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RESEARCH ARTICLE

Influence of Photoperiodic Levels on Skin Melatonization in Heteroclarias Fingerlings in Relation to Water Physico-chemical Properties in Minna, Nigeria

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ABSTRACT

An 8-week experiment was carried out to investigate the effects of photoperiodic levels on skin color of laboratory reared Heteroclarias fingerlings. Artificial lightning was used to simulate a range of photoperiod namely, continuous light period (24L: 0D), total darkness (24D: 0L), 12 hours of darkness and 12 hours of light (12D: 12L) and normal day and night period (control, i.e. ambient photoperiod). Adequately replicated representative number of Heteroclarias fingerlings were exposed to the various photoperiods and monitored for eight weeks. Results of physical observation of the fishes, following recommended fish skin color grading revealed that fingerlings reared in 24D: 0L had the darkest skin color, while those exposed to 24L: 0D had the lightest skin color. In addition, the fingerlings exposed to normal day and night period (control) had a light skin color while those exposed to 12L: 12D had a dark skin color. The physico-chemical parameters such as water temperature, pH, ammonia, biological oxygen demand and dissolved oxygen concentration were within the recommended range for fish culture and also indicated no significant differences($p>0.05$) in all the treatments throughout the experimental period irrespective of photoperiodic condition. It is hoped that the findings of this study will guide commercial fish farmers in raising Heteroclarias fish according to the preferences of market demand with respect to skin color.

Keywords: Heteroclarias, photoperiod, physico-chemical properties, skin color, Minna.

1. INTRODUCTION

More than half of world's population depends on fish as a principal source of animal protein [1]. The developing country, including Nigeria, is characterized by low food intake and poor nutritional status especially in the area of protein and energy. Research findings have rated fish nutrients quality very high thus making it an ideal source of vital nutrients both for nourishment and medicinal purposes [2]. Fish is also widely acceptable because of its high palatability, low cholesterol and tender flesh [3].

High quality aquaculture products must fulfil several requirements well appreciated by consumers, including the adequate color, which is among the most important fish attributes that influence demand. Fish color is the first characteristic perceived and is a determinant selection criterion, directly related to subsequent acceptance or rejection [4]. According to Minerva and Maurilio [5] pigments are responsible for the wide spectrum of colours in fishes which is pre-requisite for the quality, as they fetch higher price in the commercial market. The authors added that fish color is much more than a cosmetic effect; consumers associate natural coloration with healthy and high quality products. Skin color is another important factor in aquaculture influencing the commercial value of fish, mostly in those species sold live or fresh. Most studies of fish skin color in fish aquaculture have focused particularly on the effects of diet [6], background color [7] and lightning conditions [23]. Color changes in fish are often related to environmental stress and illumination could be a primary factor regulating pigment distribution through hormone regulation [7].

Adaptive color change has an important implication for many fish species to improve their fitness in nature. Some fish species could camouflage themselves to evade detection by predators or display conspicuous color to frighten predators. The color of fish skin is generated by the absorption, reflection and scattering of light by the pigments and microstructures within the fish integument [8]. Changes in color pattern are crucial for the adaptation of aquatic animals to their environments [9]. A slow color change is usually subject to variation of pigment quantity, while a fast color change is related to hormone regulation [10].

Moshood et al. [11] recently observed that fish cultured in total darkness (0L: 24D) had darker skin coloration than those cultured in 12 hours of light and 12 hours of darkness (12D: 12L). The absence of light was responsible for the very dark skin coloration observed in the fish reared under total darkness (0L: 24D). This could be due to the neuro-physiological and hormonal responses of the fish in the dark in increasing the stimulation and production of melatonin [8]. Melanins are heterogeneous polymers made up of metabolite of tryoxine which gives all the blacks, grays and browns to vertebrates and many invertebrates [12].

To support the above submission, Campagnolo and Nuner [13] reported that in periods of continuous darkness, melatonin presents a stable rhythm for some time but decreases after few days in most teleosts, due to an internal mechanism of control located in the pineal. That mechanism however is not triggered in the presence of continuous lightning condition. Fish activity like melatonization at a medium age was affected by photoperiod and light intensity; with a probable transition between young and older stages. When fish are getting older, photoperiod plays a major role in activity and gonadal development [14].

Fish dependence on water is crucial; hence, the source, volume and quality of physico-chemical properties such as dissolved oxygen, pH, temperature, biochemical oxygen demand, and ammonia are salient factors to consider in relation to fish physiology and health as documented by Ayanwale et al. [15]. Campagnolo and Nuner [13] reported that survival and growth of *Pseudoplatystoma corruscans* larvae exposed to different photoperiodic levels indicated no significant differences ($p>0.05$) in all water physico-chemical properties measured and also stayed within the acceptable range for fish cultivation [16].

Heteroclarias is among the most commonly favoured and cultured fish in the Nigerian market, and has great potentials to boost the rapidly growing Nigerian aquaculture [17]. It is also mostly cultured in Minna and its environment, Niger State, Nigeria. To support the above submissions, Khaleg [18] reported that farmers should take Heteroclarias culture as the main-stay of their family income because Heteroclarias culture is a profitable business which is capable of assisting people to alleviate poverty and earn additional income. Previous studies on the responses of fish to lighting condition have focused on how it affects fish growth [9], and behaviour [19]. Published information on interactions among light physico-chemical parameters and fish skin melatonization has been limited to commercial species [20].

The present study was carried out to elucidate the influence of photoperiodic levels on skin melatonization in Heteroclarias fingerlings, in relation to water physico-chemical parameters, under laboratory conditions.

2. MATERIALS AND METHODS

2.1 Study area

This study was conducted in Minna located within Latitude 6°33' E and Longitude 9° 3' N, covering a land area of 88km^2. The area has a tropical climate with mean annual temperature of 30.2 °C, relative humidity 61% and annual rainfall of 1,344 mm. The vegetative cover reflects that of savannah zone, dominated by grass but with scattered tree species. The area is characterized by two distinct seasons, i.e. a rainy season between April and October and dry season between November and March [21].

2.2 Source of Fingerling

Four weeks old Heteroclarias fingerlings were obtained from a homogenous source through induced breeding from a private fish farm in Lagos, Lagos state, Nigeria.

2.3 Acclimatization of the fingerlings

The fingerlings were allowed to acclimatize in rearing tanks for one week in the Biology laboratory of the Department of Biological Sciences, Federal University of Technology, Minna, Nigeria. The acclimatization allowed the fingerlings to recover from transportation stress, adapt to their new environment, ensured that they were not infected from source and also to select the right sizes of fish for the experiment [22]. During the acclimatization period, the fingerlings were fed with a commercial diet (Coppens®) to satiation during the hours of 0800 and 1800 [23].

2.4 Experimental setup and Laboratory Maintenance of Fish

The experiment consists of four treatments with three replicates each. Treatment 1 was the control (normal day and night period i.e. ambient lightning condition); treatment 2, 12 hours of light and 12 hours darkness (12L: 12D) fish exposure; treatment 3 had 24 hours of continuous light exposure (24L: 0D); and treatment 4 was total darkness (24D: 0L) [24]. The fingerlings were cultured in twelve plastic indoor aquaria tanks with 25 litres capacity (55 X 35 X 35 cm^3) each filled with borehole water up to the 25cm level. The total darkness lightning condition was achieved by covering the respective tanks with cardboard papers to simulate dark period while the continuous light treatment was also achieved with the aid of an energy saving bulb (26 W) hung above the centre of the aquaria tanks. The fingerlings during the course of the experiment were fed in the same way as during acclimatization. At the start of the experiment, the fingerlings measured mean total length of 9.53±2.18 cm and weighted 7.26±2.12 g. These experimental units consisted of a close system without water recirculation, with fingerling stocking of 150 specimens per replicate (i.e. 450 fingerlings per treatment). The tanks were drained on Tuesday and Friday in a week and replaced with fresh bore water between 08:00 and 10:00 hours. Left overfeed and faecal samples in the tanks were siphoned immediately after feeding [13]. The experiment was monitored for a period of eight weeks before termination.

2.5 Photograph of the sampled fingerlings

Photograph of representative samples of the fingerlings from each treatment were taken individually in plates with the aid of a digital camera.

2.6 Physico-chemical Analysis

The physico-chemical parameters such as water temperature, dissolved oxygen concentration, Biochemical oxygen demand, and pH and ammonia concentration were monitored weekly between 08:00 and 10:00 hours, according to recommended standard methods of water analysis [25, 26].

2.7 Physical Observation of fish skin color

Fresh living specimens of the fingerlings were retrieved weekly with the aid of hand net, for visual skin color observation. The specimens from each treatment and replicate were placed on a white tile for skin color observation. The skin color of the fishes was categorized as lightest, light, dark and darkest as described by Moshood et al. [11]. Visual inspection was done by the same individual throughout the study period to ensure consistency.

2.8 Statistical Analysis

The physico-chemical data collected were processed as mean $\pm$ standard deviation. Difference in means of the parameter among the treatments was subsequently compared for statistical significance using ANOVA, using SPSS Version 16.00. The significant means was separated using Least Significant Difference (LSD). All statistical comparisons were done at P=0.05 level of significance

3. RESULTS

3.1 Physico-chemical Analysis

The mean physico-chemical parameters of water in which the Heteroclarias fingerlings were exposed to different photoperiodic levels are presented in Table 1. The physico-chemical parameters such as mean water temperature (range= 26.43±0.66 to 26.94±0.50 °C), mean water pH (7.62±0.43 to 7.71±0.41), mean dissolved oxygen (4.44±0.69 to 5.07±0.52 mg/L), biochemical oxygen demand (1.07±0.52 to 1.22±0.17 mg/L) and ammonia (0.26±0.05 to 0.28±0.07 mg/L) indicated no significant differences (p>0.05) in all the treatments throughout the experimental period.

3.2. Fish skin Melatonization

Table 2 shows the skin color type of Heteroclarias fingerlings exposed to different photoperiodic levels for 8 weeks old. The results indicated that the Heteroclarias fingerlings exposed to ambient lightning condition i.e. (control) had the lightest skin coloration followed by fishes raised at 24 hours continuous light condition (i.e. 24L: 0D), which were categorized as light skin coloured. The fishes cultured at 12 hours light exposure and 12 hours darkness (i.e. 12L:12D) were conspicuously dark skinned. Photoperiodic exposure of the fingerlings to 24 hours continuous total darkness (i.e. 24D: 0L) produces the darkest skinned fishes.

Table 1: Physico-chemical parameters of culture of media of Heteroclarias fingerlings exposed to different photoperiodic levels for 8 weeks

Parameters	Control	12L: 12D	24L: 0D	24D: 0L
Water Temperature (°C)	$26.43±0.66^a$	$26.77±0.44^a$	$26.74±0.57^a$	$26.94±0.50^a$
Water pH	$7.62±0.43^a$	$7.64±0.41^a$	$7.71±0.38^a$	$7.71±0.41^a$
Dissolved Oxygen (mg/L)	$4.67±1.21^a$	$4.78±0.29^a$	$4.44±0.69^a$	$5.07±0.52^a$
Biochemical oxygen demand (mg/L)	$1.22±0.17^a$	$1.07±0.52^a$	$1.11±0.47^a$	$1.19±0.53^a$
Ammonia (mg/L)	$0.26±0.06^a$	$0.26±0.05^a$	$0.28±0.07^a$	$0.28±0.06^a$

^{a}Values with the same superscript along the row were not significantly different (p>0.05)
Values are expressed as Mean±SD.

Table 2: Skin Melatonization of Heteroclarias fingerlings exposed to different photoperiodic levels for eight weeks period

Photoperiods	Skin Melatonization
Control (i.e. ambient lightning)	+
24L: 0D	++
12L: 12D	+++
24D: 0L	++++

KEY: + = Lightest, ++ = light, +++ = dark and ++++ = darkest

Figure.1 Skin coloration of *Heteroclarias* fingerlings exposed to different photoperiodic levels for a period of 8 weeks. A - T_1 (Control) = lightest skin, B – T_2 (24 hours of light and zero darkness) = light skin color, C – T_3 (12 hours of light and 12 hours of darkness) = dark skin color, D – T_4 (24 hours of darkness and zero light) = darkest skin color.

4. DISCUSSION

The results of physico-chemical properties in this study were not significantly different irrespective of photoperiodic treatment and all fell within the range approved for cultivating warm water fishes. Water pH of 7.62±0.43 to 7.71±0.41 observed in this study fell within the recommended range of 6.5-9.0 as documented by Bryan [27]. Dissolved oxygen concentration of 4.44±0.09 to 5.07±0.52 mg/L falls with the acceptable level of 5 mg/L for fish culture according to Svobodova et al. [28] while the water temperature of 26.43±0.66 to 26.94±0.50 is within the range 25-32 °C acceptable for good fish growth [29]. The ammonia concentration of the water rearing media of the Heteroclarias fingerlings ranged from 0.26±0.06 to 0.28±0.06 mg/L. This observation agreed with ammonia concentration of rearing media of freshwater fingerlings ranging from 0.01 to 1.55 mg/L reported by Kohinoor et al. [30]. The biochemical oxygen demand of rearing water media which ranged from 1.07±0.52 to 1.22±0.17 mg/L as recorded in this study was also within the standard range of 1.00 to 5.00 mg/L recommended for fish growth [31]. These confirming results suggest no organic pollution from leftover feed or faecal matter in the rearing media of Heteroclarias fingerlings throughout the experimental period which in turn increased the dissolved oxygen concentration. These observations might be attributed to constant aeration and changing of water in all the experimental tanks [32]. This finding suggests that fish in the wild must be free from pollutants such as livestock water, fertilizer, pesticide and herbicide. These pollutants usually increase the biochemical oxygen demand and hence low dissolved oxygen demand [33]. Therefore, productivity of *Clarias* especially Heteroclarias may be greatly enhanced in the wild, if facilities for adequate aeration and refreshment (e.g. recirculatory system) of pond water are put in place by such fish farmers.

The insignificant differences in the physicochemical properties encountered in this study agrees with the finding of Campagnolo and Nuner [13] who reported that *Pseudoplatystoma corruscans* fingerlings exposed to different photoperiodic levels indicated no significant differences ($p>0.05$) in all the physicochemical properties measured and also stayed within the acceptable range for fish culture. The lightest skin and light skin observed in Heteroclarias fingerlings exposed to continuous 24 hours exposure to light and control respectively were in conformity with the works of Adachi et al. [34] who reported that sun shading or light exposure partially prevented the occurrence of melanophore in the fish skin. To support the above submissions, Fuji [8] reported that fish skin color is controlled by chromatophores, melanophores (ocher or yellow), erythrophores (red) and leucophores (whitish); while the activities of chromatophores including melanophore is modulated via hormonally, neurophysiologically and physical stimuli such as light [8, 35]. The darkest skin color (melatonization) observed in the Heteroclarias fingerlings exposed to continuous darkness (24D: 0L) conformed with the findings of Moshood et al. [11] who noted that fish culture in total darkness (0L: 24D) had darkest skin coloration than those cultured in 12 hours of light and 12 hours of darkness (12L: 12D). He also added that the absence of light was responsible for the very dark skin coloration observed in the fish reared under total darkness. Similarly, Hisar et al. [36] and Campagnolo and Nuner [13] reported that these phenomena is a physiological response of the fish which results in increasing the stimulation and production of melatonin. This is triggered only in the dark or not in the presence of continuous light.

The skin colorations encountered in this study were in agreement with the findings of Minerva and Maurillo [5] who documented that consumers subconsciously relate product color to nutritive value, healthiness, freshness and taste. Ecological explanation for the differential skin color in relation to duration of exposure to light, maybe found in results of Hidekei and Reiko [37] who reported that skin colours of fish and squid are rapidly altered in response to environmental stimuli such as background colour, light intensity or changing social context.

5. CONCLUSION

The Heteroclarias hybrid is adapted to surviving under possible range of photoperiodic conditions. However, the skin coloration of the hybrid responds vertically in variations in duration of lightning conditions, a possible result of differential physiological and/or metabolic activities under equally varying photoperiodic conditions. However, photoperiod had no significant effect on physico-chemical properties of water in which Heteroclarias grows; which in turn revealed that skin melatonization in fishes may not be directly conditioned by such physico-chemical properties. Skin color influences the acceptability and cost of fishes in many areas, therefore the findings of this study should guide the commercial fish farmers in raising Heteroclarias fishes suited to the preferences of the market demands, with respect to fish color.

Conflicts of Interest

There are no conflicts of interest.

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