and scattering of light wavelengths are much less than in nature. Consequently, the coloration of the laboratories and indoor facilities used in aquaculture may impact the behavior, feeding, and growth of fish (Mesa and Schreck, 1989).

In this study, *O. niloticus* was used given that it is a cichlid fish with high ecological, nutritional, and economic importance. It serves as a rich source of food (protein). It is a species that accepts artificial diets, is resistant to disease, has good and reasonable feed conversion ability, and breeds in captivity. Its growth and behavior are very important areas of research in the study of the species and they must be cultured properly for maximum production. Environmental factors such as light, temperature, color, etc. play a crucial role in the life of organisms (fish) as they affect their behavior and responses in their life processes. Some fishes are photophobic and see light or brightly colored environments as a stressor. Also, the color of the environment influences the body color of many fishes as seen in the case of *Clarias gariepinus* (African catfish).

C. gariepinus reared in a shaded environment appear darker than their counterparts reared in a bright environment. Moreover, the color of the rearing environment affects the behavior (either boldness or aggressiveness) of fish. The shy fishes hardly come out and are reluctant to approach a food source. This reduces their feed intake which also affects their growth, development, reproduction, resistance to diseases, etc. On the other hand, aggressive fishes are hyperactive having an increased rate of metabolic activities in them. Although they feed better than non-aggressive ones, their increased metabolic rates utilize a higher percentage of the energy and nutrients that could have been used for normal life processes hence they may be small in size in the long run.

It is therefore imperative to investigate the color of rearing facilities that will give the normal behavior and responses in aquaculture fish species (*O. niloticus*) to reduce environmental stresses that may be imposed and increase their feed utilization ability. Therefore, this present research investigated and determined the color of the rearing facility suitable for the production of *O. niloticus* to reduce stress due to environmental factors and increase their feed utilization for normal growth and development.

METHODOLOGY
Ethical Approval

All procedures were carried out in the Analytical techniques laboratory of the Department of Fisheries and Aquaculture

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following the ethical standard of the animal ethics committee of Federal University, Oye Ekiti, Nigeria.

Place and Time

The experiment was carried out in the laboratory of the Department of Fisheries and Aquaculture, Federal University Oye Ekiti, Ekiti State. 150 *O. niloticus* were collected from Chilanfarmz Agro Enterprises in Ibadan, Nigeria, and transferred in oxygenated plastic bags to Federal University, Oye Ekiti's Analytical Techniques laboratory and acclimatized for two weeks while the main experiment lasted for 9 weeks.

Research Materials

Transparent tanks, blue tanks, red tanks, green tanks, black tanks, Water test kit (Hanna-HI3817), weighing scale (TS500-GE779CA104IXUNAFAMZ) net, ruler, siphoning hose, camera (Canon 7D Mark II), marker, mirror, white plain sheet of paper, SPSS system software for Data analysis.

Research Design

The study began with a 14-day acclimatization period for the experimental fish, during which they were fed a commercial diet. Using a completely randomized design, 150 *O. niloticus* juveniles (average weight 2.51g) were randomly distributed into 15 plastic tanks for a 5-treatment setup, each with three replicates.

Work Procedure

Fish Collection and Acclimatization

A total of 150 Nile tilapia mixed-sex juveniles weighing an average of 2.51g were selected for acclimatization and were fed twice daily with commercial feed. Physiochemical parameters of water such as temperature, dissolved oxygen, salinity, total dissolved solids, and pH levels were measured using established procedures before stocking and after stocking the fish. Ten (10) fish were randomly allocated in each of the blue, red, green, black, and clear aquariums after the acclimation phase.

Monitoring of Water Quality Parameters

During the experimental period, the water temperature, dissolved oxygen, Total dissolved solids, and pH were monitored using a water test kit. Uneaten feeds were regularly siphoned changing not more than 10% of the holding water at a time. The temperature was determined using mercury in a glass thermometer calibrated in (°C). It was inserted into the water in each of the plastic tanks containing individual fish then the readings were taken.

Behavioral Test

Test of Boldness

The open-field test was used to test for the boldness of fish following the procedure outlined by Ariyomo and Watt (2015). A tank measuring 60 X 30 X 23.4 cm (Length X Breadth X Height) with its bottom marked into 72 squares (Fig. 1), filled with 10 liters of water was used as the open field. Each fish was placed in the middle of the tank and left to acclimatize for 60 seconds. After the acclimatization period, the number of lines crossed by each fish in the subsequent 180 seconds was recorded as a measure of boldness for each fish. A high rate of movement was also taken as an indicator of boldness because it reflected the fish's ability to explore its environment. Fish was tested for boldness after stocking in the first, third, sixth, and ninth weeks.

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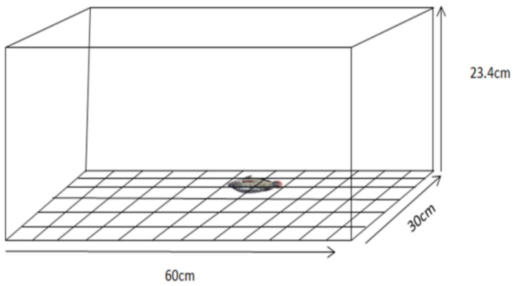

Figure 1. Diagrammatic representation of the open field test. Adapted from Ariyomo and Watt (2012).

Aggression Test

The inclined mirror test was used to measure the aggressive behavior of each fish as outlined by Ariyomo and Watt (2015). A glass tank measuring 60 X 30 X 23.4 cm was filled with 10 liters of water. A mirror was placed on the side of the tank at an angle of 22.5° (Fig. 2). An opaque material was also used to cover the mirror before the start of the experiment and a fish was placed at the center of the tank and left to acclimatize for 60 seconds. The number of aggressive interactions the fish made towards its mirror image in 300 seconds after the removal of the opaque material was counted and recorded.

The aggressive interactions include the number of bites, nips, and fast bouts of movements toward the mirror image and the number of displays were recorded immediately after counting. Fish were returned to their tanks once they had been tested. To ensure uniformity in hunger levels, fish were fed only after the experimental trial on the test day. Fish was tested for aggression in the first, third, sixth, and ninth weeks.

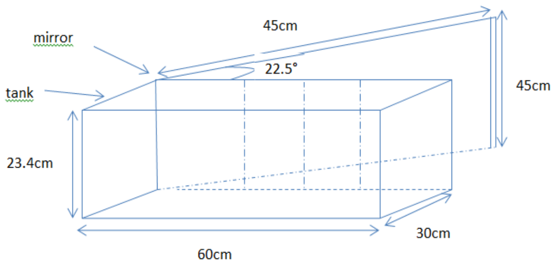

Figure 2. Diagrammatic representation of the mirror test. Adapted from Ariyomo and Watt (2012).

Growth Monitoring

The weight of the fish was taken using a loading digital weighing scale. The weighing exercise was done in the first, third, sixth, and ninth weeks.

Data Analysis

The data collected were subjected to a one-way statistical analysis of variance (ANOVA) and the significant differences in means were determined using Duncan's Multiple Range Test. The tests use SPSS software, version 20 (2011). The statistical significance of the parameters measured was set at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

Boldness of *O. niloticus* in the Different Colored Tanks Across Weeks

There were significant differences in the mean boldness level of fish in the different colored rearing tanks across weeks ($F_{4, 49} = 1.83$; $p<0.05$, Fig 3). During the first week, boldness did not differ significantly among the different colored rearing tanks ($p>0.05$). However, in the

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third week, boldness differed significantly among individuals in the different colored rearing tanks ($p<0.05$) with the highest level of boldness recorded in fish in the blue and transparent tanks but boldness did not differ significantly between fish in these two tanks ($p>0.05$). Fish in the green and red tanks had similar boldness levels ($p>0.05$) and were the least bold in the third week. The boldness of fish in the black tank was significantly higher than fish in the green and red tanks ($p<0.05$) but significantly lower than fish in the blue and transparent tanks ($p<0.05$).

In the sixth week, the boldness of fish in the black and transparent tanks was not significantly different ($p>0.05$) but the levels of boldness in the black and transparent tanks were higher and differed significantly from the boldness of the individuals in the blue and red tanks ($p<0.05$). Fish in the red tank were significantly less bold than those in the blue tank ($p<0.05$).

In the ninth week, boldness was significantly lower in fish raised in the black tank ($p<0.05$) than those reared in the red and transparent tanks but the boldness of fish was significantly higher in the red tank than in the transparent tanks ($p<0.05$).

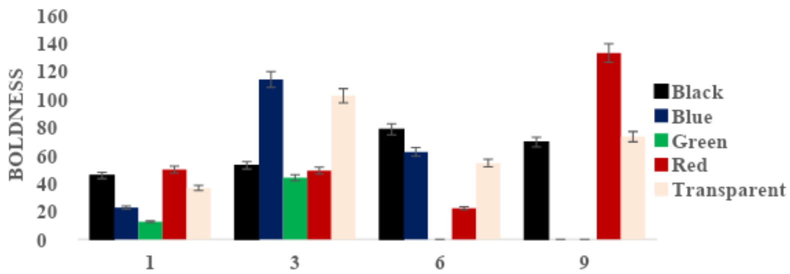

Figure 3. Boldness levels of *O.niloticus* in the different colored tanks across weeks.

Aggressive Behavior in *O. niloticus* in the Different Colored Tanks Across Weeks

The means of the number of aggressive interactions of fish in the different colored rearing tanks across weeks were significantly different ($F4, 49 = 4.42$; $p<0.05$, Table 1). Aggressive interactions of fish in week one of the study were similar ($p>0.05$) in the blue, green, red, and transparent tanks. However, aggressive interactions were significantly higher in the black tank (58.8) than in the individuals in the blue, green, red, and transparent tanks ($p<0.05$).

Fish in the blue and transparent tanks were significantly more aggressive than those in the black, green, and red tanks, during the third week. Fish raised in the black, blue, and transparent tanks showed similar rates of aggression ($p>0.05$) in the sixth week, these rates of aggression were significantly higher than fish in the red tank ($p<0.05$) with the lowest aggressive interactions. Furthermore, in the 9^{th} week, mean aggressive interaction was significantly lower in fish raised in the red tank ($p<0.05$) than those reared in the black and transparent tanks.

Table 1. Aggressive Behaviour in *O. niloticus* during the mirror test across weeks.

Period/Color	Black	Blue	Green	Red	Transparent
Week 1	58.80 ± 23.66^{b}	7.30 ± 2.30^{a}	5.10 ± 1.79^{a}	8.4 ± 2.27^{a}	12.90 ± 3.14^{a}
Week 3	15.40 ± 8.82^{a}	31.40 ± 13.91^{b}	11.20 ± 2.33^{a}	9.80 ± 2.22^{a}	23.20 ± 8.00^{b}
Week 6	28.60 ± 8.90^{b}	29.20 ± 12.94^{b}	0.00 ± 0.00	6.60 ± 1.96^{a}	28.80 ± 13.77^{b}
Week 9	18.80 ± 9.31^{b}	0.00 ± 0.00	0.00 ± 0.00	12.00 ± 1.14^{a}	21.60 ± 15.06^{b}

Means ± S. E with different superscripts are significantly different at $p \leq 0.05$.

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Weight of *O. niloticus* in the Different Colored Tanks Across Weeks

There were significant differences in the weight of fish in the different colored rearing tanks across weeks ($F4, 49 = 3.80$; $p>0.05$, Fig 4). After the first week, fish in the black and red had significantly similar weights (4.68g and 4.48g: $p>0.05$) compared with the 3.48g, 3.52g, and 2.57g recorded for fish in the blue, green, and transparent tanks respectively which were significantly lower ($p<0.05$) but did not differ significantly from each other ($p>0.05$).

In the third week, the fish in the black tank was significantly weightier (5.79g; $p<0.05$) than the weight recorded in the blue, green, red, and transparent tanks which did not differ significantly ($p>0.05$). In the sixth week, the fish in the black tank equally had the best weights (6.38g; $p<0.05$) compared with the weights of fish in the blue (2.30g), red (4.53g), and transparent (4.23) tanks. Fish in the black tank was the weightiest (7.05g; $p<0.05$) in the 9th week of the experiment with the least recorded in the transparent tank (4.18g).

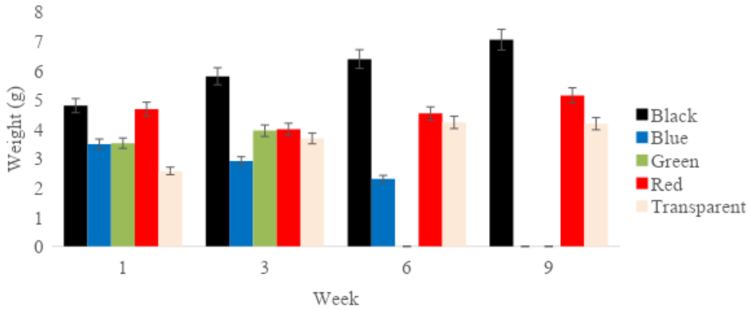

Figure 4. Weights of *O. niloticus* in the different colored tanks across weeks.

Mortality

In this study, there were variations in the mortality of fish. The highest survival rate of the entire group was recorded in the black tank (80%), while the green and blue tanks had the highest mortalities (35%).

This study showed that the color of rearing tanks has significant effects on the boldness, aggression, and growth of *O. niloticus*. Initially, there was no difference in the boldness and aggressiveness of fish in the different colored rearing tanks. As the weeks progressed, the red tanks seemed to support and promote boldness. However, the growth rate of fish in terms of weight did not significantly align with the increased boldness level as the week progressed which implies a negative consequence on the growth of the fish in the red tank. The effects of the red tank on Nile tilapia could be expected, given that a previous study found yellow to be this species' color preference.

Luchiari and Freire (2009) found that fish held in the red tank when isolated or grouped showed decreased weight gain and increased growth heterogeneity within the group respectively. The low weight gain in the red tank suggests that there was some negative effect of the color on Nile Tilapia growth. Indeed, several studies addressed the harmful effects of red light on the growth rate of various fish species (Ruchin, 2019), which agrees with the result obtained in the present study on Nile tilapia. Ruchin (2004) suggested that the effect of red light might be explained by changes in energy metabolism, endocrinological changes, or other biochemical or physiological changes.

Also, fish reared in the transparent tanks showed the highest rate of aggressiveness towards the end of the study (sixth and ninth weeks) when compared with fish in the other tanks, particularly in the black tank given that the transparent tank is well-lighted the other tanks, they may have been able to sight each other clearly with no background to hid from conspecifics, consequently, this could have

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elicited aggression amongst the fish. Previous studies conducted on *O. niloticus* and in other species by Carvalho *et al.* (2012) on *Geophagus proximus* and Gaffney *et al*. (2016) on *Oncorhynchus kisutch* found that these species preferred darker tanks to light-colored ones and consequently improving the species' welfare.

In terms of growth, fish reared in the black tank had the highest weight throughout the study. This result showed that the black tank improved the physiological and metabolic activities of the fish in the tank and improved the utilization of feed which have a direct positive effect on the growth of the fish. In their natural environments, tilapia is found in diverse water bodies that range from clear to turbid waters, which typically feature a complex interplay of light and shadow. This natural setting provides various backgrounds that may influence their feeding behavior and growth.

Tilapia exhibit a high degree of adaptability to different environmental conditions, including variations in water clarity and color. This is also in harmony with the study of Britz and Pienaar (2009) who found that raising catfish larvae in a dark environment, reduced activity levels, territorial aggression, stress, and consequently enhanced growth rate This finding is not in harmony with Opiyo *et al*. (2014) and Aly *et al*. (2017) in their respective study which recorded retarded growth in black and white background tank compared to blue tank and red tank respectively. However, studies have shown that black tanks appear to promote growth when compared to colors at either end of the visible spectrum (Papoutsoglou *et al.,* 2000). The differences in these studies may stem from variations in environmental conditions, management practices, and fish populations.

From the results of the study, it is quite clear that *O. niloticus* can survive and grow faster in colored rearing tanks, particularly black tanks. Boldness and aggression increased in other tanks in the subsequent weeks, more than in the black tank. The increased rate of aggressive behavior may also explain the mortality rate recorded in the blue and green tanks because they were better-lighted than the black tank and as a result, fish in the well-lighted tanks showed more aggression towards each other because they were able to sight other conspecifics better than in a black tank. In other contexts, being bold and aggressive may be beneficial, for example in being able to secure a food source, territories, mate, and evade predators (Ariyomo *et al.,* 2017).

CONCLUSION

Black-colored tank is the optimal choice for the successful culture of *Oreochromis niloticus*. This study found that a black tank sets an environment that enhances the survival and growth of *O. niloticus*. It also found that boldness and aggression increased among the fish in tanks that were not black, and this effect persisted for weeks. The study thereby recommends utilizing black-colored tanks for tilapia cultivation, as they foster optimal growth and survival rates while minimizing aggressive behavior, offering a conducive environment for *O. niloticus*.

CONFLICT OF INTEREST

The Authors hereby declare that they have no competing interest in the research.

AUTHOR CONTRIBUTION

All authors listed in this paper have contributed significantly to the research.

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Not Applicable.

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