Influence of different photoperiod regimes on growth performance and feed utilization efficiency of Nile tilapia (*Oreochromis niloticus*) fry reared in a hapa-based nursery system

[1,2]Reniel R. Dandan, [1,3]Emmanuel M. Vera Cruz

[1] College of Fisheries, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines; [2] Department of Agriculture, National Fisheries Research and Development Institute, Diliman, Quezon City, Philippines; [3] Freshwater Aquaculture Center, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines. Corresponding author: E. M. Vera Cruz, emmanuel.veracruz@clsu2.edu.ph

Abstract. In aquaculture, photoperiod acts as a key environmental signal. It synchronizes fish endogenous rhythms and boosts growth hormone secretion, feeding activity, metabolism, and survival. This study assessed the effects of different photoperiod regimes on growth performance and feed utilization efficiency of Nile tilapia (*Oreochromis niloticus* L.) fry reared in outdoor nursery hapa systems. One-month-old fry (0.12–0.13 g) were subjected to 12 hours of light: 12 hours of dark (natural daylight), 18 hours of light: 6 hours of dark (natural daylight + 1,600-lux LED), or 24 hours of light: 0 hours of dark (natural daylight + 1,600-lux LED) for 14 days. Fish were fed a commercial diet at 20% body weight twice daily. Water quality parameters were monitored bi-weekly and remained within optimal ranges throughout the study with dissolved oxygen range from 5.47 to 7.76 mg L^{-1}, temperature between 30.11 and 31.61°C, and pH between 8.72 and 9.15. Extended (18 hours of light: 6 hours of dark) and continuous (24 hours of light: 0 hours of dark) photoperiods significantly improved growth performance and utilization efficiency of *O. niloticus* fry, determining the highest final weight, weight gain, final length, length gain, specific growth rate and absolute growth rate, and feed conversion ratio, while the survival rate was not significantly affected. The study findings indicated that 18 hours of light: 6 hours of dark and 24 hours of light: 0 hours of dark photoperiod enhanced growth performance and feed utilization efficiency in outdoor *O. niloticus* nursery, by decreasing the standard metabolic rate, and increasing the feeding activity and hormonal stimulation, suggesting 18 hours of light: 6 hours of dark for cost-effective production. Future research should assess stress response, optimize stocking density of *O. niloticus*, plankton dynamics under different photoperiod regimes and effect of different light intensity.
Key Words: fry production, light regime, aquaculture management, feed conversion ratio, fish nursery.

Introduction. Photoperiod is the duration of light exposure within a 24 hour cycle. In aquaculture, it is an important factor influencing fish growth, development, feeding behavior, survival, pigmentation and reproductive activities. The manipulation of environmental factors such as day length or photoperiod to enhance production output and reduce production cost has become a common trend in recent years (Villamizar et al 2011). Photoperiod acts as an external regulator of the endogenous daily rhythms of fish, thereby influencing growth and development across all life stages (Ayson & Takemura 2006; Falcón et al 2007; Biswas et al 2008; Villamizar et al 2011).

Nile tilapia (*Oreochromis niloticus* L.) are diurnal fish, exhibiting activity primarily during daylight hour. Several studies have reported that extended photoperiod improved growth and development in fish species that are typically active during the day (Fielder et al 2002; Stuart & Drawbridge 2011; Arambam et al 2020; Ma et al 2021). Fish under continuous 24 hour light exhibited increase locomotor activity, feed intake, and conversion efficiency, which ultimately lead to improved growth performance (Blanco-Vives et al 2010; Veras et al 2013; Imsland et al 2018). This regime promotes lipid accumulation, enzymatic activity, swim bladder health, and improved visual recognition of food which contribute to enhanced growth performance, metabolism, nutrient utilization, and somatic growth, primarily through the stimulated of growth hormone (GH) and insulin-like growth factor-I (IGF-1) secretion (Fielder et al 2002; Puvanendran & Brown 2002; Taylor et al 2006; Imsland et al 2008; Vera Cruz & Brown 2009; Martínez-Chavez et al 2014; Ramzanzadeh et al 2016; Kurata et al 2017).

In the Philippines, *O. niloticus* aquaculture, particularly nursery operations, is well established. Increasing demand for *O. niloticus* fingerlings for grow-out production needs innovative solutions such as extending the daylight in *O. niloticus* nursery, which have emerged as potential strategies to sustain and further support the industry (BFAR 2022). Photoperiod has been extensively studied in aquaculture, demonstrating a positive effect on growth and development in many fish species (Al-Emran et al 2024). Previous photoperiod studies on *O. niloticus* have focused on nursery, grow-out and broodstock phases using a conventional artificial lighting in an indoor facility. However, information on the effects of extended and continuous photoperiod in outdoor culture systems, such as combination of natural daylight and artificial lighting in a hapa-based nursery rearing in earthen ponds, particularly on growth performance and feed utilization of Nile tilapia fry is limited. Therefore, this study was conducted to evaluate the effect of extended and continuous photoperiod on the nursery rearing of *O. niloticus*. Specifically, the study assessed the effect of different photoperiod regimes on the growth performance and feed utilization efficiency of *O. niloticus* fry reared in an outdoor hapa-based system.

Material and Method

Fish and culture facilities. The study used one month old *O. niloticus* fry of the Freshwater Aquaculture Center Selected Tilapia (FaST) strain (0.12–0.13 g). A 500 m^{-2} earthen pond located at the Freshwater Aquaculture Center (FAC) of Central Luzon State University (CLSU) in Science City of Muñoz, Nueva Ecija, Philippines, served as experimental site. Water quality parameters such as dissolved oxygen (DO), temperature, and pH were monitored bi-weekly between 9:00 AM and 3:00 PM. Mean values recorded during the experiment were 5.47±0.05 to 7.76±0.06 mg L^{-1} (DO), 30.11±0.03 to 31.61±0.05°C (temperature), and 8.72±0.03 to 9.15±0.00 (pH).

Experimental unit and design. Three treatments with three replicates each were used in the study. Each treatment- replicate was assigned to one of the nine units of 1x1 m^2 nursery hapa installed in a 500 m^2 earthen pond, following a randomized complete block design. Six of the nursery hapas were equipped with 1,600-lux LED light bulb to provide artificial photoperiod for Treatment II (18 hours Light: 6 hours Dark) and Treatment III (24 h L: 0 h D) during night time, while Treatment I (12 h L: 12 h D) solely relied on natural day light (Figure 1). To concentrate lighting during the night, black-colored polyethylene plastics were installed around the sides of nursery hapas. Photoperiod for artificial light was powered by electricity and regulated using a digital timer.

Figure 1. Experimental units and design of the study.

Fish stocking, feeding and sampling. Stocking of fry was conducted early morning, followed by acclimation. Initial weight and length of fry were recorded before stocking.

Each hapa (1 m^2 capacity) was stocked with 500 fry m^{-2} and were subjected to three photoperiod regimes (Table 1). The fry specimens were fed commercial feed containing 40% protein twice daily at 20% of their total body weight (equivalent to 12 g per replicate per day) throughout the 14 day nursing period. Sampling was conducted at start and end of the experiment to assess length and weight increments and to reduce handing stress. The following parameters and formulas were used to evaluate the growth performance of and feed conversion ratio:

Specific growth rate (%) = {(ln Final weight (g) – ln Initial weight (g) / Culture days)} x 100

Absolute growth rate = (Final weight − Initial weight) / number of days

Length gain = Final length – Initial length

Weight gain = Final weight – Initial weight

Survival rate (%) = (No. of stocks harvested / Initial no. of stocks) x 100

FCR = Total feed given (g) / Total weight gain (g)

Table 1

Description of photoperiod treatments (light: dark cycle) used in the study

Treatment	*Light to dark cycle*	*Light source*
I	12 h light - 12 h dark	Natural daylight (12)
II	18 h light - 6 h dark	Natural daylight (12 h) + 1,600-lux LED lighting (6 h)
III	24 h light - 0 h dark	Natural daylight (12 h) + 1,600-lux LED lighting (12 h)

Photoperiod treatments were expressed as L:D, where L represents hours of light and D represents hours of dark, within a 24 h cycle.

Statistical analysis. One-way Analysis of variance (ANOVA) was used to evaluate the effect of photoperiod on the growth performance and feed utilization efficiency of Nile tilapia fry using the Statistical Tool for Agricultural Research (STAR), version 2.0.1 2014 software. Post-hoc Least Significant Difference (LSD) test was used to compare the mean at a significance level of 5%.

Results. The growth performance of *O. niloticus* fry was evaluated under three photoperiod regimes, namely 12 h L: 12 h D, 18 h L: 6 h D, and 24 h L: 0 h D (Table 2).

Table 2

Growth performance of *Oreochromis niloticus* fry under different photoperiod regimes during the experiment

Parameters	*Light to dark cycle*		
	Treatment I *12 h L: 12 h D*	*Treatment II* *18 h L: 6 h D*	*Treatment III* *24 h L: 0 h D*
Initial weight (g)	0.13 ± 0.01^a	0.12 ± 0.01^a	0.13 ± 0.01^a
Final weight (g)	0.89 ± 0.34^b	1.39 ± 0.64^a	1.43 ± 0.52^a
Weight gain (g)	0.76 ± 0.34^b	1.27 ± 0.63^a	1.32 ± 0.52^a
Initial length (mm)	19.44 ± 1.30^a	19.39 ± 1.30^a	19.43 ± 1.33^a
Final length (mm)	36.75 ± 4.93^b	42.83 ± 5.91^a	43.41 ± 5.50^a
Length gain (mm)	17.31 ± 5.36^b	23.43 ± 5.90^a	23.98 ± 5.35^a
AGR (g day^{-1})	0.03 ± 0.01^b	0.04 ± 0.01^a	0.04 ± 0.01^a
SGR (%)	6.28 ± 1.53^c	7.73 ± 1.45^b	8.17 ± 1.17^a
Survival rate (%)	50.33 ± 5.51^a	49.60 ± 3.12^a	50.73 ± 4.43^a

Mean±SD values with the same superscript letter within a row are not significantly different (P>0.05).

Extended and continuous photoperiod significantly influence the growth performance of *O. niloticus* fry. Fry reared under extended and continuous photoperiod photoperiods (18 h L: 6 h D, and 24 h L: 0 h D) exhibited significantly higher final weight, weight gain, final length, and length gain compared with those fry maintained under the natural photoperiod (12 h L: 12 h D) ($p<0.05$). The average growth rate (AGR) was significantly higher in 18 h L: 6 h D and 24 h L: 0 h D treatments, while the specific growth rate (SGR) significantly and progressively increased from 12 h L: 12 h D to 24 h L: 0 h D ($p<0.05$). In contrast, the survival rate did not differ significantly among treatments ($p>0.05$).

The feed conversion ratio was significantly affected by the photoperiod regimes (Table 3). *O. niloticus* fry reared under extended photoperiod 18 h L: 6 h D (0.57±0.14) and continuous photoperiod 24 h L: 0 h D (0.61±0.15) obtained significantly lower FCR compared with those maintained under natural photoperiod 12 h L: 12 h D (1.09±0.15) ($p<0.05$), indicating improved feed utilization under prolonged photoperiod. There is no significant difference observed between 18 h L: 6 h D and 24 h L: 0 h D photoperiod treatments ($p>0.05$).

Table 3

Feed conversion ratio of *Oreochromis niloticus* fry under different photoperiod regimes during the experiment

Parameter	*Light to dark cycle*		
	Treatment I *12 h L: 12 h D*	*Treatment II* *18 h L: 6 h D*	*Treatment III* *24 h L: 0 h D*
Feed conversion ratio	1.09±0.15^{a}	0.57±0.14^{b}	0.61±0.15^{b}

Mean±SD values with the same superscript letter within a row are not significantly different ($P>0.05$).

Discussion. The present study revealed that extended and continuous photoperiod significantly influences growth performance and feed utilization in *O. niloticus* fry reared in a nursery hapa-based system. The final weight (1.43±0.52 g), weight gain (1.32±0.52 g), final length (43.41±5.50 mm), length gain (23.98±5.35 mm), AGR (0.04±0.01 g day^{-1}), and SGR (8.17±1.17%) were highest under continuous photoperiod (24 h L: 0 h D) followed by extended photoperiod (12 h L: 0 h D), while natural photoperiod (12 h L: 12 h D) obtained lowest value ($p<0.05$). This growth performance trend aligned with previous studies reporting that extended and continuous photoperiod exposure can stimulate growth in *O. niloticus* fry and fingerlings likely through decrease of standard metabolic rate (El-Sayed & Kawanna 2004; Elsbaay 2013). The natural photoperiod may weaken *O. niloticus* fry growth by limiting the time available to develop stable endogenous rhythms (Biswas et al 2002). Synchronization of these internal rhythms with external light cues could also impose higher energy demands during short or natural photoperiod, thereby reducing energy allocation to somatic growth (El-Sayed & Kawanna 2004).

Feed conversion ratio was significantly improved under the extended 18 h L: 6 h D (0.57±0.14) and continuous 24 h L: 0 h D (0.61±0.15) photoperiod, signifying that extended and continuous photoperiod improve feed utilization efficiency. These results are consistent with the previous finding of El-Sayed & Kawanna (2004), Biswas et al (2005), and Cinense et al (2018) that prolonged photoperiod enhance feeding activity and metabolic efficiency without causing excessive stress to fish. Extended and continuous photoperiod most probably increased feeding opportunities, in turn allowing the fish to consume more food during daylight, which contributed to improve FCR (Biswas et al 2005). In the context of the present study, which was conducted in a hapa-based systems under uncontrolled environmental condition, the improvement in FCR agreed with previously mentioned findings and may also be influenced by increased natural food availability during prolonged photoperiod, further aiding FCR. Additionally, the presence of insects attracted to artificial lighting under extended and continuous photoperiod treatments was observed during the study. Insects may have served as an additional food source and thereby may also contributed to the improved FCR. However, in the succeeding studies, it is suggested to conduct assessment on plankton community dynamics under different photoperiod regimes in order to further evaluate the improvement in growth performance and feed utilization efficiency of *O. niloticus* fry.

Photoperiod may also affect fish growth through endocrine activity and key growth-related hormones, which are affected by light-dark cycles and subsequently influence metabolic processes and growth performance. Vera Cruz & Brown (2009), reported that *O. niloticus* subjected to extended photoperiod obtained the highest hepatic insulin-like growth factor-I (IGF-I), which showed a positive correlation with the growth performance. The improved feed conversion ratio under the extended and continuous photoperiod (18 h L: 6 h D and 24 h L: 0 h D) of this study, can also be associated with elevated IGF-I levels in *O. niloticus* fry, denoting that photoperiod can enhance somatic growth through endocrine mechanisms.

The result of *O. niloticus* fry survival rate was generally unaffected by the photoperiod, suggesting that all regimes (12 h L: 12 h D, 18 h L: 6 h D, and 24 h L: 0 h D) are suitable for its culture. The *O. niloticus* fry was reared in hapa systems, the survival rates recorded are consistently low among the treatments, with values such as 50.33±5.51% (12 h L: 12 h D), 49.60±3.12% (18 h L: 6 h D), and 50.73±4.43% (24 h L: 0 h D), respectively. These findings contrast the results of the studies of El-Sayed & Kawanna (2004) and Elsbaay (2013), who reported significant effects of prolonged photoperiod on survival of Nile tilapia. According to Biswas et al (2005), environmental factors such as water quality and stocking density can influence survival performance. In the present study, a stocking density of 500 fry m^{-2} was considered slightly high, while water quality recorded was within acceptable limits, except for pH, which was slightly alkaline but remained within the tolerable range for *O. niloticus* culture. Dissolved oxygen ranged from 5.47±0.05 to 7.76±0.06 mg L^{-1}, temperature from 30.11±0.03 to 31.61±0.05°C, and pH from 8.72±0.03 to 9.15±0.00. Although the stocking density was relatively high, these water quality parameters showed minimal difference among treatments, indicating that they did not influence the survival rate.

Additionally, photoperiod changes the hematological parameters in many cases, it disrupts the physiological homeostasis in fish, eventually results in an increased in blood glucose as a result of chronic stress, providing energy for the “fight or flight” reaction. Moreover, glucocorticoids are a class of steroid hormones, such as cortisol, that are synthesized by internal tissues including brain, adrenal gland and sympathetic nerve fibers in fish. It also plays an important role in stress response, behavior, osmoregulation, metabolism, growth, reproduction and immune function (Ruane et al 2000; Okomoda et al 2013; Zahangir et al 2015; Shahjahan et al 2018; Shahjahan et al 2019; Shahjahan et al 2020; Islam et al 2020; Islam et al 2021; Shahjahan et al 2021; Shahjahan et al 2022). Nonetheless, since survival rate were consistent low across the treatment, even though stress response indicators such as cortisol and glucose were not measured in this study, it is assumed that these factors are not considered to have an effect on survival performance of the *O. niloticus* fry.

Photoperiod also varies depending on life stage of fish and species such as freshwater or marine species. According to studies, fry and early juvenile stage are more responsive to extended photoperiod compared to fingerlings, while marine species is more sensitive to photoperiod than freshwater species (El-Sayed & Kawanna 2004; Biswas et al 2005). Likewise, environmental factors including light intensity, feeding frequency, water quality, and stocking density may be associated with photoperiod to influence growth, survival, and feed utilization, particularly in outdoor systems. Photoperiod extension in uncontrolled environmental conditions can increase energy allocation toward somatic growth in *O. niloticus* fry, increase locomotor activity, and promote more frequent feeding, thereby improving growth performance and feed utilization (Biswas et al 2005; Vera Cruz & Brown 2009).

Conclusions. The study showed that extended and continuous photoperiod enhanced growth performance and feed utilization. Weight and length gain, specific growth rate, and absolute growth rate obtained the highest value under 18 h L: 6 h D and 24 h L: 0 h D, while survival remained stable in all treatments. Significantly lower FCRs were obtained under 18 h L: 6 h D and 24 h L: 0 h D, while 12 h L: 12 h D recorded significantly higher value. This study recommended 18 h L: 6 h D light-dark cycle for *O. niloticus* nursery production, as it enhances growth and feed efficiency while being more economically practical than continuous lightning. Future research may explore relationship of fry growth performance and plankton community dynamics, as well as the effect different light intensities. In addition, further evaluation of stress responses and effect of reduced stocking densities (200 to 300 fry m^{-2}) of *O. niloticus* under varying photoperiod regimes is recommended to better understand their influence on survival performance. This study supports the use of photoperiod manipulation as a strategy to improve nursery performance of *O. niloticus* in a hapa-based system.

Acknowledgements. The authors would like to express their gratitude to the faculty and staff members of the College of Fisheries and Freshwater Aquaculture Center at Central Luzon State University for their invaluable support and assistance throughout the conduct of this study. Their expertise, guidance and resources greatly contributed to the success of this research. This study was financially supported by the Department of Agriculture–Bureau of Agricultural Research (DA-BAR) through the Degree Scholarship Program implemented by the University of the Philippines Los Baños Foundation, Inc. (UPLBFI).

Conflict of interest. The authors declare that there is no conflict of interest.

References

Al-Emran M., Zahangir M. M., Badruzzaman M., Shahjahan M., 2024 Influences of photoperiod on growth and reproduction of farmed fishes-prospects in aquaculture. Aquaculture Reports 35:101978.

Arambam K., Singh S. K., Biswas P., Patel A. B., Jena A. K., Pandey P. K., 2020 Influence of light intensity and photoperiod on embryonic development, survival and growth of threatened catfish *Ompok bimaculatus* early larvae. Journal of Fish Biology 97(3):740-752.

Ayson F. G., Takemura A., 2006 Daily expression patterns for mRNAs of GH, PRL, SL, IGF-I and IGF-II in juvenile rabbitfish, *Siganus guttatus*, during 24-h light and dark cycles. General and Comparative Endocrinology 149(3):261-268.

Biswas A. K., Endo M., Takeuchi T., 2002 Effect of different photoperiod cycles on metabolic rate and energy loss of both fed and unfed young tilapia *Oreochromis niloticus*: Part I. Fisheries science 68(3):465-477.

Biswas A. K., Seoka M., Inoue Y., Takii K., Kumai H., 2005 Photoperiod influences the growth, food intake, feed efficiency and digestibility of red sea bream (*Pagrus major*). Aquaculture 250(3-4):666-673.

Biswas A. K., Seoka M., Ueno K., Takii K., Kumai H., 2008 Stimulation of growth performance without causing stress response in young red sea bream, *Pagrus major* (Temminck & Schlegel), by photoperiod manipulation. Aquaculture Research 39(5):457-463.

Blanco-Vives B., Villamizar N., Ramos J., Fernald R. D., Sánchez-Vázquez F. J., Madrid J. A., 2010 Effect of daily thermo- and photo-cycles of different light spectrum on the development of Senegal sole (*Solea senegalensis*) larvae. Aquaculture 306(1-4):137-145.

Cinense M., Agulto I., Espino A., Gavino R., Sicat E., Taylan V., 2018 Modified photoperiods and light intensities for grow-out production of Nile tilapia (*O. niloticus*) under indoor tank culture system. MATEC Web of Conferences 192:03011.

Elsbaay A., 2013 Effects of photoperiod and different artificial light colors on Nile tilapia growth rate. IOSR Journal of Agriculture and Veterinary Science 3(3):5-12.

El-Sayed A. F. M., Kawanna M., 2004 Effects of photoperiod on the performance of farmed Nile tilapia *Oreochromis niloticus*: I. Growth, feed utilization efficiency and survival of fry and fingerlings. Aquaculture 231(1-4):393-402.

Falcón J., Besseau L., Sauzet S., Boeuf G., 2007 Melatonin effects on the hypothalamo–pituitary axis in fish. Trends in Endocrinology & Metabolism 18(2):81-88.
Fielder D. S., Bardsley W. J., Allan G. L., Pankhurst P. M., 2002 Effect of photoperiod on growth and survival of snapper *Pagrus auratus* larvae. Aquaculture 211:135–150.
Imsland A. K., Jonassen T. M., Hangstad T. A., Stefansson S. O., Elvegård T. A., Lemmens S. C., Reynholds P., 2018 The effect of continuous light and compressed photoperiods on growth and maturation in lumpfish *Cyclopterus lumpus*. Aquaculture 485:166-172.
Islam M. M., Zenia F., Mamun M. M. M., Akhter F., Zahangir M. M., 2021 Amelioration of growth, blood physiology and water quality by exogenous dietary supplementation of pepsin in stripped catfish, *Pangasiadon hypophthalmus*. Aquaculture 530:735840.
Islam S. M. M., Zahangir M. M., Jannat Z., Hasan M. N., Suchana S. A., Rohani M. F., Shahjahan M., 2020 Hypoxia reduced upper thermal limits causing cellular and nuclear abnormalities of erythrocytes in Nile tilapia, *Oreochromis niloticus*. Journal of Thermal Biology 90:102604.
Kurata M., Tamura Y., Honryo T., Ishibashi Y., Sawada Y., 2017 Effects of photoperiod and night-time aeration rate on swim bladder inflation and survival in Pacific bluefin tuna, *Thunnus orientalis* (Temminck & Schlegel), larvae. Aquaculture Research 48(8):4486-4502.
Ma H., Wei P., Li X., Liu S., Tian Y., Zhang Q., Liu Y., 2021 Effects of photoperiod on growth, digestive, metabolic and non-special immunity enzymes of Takifugu rubripes larvae. Aquaculture 542:736840.
Martínez-Chávez C. C., Tello-Ballinas A., Fonseca-Madrigal J., Ross L. G., Martínez-Palacios C. A., 2014 Photoperiodic growth enhancement in a tropical batch spawning atherinopsid, pike silverside *Chirostoma estor*. Journal of Fish Biology 85(2):546-553.
Okomoda V. T., Ataguba G. A., Ayuba V. O., 2013 Hematological response of *Clarias gariepinus* fingerlings exposed to acute concentrations of Sunsate. Journal of Stress Physiology & Biochemistry 9(2):271–278.
Puvanendran V., Brown J. A., 2002 Foraging, growth and survival of Atlantic cod larvae reared in different light intensities and photoperiods. Aquaculture 214(1-4):131-151.
Ramzanzadeh F., Yeganeh S., JaniKhalili K., Babaei S. S., 2016 Effects of different photoperiods on digestive enzyme activities in rainbow trout (*Oncorhynchus mykiss*) alevin and fry. Canadian Journal of Zoology 94(6):435-442.
Ruane N. M., Nolan D. T., Rotllant J., Costelloe J., Bonga S. W., 2000 Experimental exposure of rainbow trout *Oncorhynchus mykiss* (Walbaum) to the infective stages of the sea louse *Lepeophtheirus salmonis* (Krøyer) influences the physiological response to an acute stressor. Fish & Shellfish Immunology 10(5):451-463.
Shahjahan M. D., Uddin M. H., Bain V., Haque M. M., 2018 Increased water temperature altered hemato-biochemical parameters and structure of peripheral erythrocytes in striped catfish *Pangasianodon hypophthalmus*. Fish Physiology and Biochemistry 44(5):1309-1318.
Shahjahan M., Rahman M. S., Islam S. M. M., Uddin M. H., Al-Emran M., 2019 Increase in water temperature increases acute toxicity of sumithion causing nuclear and cellular abnormalities in peripheral erythrocytes of zebrafish *Danio rerio*. Environmental Science and Pollution Research 26:36903–36912.
Shahjahan M., Al-Emran M., Islam S. M., Baten S. A., Rashid H., Haque M. M., 2020 Prolonged photoperiod inhibits growth and reproductive functions of rohu *Labeo rohita*. Aquaculture Report 16:1000272.
Shahjahan M., Islam S. M. M., Bablee A. L., Siddik M. A. B., Fotedar R., 2021 Sumithion usage in aquaculture: benefit or forfeit? Reviews in Aquaculture 13(4):2092-2111.
Shahjahan M., Isla M. J., Hossain M. T., Mishu M. A., Hasan J., Brown C., 2022 Blood biomarkers as diagnostic tools: an overview of climate-driven stress responses in fish. Science of the Total Environment 843:156910.

Stuart K. R., Drawbridge M., 2011 The effect of light intensity and green water on survival and growth of cultured larval California yellowtail (*Seriola lalandi*). Aquaculture 321(1-2):152-156.
Taylor J. F., North B. P., Porter M. J. R., Bromage N. R., Migaud H., 2006 Photoperiod can be used to enhance growth and improve feeding efficiency in farmed rainbow trout, *Oncorhynchus mykiss*. Aquaculture 256(1-4):216-234.
Vera Cruz E. M., Brown C. L., 2009 Influence of the photoperiod on growth rate and insulin-like growth factor-I gene expression in Nile tilapia *Oreochromis niloticus*. Journal of Fish Biology 75(1):130-141.
Veras G. C., Murgas L. D. S., Rosa P. V., Zangeronimo M. G., Ferreira M. S. D. S., Leon J. A. S. D., 2013 Effect of photoperiod on locomotor activity, growth, feed efficiency and gonadal development of Nile tilapia. Revista Brasileira de Zootecnia 42:844-849.
Villamizar N., Blanco-Vives B., Migaud H., Davie A., Carboni S., Sanchez-Vazquez F. J., 2011 Effects of light during early larval development of some aquacultured teleosts: A review. Aquaculture 315(1-2):86-94.
Zahangir M. M., Haque F., Mostakim G. M., Islam M. S., 2015 Secondary stress responses of zebrafish to different pH: Evaluation in a seasonal manner. Aquaculture Reports 2:91–96.
*** BFAR, Bureau of Fisheries and Aquatic Resources, 2022 Comprehensive national fisheries industry development plan 2021–2025. Available at: https://www.bfar.da.gov.ph/wp-content/uploads/2022/10/Comprehensive-National-Fisheries-Industry-Development -Plan-CNFIDP-2021-2025.pdf

Received: 14 January 2026. Accepted: 05 March 2026. Published online: 26 March 2026.
Authors:
Reniel Reyes Dandan, College of Fisheries, Central Luzon State University, Science City of Muñoz, Nueva Ecija, 3120, Philippines, e-mail: dandan.reniel@clsu2.edu.ph
Emmanuel Manalad Vera Cruz, College of Fisheries, Central Luzon State University, Science City of Muñoz, Nueva Ecija, 3120, Philippines, e-mail: emmanuel.veracruz@clsu2.edu.ph

How to cite this article:
Dandan R. R., Vera Cruz E. M., 2026 Influence of different photoperiod regimes on growth performance and feed utilization efficiency of Nile tilapia (*Oreochromis niloticus*) fry reared in a hapa-based nursery system. AACL Bioflux 19(2):552-559.