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Effect of different satiation level on the growth and survival of Nile tilapia *Oreochromis niloticus* L. under continuous illumination

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Abstract: *The study evaluated the effect of different SL (100%, 80% & 60%) on the growth and survival of Nile tilapia (Oreochromis niloticus) under continuous illumination using indoor recirculating system. Statistical analysis showed no significant difference (ANOVA, p>0.05) existed on growth and survival of the fish after the experiment. Apparently, growth performance indicators (FABW, WG, SGR) of the fish slightly improved as the SL or FI increases. However, the survival of the fish was negatively affected because as the SL increases, the survival of the fish declines, and mortality rate increases. Results indicated that the insignificant growth of the fish is a consequence of increased physical activity under continuous illumination and the higher the SL, the more prone the fish to stress thereby negatively affecting fish survival. In conclusion, slightly improved growth could be obtained using higher SL (100%) but greater survival could be attained using low SL (60%) under continuous illumination.*

Keywords: *Photoperiod, vision, aggressive behaviour, social stress, fish welfare*

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I. Introduction

Several studies have been carried out on cultured marine fish larvae, supplying light either continually or over very long periods, compared to natural conditions. Results varied and the receptivity of fish to light profoundly changes according to the species and the developmental status [1]. The growth of flounder *Pleuronectes ferrugineus* (Storer) [2], rainbow trout *Oncorhynchus mykiss* (Walbaum) [3], and sunshine bass *Morone chrysops* (Rafinesque) × *Morone saxatilis* (Walbaum) [4] were not significantly affected by photoperiod. In contrast, manipulation of photoperiod has been used successfully to improve growth in atlantic salmon *Salmo salar* [5], Atlantic cod *Gadus morhua* [6], barramundi *Lates calcarifer* [7], haddock *Melanogrammus aeglefinus* [8], and snubnose pompano *Trachinotus blochii* [9].

In tilapia, the effect of photoperiod was evaluated in several studies. In reproduction of Nile tilapia *Oreochromis niloticus*, investigation showed that long daylength (18L:6D) helps improve some of its important reproductive traits [10] while [11] suggest that photoperiod manipulation can be used to arrest the spawning of the fish. [12] concluded that a natural photoperiod regime should be adopted for maximum fecundity, seed production and spawning frequencies of the fish broodstock reared in intensive, recirculating systems; however, a near-natural day length photoperiod should be used for maximum reproduction. Recently, [13] study showed that exposure to low or high light intensity affects pituitary-testicular activity in the fish indicating the importance of optimum lighting conditions for achieving successful reproduction. In rearing experiments, [14] and [15] reported that Nile tilapia fry and not fingerlings were significantly affected by longer day light producing higher growth. In contrast, [16] observed that the growth and survival of red tilapia fry were not significantly affected by different photoperiods. Other studies reported that extended photoperiod had a benefic impact on growth rate and differential gene expression of Nile tilapia compared to those reared under natural photoperiod [17] and a 20-hours photoperiod and 40 watts m^{-2} light intensity is just enough to sustain the recommended water quality and better growth performance of the cultured fish [18]. On the other hand, [19] findings revealed that continuous illumination was more suitable for optimum growth performance, survival rate and skin color of the fish fingerlings than any other photoperiods.

Fish can be fed in two main ways: feeding to satiation and feeding to weight. Feeding to satiation involves providing the fish with food until they stop feeding (feeding until they are full). The feeding by weight method involves knowing the approximate weight of the fish and feeding a percentage per day. Studies on the influence of photoperiod manipulations as mentioned in rearing of tilapia were carried out using feeding to weight, and it was only a part of their experimental procedures. In order to optimize growth rates and FCR, feeding strategies take into consideration ration size, feeding frequency and duration, appetite, feeding method, and feed monitoring [20]. Generally, increasing daily rations may lead to improved growth rates. [21] tested both feeding to satiation and feeding to weight under different photoperiod and feeding interval experiments. Results showed that the growth of the fish could be controlled by the manipulation of photoperiod and feeding interval. To date, no further studies were conducted on the use of satiation feeding in tilapia rearing under photoperiod manipulation. The response of the fish to a certain condition is necessary to investigate, thus, this study evaluated the effect of different satiation level (SL) on the growth and survival of Nile tilapia *Oreochromis niloticus* under continuous illumination.

II. Materials and Methods

Study Site

The study was conducted at the Multi-species hatchery of the Institute of Aquaculture (IA), College of Fisheries and Ocean sciences (CFOS), University of the Philippines Visayas (UPV), Miagao, Iloilo, Philippines for a duration of 16 days.

Experimental Fish

Nile tilapia *Oreochromis niloticus* fingerlings were obtained at the Freshwater Aquaculture Station (FAS) of the same university. They were transported to the study site early in the morning and stocked to indoor fiberglass tanks. After 12-hours, tank water temperature was slowly increased to 29°C within 12-hours using heater (Aqua Zonic® 100w). The temperature was maintained within 7 days to acclimate and condition the fish at the same time. Feeding of the fingerlings to apparent satiation starts 24-hours after stocking using commercial tilapia feeds (Tateh® Aquafeeds) containing 42% crude protein, 5% crude fat, 5% crude fiber, 16% ash and 12% moisture.

Experimental Treatments and Set-up

The effect of different SL on the growth and survival of Nile tilapia *Oreochromis niloticus* under continuous illumination was evaluated indoor using 9 units (65L capacity) plastic container in three treatments with three replicates each. SL treatments include 100% (T1), 80% (T2), and 60% (T3). Tanks were set-up following Completely Randomized Design (CRD). Each tank was provided with individual recirculating and aeration system, water heater (Aqua Zonic® 100w) and terrarium digital LCD display thermometer temperature meter. The recirculating system (Eco green series 3 in 1 RS-088A 10W) is composed of a submersible pump (10W) with built-in aeration and a filter box, which contains charcoal and washable filter mat on top to collect solid waste. To provide continuous illumination (24-hours light), 2 units daylight bulb (Firely, 9w) were installed 1 meter above the tanks. The experimental set-up was affected by indoor natural light during daytime. Surface light intensity was measured using light meter (EXTECT measurements, EA30-EasyView™ Wide Range Light Meter).

Stocking

A total of 40 apparently healthy fingerlings with an average total length (TL) and weight of 4.65±0.40cm and 1.29±0.33g, respectively, were stocked randomly in each tank. The fish were acclimated to continuous illumination within 24-hours. No feeding was done, and the experiment begins thereafter.

Feeding

SL levels were determined on the 1st, 5th, 9th and 13th days of the experiment at 0700h. Following the method of [22], pre-weighed feeds were fed to the stocks in each tank until feeding activity stopped (about 30 minutes). The total amount of feeds before the fish stop taking feed is 100% satiation. Following the experimental treatments SL, feeding starts at 1700h after SL were determined and thrice a day (0700h, 1200h & 1700h) before the next schedule. The same commercial feeds used during the acclimation and conditioning were given.

Water Quality Monitoring and Management

Water quality monitoring was conducted using water test kit for pH, ammonia, nitrite (API® freshwater master test kit) and dissolved oxygen (DO) (TBS® water test kit) following the standard procedure. DO and temperature were closely monitored and maintained at 6mg/L and 28-30^{o}C, respectively. Adjustment of the water heater was done if necessary, to maintain the temperature within the range.

Fish waste was siphoned daily before feeding in the morning. Clean water was added to maintain the rearing container volume (65L) after siphon and if necessary due to water loss caused by evaporation and washing of filter mat. Water change of around 50% of the total volume was done every 5 days.

Estimation of response parameters.

Growth and survival of the fish were evaluated after the experiments. All the remaining fish in each container were weighed, measured and counted. Response parameters were evaluated following the formula [23] below:

Weight gain, WG (g) = FABW – IABW
Specific Growth Rate (SGR, %/day) = 100*(lnFABW–lnIABW)/ (T2-T1)
Feed Conversion Ratio (FCR) = FI (g) /WG (g)
Survival rate (%) = 100*(final count/initial count)
Where: FABW = Final average body weight (g) and
IABW = Initial average body weight (g)
lnFABW = the natural logarithm of the final average body weight (g)
lnIABW = the natural logarithm of the initial average body weight (g)
T2-T1 = time (days) between lnFABW and lnIABW
FI= total individual feed intake (g)
Mortality rate (%) = 100* (number of mortality/total stocking density)

Statistical Analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 20 software. Data were tested for homogeneity of variance using Levene's test. The one-way analysis of variance (ANOVA) was used on data which passed the tests while those that did not were subjected to log or arcsine transformation. Tukey's test was applied when statistically significant differences between means were occurred ($p \leq 0.05$).

III. Results

Statistical analysis showed no significant difference (ANOVA, p>0.05) existed on growth performance indicators (FAL, FABW, WG, SGR, FI & FCR) and survival of Nile tilapia *Oreochromis niloticus* fed with different SL under continuous illumination (Table 1). Apparently, there is a correlation between fish body weight and SL because the growth performance indicators (FABW, WG, SGR) of the fish slightly improves as the SL or FI increases except at 80% SL wherein the fish has larger FAL. In contrast, as the SL decreases, the survival of the fish improves, and mortality rates declined. Evidently, the fish survival was negatively affected by satiation levels under continuous illumination.

Table 1. Growth performance and survival of Nile tilapia *Oreochromis niloticus* fed with different satiation levels under continuous illumination

SL	*FAL (cm)*	*FABW (g)*	*WG (g)*	*SGR (%/day)*	*FI (g)*	*FCR*	*MR (%)*	*SR (%)*
100%	51.93±1.46[a]	2.03±0.25[a]	0.74±0.24[a]	2.81±0.78[a]	1.40±0.36a	2.10±1.02[a]	58.33±11.55[a]	41.67±11.55[a]
80%	52.11±1.04[a]	1.96±0.10[a]	0.67±0.10[a]	2.60±0.32[a]	1.37±0.73a	1.10±0.79[a]	53.33±16.27[a]	46.67±16.27[a]
60%	51.27±1.21[a]	1.91±0.14[a]	0.62±0.14[a]	2.43±0.47[a]	0.68±0.22a	1.09±0.09[a]	34.17±19.42[a]	65.83±19.42[a]

SL = satiation level (%); FAL = final average length (cm); FABW = final average body weight (g); WG = weight gain (g); SGR = specific growth rate (%/day); FI= total individual feed intake (g); FCR = feed conversion rate; MR = mortality rate (%); SR = survival rate (%)
Data are expressed as mean ± SD
Values in the same column with the same superscripts are not significantly different (p>0.05).

The water temperature and DO of the experimental rearing tanks were maintained at 28-30^{o}C and 6mg/L respectively, during the rearing period. Other water quality parameters are presented in table 2. Ammonia was not observed while nitrite and pH of the different SL under continuous illumination falls at range of 1.58-2.0ppm and 7.53-8.30, respectively.

Table 2. Mean values of water quality parameters during the experimental period (16 days)

SL	*Day 1*	*Day 5*		*Day 10*		*Day 15*	
	pH	pH	Nitrite (mg/L)	pH	Nitrite (mg/L)	pH	Nitrite (mg/L)
100%	7.6	8.13	2.0	7.90	1.75	7.73	1.75
80%	7.6	8.13	2.0	8.30	1.58	7.53	1.75
60%	7.6	8.13	2.0	8.20	1.75	7.73	1.75

IV. Discussions

Several experiments have shown that growth responses of fish species to different photoperiods depend on the developmental stages of the fish and the fish itself [7]. It has been observed that continuous light increased the growth hormone levels in the species such as salmon smolts [24]. [25] reported that increased photoperiod increases plasma growth hormone levels in fish species. The performance of fish under particular conditions can be assessed by growth trials, in which growth rates and feed conversion ratios are determined [26]. Using feeding to weight, positive correlation between tilapia growth and continuous illumination has been reported [14, 15, 27]. In this study, different SL insignificantly affects the growth of Nile tilapia *Oreochromis niloticus* in recirculating system under continuous illumination, although it can be observed that the FABW, WG, and SGR of the fish slightly improved as the SL increases. The insignificant result may be due to the duration of the study (16 days), social interaction, and possibly the fish may have undergone more acclimation time to the continuous illumination and uncontrolled light intensity. Depending on the weather condition, recorded average surface light intensity during daytime and nighttime ranges from 1,098 - 4,650 lux and 85 lux, respectively. According to [27], while increasing daily rations generally may lead to improve growth rates, this does not necessarily mean that nutrients are utilized more efficiently. Arctic char [29] and gilthead sea bream [30] growth rate and food conversion efficiency were reduced under continuous light. [31] suggests that it may be a consequence of increased physical activity leading to greater metabolism and a smaller increase in food conversion efficiency of fish exposed to continuous lighting. To optimize the growth of the tilapia, continuous illumination should be employed with the light intensity > 400 lx and 40 watts with four weeks of acclimation before culture of the fish [32]. In this study, the fish was acclimated within 24 hours under continuous illumination and uncontrolled light intensity.

Photoperiod has also been reported to compromise fish welfare [33, 34, 35] and this could affect their survival especially the fry and fingerlings often leading to mortality [32]. In this study, the survival of the fish was negatively affected under continuous illumination and uncontrolled light intensity regardless of SL. However, it is apparent that the higher the SL, the higher the mortality thereby affecting the survival of the fish. It has been observed that the fish shows aggressive behavior and they often fights or attacks each other. [36] explained that fish social behavior can be affected by artificial environments, particularly by factors that act upon species that show aggressive behavior to set social rank hierarchy. Although aggressive interactions are part of the natural behavior in fish, if constant and intense, such interactions can cause severe body injuries, increase energy expenditure, and lead the animals to suffer from social stress. The immediate consequence of these factors is a reduced welfare in social fish species. In this case, result of this study suggests that the higher the SL consumed by the fish, the prone it suffers from social stress under continuous illumination and uncontrolled light intensity (1,098 - 4,650 lux). Environment lighting is a matter of consideration for the Nile tilapia welfare, because they have a good sense of vision [37, 38]; consequently, light affects their behavior and physiology in several ways, and these factors are more relevant in aquaria systems, inside laboratories, where the environment is more translucent than in ponds [36]. Other studies revealed that Nile tilapia exposed to increased light intensity (from 280 to 1390 lx) reduces aggressive interactions between pairs of juvenile males [39], whereas it clearly increases fights among adult males [40]. Other cichlids such as *Cichlasoma dimerus* [41] and *Tilapia rendalli* [36] are more aggressive and tend to become dominant under long photoperiods.

Water quality in recirculating aquaculture systems is a function of many variables including system design, loading, and management; temperature; feeding rate, and other variables [42]. A carefully selected feed ration helps maintain the physical and chemical water parameters, such as ammonia, nitrites and suspension concentration, at the lowest level possible [43]. The recommended feed rate varies between 1.5 and 15% of biomass weight per day depending on the stage of growth and the species of fish cultured [44]. Under the influence of light conditions, 20 hours photoperiod and 40 watts m^{-2} light intensity is just enough to sustain the recommended water quality in cultured tilapia in indoor tank system at a feeding rate of 4% biomass day^{-1} [18]. In this study, temperature and DO were controlled at 28-30^{o}C and 6mg L^{-1}, respectively. Ammonia were not observed while nitrite and pH of the different SL under continuous illumination falls at range of 1.58-2.0 mg L^{-1} and 7.53-8.30, respectively. For warm water species like tilapia, fish require a minimum DO concentration of approximately 5.0 mg L^{-1} [45], ideal pH ranges between 6.5 and 9 [46], optimal growing temperature in a controlled environment of approximately 27–30°C [47] while [48] states that tilapia begin to die when nitrite concentrations reach 5 mg L^{-1} as NO^2-N. Ammonia were not detected due to the used of carbon (charcoal) in the filtration system which is efficient in eliminating the toxic chemical. The study of [49] indicated that ammonia can be removed from the aquaculture water using activated maize cob carbon. Results showed that water parameters were maintained at ideal level for tilapia rearing during the study.

V. Conclusion

In conclusion, growth performance of Nile tilapia *Oreochromis niloticus* could be slightly improved using higher SL (100%) but greater survival could be obtained using lower SL (60%) under continuous illumination.

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