IMPACTS OF ILLUMINATION TIME AND COLOR ON TILAPIA OUTGROWTH AND FISH FLESH QUALITY

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ABSTRACT

The present study was aimed to look at the impacts of illumination time and illumination color on outgrowth and activity of Nil Tilapia (Tilapia Niloticus). A commercial food was used for feeding fish during experimental period. The data obtained from the experiment were subjected to one-way analysis of variance (ANOVA) (using SPSS program). The results indicated that illumination time (24, 16 hour and control) and illumination colors (white, red and blue) were significantly affected on fish activity. The fish outgrowth at illumination blue was higher than other illumination colors for all illumination time. The illumination blue and long illumination time (24 light hours) created the top fish percentage weight gained during feeding period (WGDFP = 52.9 g), specific growth rate (SGR = 4.08 %), daily growth rate (DGR = 17.63 %) and growth efficiency (GE = 29 %). On the other side, the blue illumination and short illumination time 16 h created weight gained during feeding period (WGDFP = 46.5 g), specific growth rate (SGR = 3.89 %), daily growth rate (DGR = 15.51 %) and growth efficiency (GE = 28 %). At long illumination time, the feed conversation efficiency (FCE) was 92, 95 and 98 % at illumination white, red and blue respectively. There were significant differences in crude protein and crude fat contents among fish exposed to different photoperiod regimes. Fish exposed to (24 h) illumination regime had significantly lower crude fat and ash than those of the other.

Keywords: *illumination, colors, fish, outgrowth, quality, protein*

1. INTRODUCTION

Aquaculture has been growing steadily in recent times as an excellent source of high-quality protein. It is growing at 9% every year and it is estimated to grow up to 41% (53.6 million tons) of the fish production worldwide by the year 2020 (Krishen *et al.*,

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2009). Tilapia culture is a fast growing commercial endeavour and these fishes have emerged as the third most important cultured fish commodity in the world, next to carps and salmonids (FAO, 2005). During culture, growth performance of this species has been controlled by the manipulation of food ingredients (Hu *et al*., 2006), addition of growth promoters (Lara-Flores *et al.*, 2003) and manipulation of environmental conditions (Vera Cruz and Brown, 2009 and Fuentes-Silva et al. 2015)

The intensive culture of tilapia under controlled management systems is widely expanding to meet the increasing demands for these fishes, especially in developing countries. In this regard, the use of closed culture systems has received a considerable attention, and is becoming more common worldwide, particularly in arid areas that face shortage in fresh water or brackish water, or in areas where environmental parameters, such as salinity and temperature, are outside the tolerance range of tilapia (El-Sayed and Kawanna, 2004).

Light rays of various wavelength pass through the water to different depths depending on light reflection, absorption and diffusion as well as on availability of admixtures and small organisms in a water body. Photoperiod acts as an artificial Zeitgeber (cue or synchronizer), regulating the daily endogenous rhythms in fish and also affects fish growth, metabolic rates, body pigmentation, sexual maturation and reproduction (Biswas et al., 2002; Biswas et al., 2005). On the other hand, the growth and metabolic rates of several other species were not significantly affected by photoperiods (Purchase et al., 2000 and Elsbaay, 2013). Meanwhile, photoperiod may positively affect larval stages, but not juvenile stages.

Adaptations of fish to their natural environment may also influence their response to the farming environment. As in nature, light intensity and background color can affect feed detection and feeding success of cultured fish, thus influencing fish growth and mortality. In general, the highest growth rates of fish larvae are achieved when light conditions and background color optimize the contrast between the feed and the background (Jentoft et al., 2006; Strand et al., 2007). Light intensity may also affect the size of prey preferred by juvenile fish.

In most studies fluorescent lamps are used, resulting in what humans perceive as white light, despite the fact that: (a) in natural fish habitat, wavelength of light penetrating water varies greatly, (b) fish vision and spectrum perception are strongly adapted to each species natural habitat and living ethology (Pointer et al., 2005), and (c) recent studies indicate that light spectrum affects farmed fish growth performance (Karakatsouli et al., 2008), behavior (Marchesan et al., 2005) and physiological status (Karakatsouli et al. 2010).

Knowledge of the chemical composition of fish is necessary for a more effective introduction in the market, allowing competition with other widely consumed sources of animal protein, as beef, pork and poultry (Kristinsson and Rasco, 2000). The yield in fillet a fish depends on the weight, sex, body composition, anatomical features (relative head / body), mechanization level in the process, filleting method and skill of the operator (Clement and Lovell, 1994). As for the nutritional aspect, it is important to know the chemical composition of fish for consumption is stimulated, allowing competition with other protein sources widely used such as beef, pork and poultry (Garduno-Lugo et al., 2003). The photoperiod in addition to stimulating growth, can lead to changes in the chemical composition of fish (Biswas et al., 2005), since it influences the development and survival in different ontogenic phase. In addition, photoperiod influences both the feeding strategies as in the stimulation of the metabolic activities of various fish (Biswas et al., 2002). For some species, days or long photoperiods may indirectly modify the growth is by inducing an increase feed intake, dough development muscle due to the increased locomotor activity of animals , better efficiency in the use of nutrients and due to diversion of energy from maturation to somatic growth (Rad et al., 2006). However, there is little information on the effects of environmental factors on the chemical composition of fish, such as Nile tilapia, at different stages of production.

The present study aimed to, firstly, clear the impacts of illumination color and illumination time on outgrowth and activity of fish (Nil Tilapia). Secondly, study the fish flesh quality through chemical composition of fish.

2. MATERIALS AND METHODS

2.1. Experimental design:

The experimental system was constructed and carried out in the Kafr ElSheikh Governorate, Egypt (30.95° N and 31.9° E, and 9.0 m above the sea level) through the period 1st March, 2016 to 1st May, 2016. The experiments were studied 84 Nile tilapia fingerlings with initial weight 5 g in glass tanks (21 tanks). Experimental tanks (length × height × width: 0.7 × 0.5 × 0.35 m, volume capacity $0.1225 m^3$), the tanks were provided with central drainage pipes surrounded by outer sleeves pipes, perforated at the bottom, to facilitate self-cleaning and waste removal. Continuous aeration through an air pump (Boyu, U -9900, 3.2 l/mint) and heaters, with thermostats, to keep water temperature at 26 °C. Fig. 1 shows the schematic diagram of experimental design. About 20% of the water was replaced daily by new fresh water at the same temperature. Water quality parameters, including dissolved oxygen (DO), ammonia and pH were recorded every ten days.

The examination was intended to study the impact of illumination time and illumination color on Nile tilapia outgrowth, feed utilization efficiency and survival of Nile tilapia. The fish were exposed to two illumination time (24 and 16 h) by using fluorescent lamps and natural daylight (control, at experiment starting 11 h 37 mint and experiment end 13 h 24 mint). Illumination in each treatment was provided by two fluorescent lamps (36 W) suspended about 1 m above the water surface. On the other side, the fish were exposed to three types of illumination color (whit, red and blue). Light intensity was measured every ten days at water surface (at tank center) by a digital Lux Meter (Digital light meter Nicety LX-802) and was constant at around 400 lx throughout the experiment in artificial illumination groups. Light color (red 605 nm, 90% relative transmission; blue 480 nm, 83% relative transmission; white full-spectrum) and control was applied as previously described (Karakatsouli et al., 2008).

Fish were acclimated to experimental tanks for 1 day under room ambient lighting. After the acclimation period white, red and blue light color and photoperiod were applied and fish remained in these conditions for 60 days. Light color was achieved by covering light source. The fish were fed by hand a commercial feed (crude protein, 27 %; crude lipid 5.06 %; crude fiber 5.08 %; total energy 4000 kcal/kg) for 60 days. The diet was offered twice a day at 10:00 h and 16:00 h. Daily feeding rates (% BW/day) were determined based on recommendations of different researchers (El-Sayed, 2002).

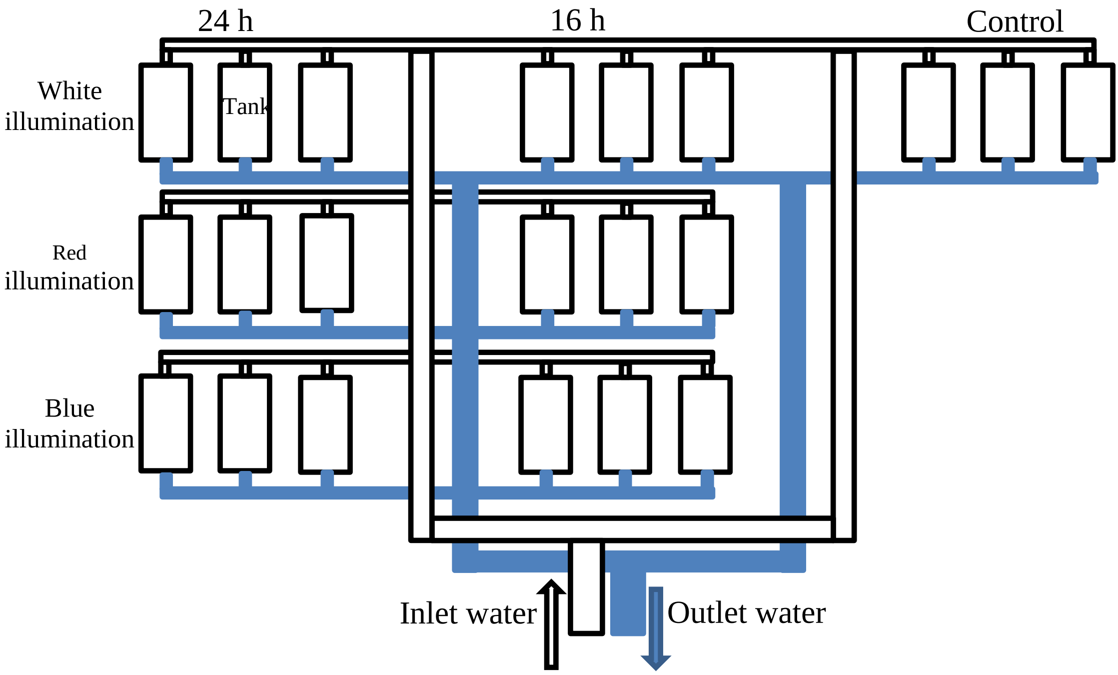


Fig. 1: Schematic diagram of the experimental design.

2.2. Grow-out performance analysis:

Therefore, the daily rates were of 6 % BW/day for 30 days and reduced to 5 % BW/day for other 30 days. Fish were weighed at 10 days intervals (days: 0 , 10, 20, 30, 40, 50 and 60) and feed intake were adjusted every 10 days also. Fish were weighed using an electronic balance (Shimadzu, EB-620SU ± 0.01 g sensitivity). The data collected every ten days and the growth rates were measured in terms of specific growth rate (SGR), weight gain during feed period (WGDFP), feed conversation efficiency (FCE) and condition factor (K) as the following (Fuentes-Silva et al. 2015):

$$WGDFP = FW - IW \qquad \dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots.(1)$$

Where:

FW= final weight, g. IW= initial weight, g.

$$DGR = \frac{Fw - IW}{experimental\ period\ \times IW} \times 100 \qquad \dots\dots\dots\dots..(2)$$

Where:

DGR= daily growth rate, %

$$SGR = \left(\frac{\ln FW - \ln IW}{time\ (day)}\right) * 100 \qquad \dots\dots\dots\dots\dots\dots\dots..\dots\dots\dots..(3)$$

$$FCE = \frac{mass\ gained\ (g)}{total\ amount\ of\ feed\ consumed\ (g)} \qquad \dots\dots\dots\dots\dots(4)$$

To evaluate energy expenditure, the energetic growth efficiency (GE) was calculated, where GE is the ratio between the energy of the weight increase of the fish and the total energy intake of the fish (Larsson and Berglund, 2005):

$$GE = \frac{\left(J \times (FW - IW)\right)}{(FI \times DE)} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots.(5)$$

Where: J is the conversion factor of mass to energy for percids (5.0 kJ g^{-1} wet weight) (calculated average from Bryan et al., 1996),

FI is the feed intake (g), and DE is the digestible energy content of the feed (16.747 kJ·g^{-1}, obtained from the manufacturer).

2.3. Body composition analysis:

Chemical composition of Nile Tilapia flesh (moisture; crude protein; lipid and ash) was estimated using the AOAC (2000) methods. Amino acids determination: Amino acids of isolated protein were determined in agricultural Res., Center, Cairo, based to the method described by Pellet and Young (1980).

2.4. Statistical analysis:

The data obtained from the experiment were subjected to one-way analysis of variance (ANOVA) (using SPSS program) to test the effect of photoperiod and light color on the growth rates, feed utilization efficiency. When ANOVA identified significant difference among groups. Least significant difference (LSD) was used to compare means at $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Water quality management:

Results indicated that the water parameters (salinity, temperature, hardness, pH, ammonia, nitrite and dissolved oxygen) in water used for breeding of *Nile Tilapia.* The water temperature in the all ta of the experiment ranged from 23 to 28 ^{o}C, pH degree ranged from 7.6 to 7.8, dissolved oxygen ranged from 6.50 to 7.4 ppm, nitrite ranged from 0.02 to 0.14 ppm, nitrate ranged from 1.8 to 2.3 ppm, ammonia 0.13 to 0.19 and the salinity level in the experiment not changed and reached to 1 ppm. The present results also showed that, the recorded levels of water parameters not exceeds the permissible levels required for fish breeding and production.

3.2. Fish growth performance under different illumination time:

Data illustrations on growth performance of Nile tilapia exposed to two illumination time are presented in and Fig.2. The results of experiment indicated that illumination time (24 and 16 h) and ambient light regime (control) significantly affected fish growth performance (Fig. 2 and Fig. 3). The continuous illumination time regime (24 h) created the top mean final weight 50.6 ± 0.30 g. Mean final weights of fish exposed to illumination time 16 h and control treatment were measured as 47.3 ± 0.20 and 43.1 ± 0.20 g, respectively. Consequentially, the weight gained during feed period was higher under continuous illumination regime (24 h) for all color light (45.6, 48.8 and 52.8 g for white, red and blue respectively). At the end of experiment, there are significant differences between photoperiods ($p< 0.05$). Significant differences in mean body weights of photoperiod groups and control were only detectable during the second month (days 30–60) of the experiment. Throughout this stage, mean body weight of fish at continuous illumination regime (24 h) was significantly different and higher than that of other illumination time regime (16 h) and control ($p<0.05$). Moreover, mean body weights of fish exposed to 16 h illumination time groups were also found to be significantly different from that of control during this development stage.

The results indicated that illumination time was significantly affected fish growth performance (Fig. 3 and Fig. 4). The continuous illumination time regime (24 h) created the best fish percentage weight gain during feed period (WGDFP= 45.6 g), specific growth rate (SGR =3.86 %), daily growth rate (DGR = 15.21 %) and growth efficiency (GE = 27 %). The control treatment created the lowest values of weight gain during feeding period (WGDFP = 38.1 g), specific growth rate (SGR = 3.59 %), daily growth rate (DGR = 12.72 %) and growth efficiency (GE = 25 %). On the other side, the highest mean value of feed conversation efficiency (FCE = 92 %) was observed in continuous illumination time regime (24 h), while, the lowest mean value of feed conversation efficiency (FCE = 85 %) was observed in control treatment.

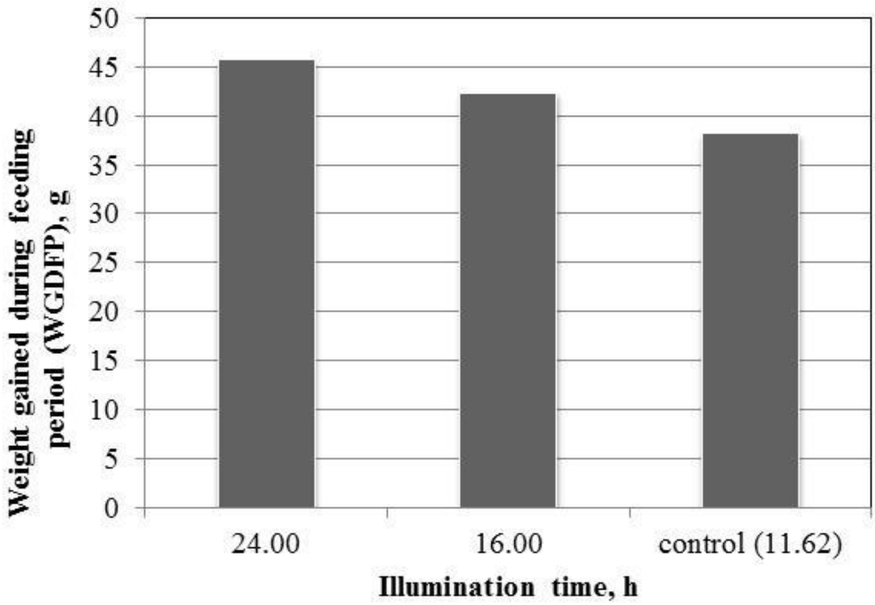


Fig. 2. Weight gained during feeding period (WGDFP) of Nile tilapia under different illumination time regimes.

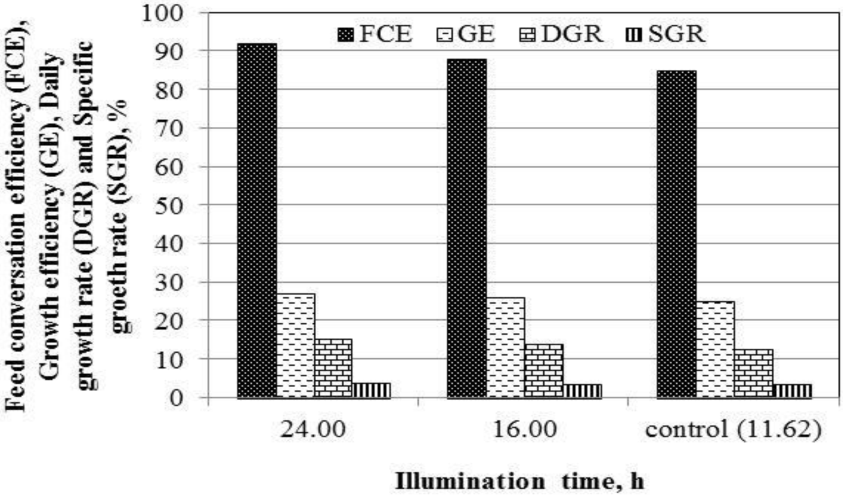
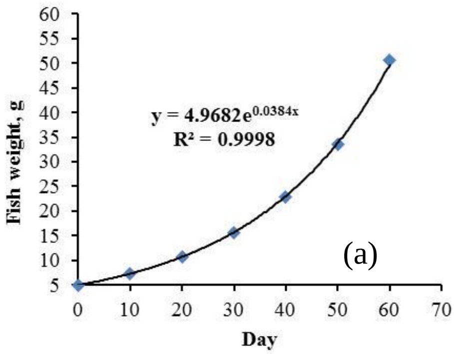
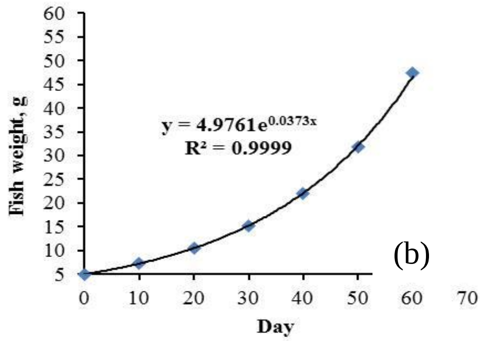


Fig. 3. The growth performance (FCE, DGR, GE and SGR) of Nile tilapia under different illumination time regimes.





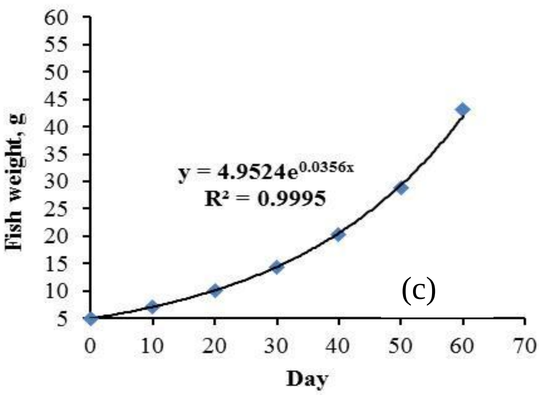


Fig.4: The growth rate fitting curve of Nile tilapia under different illumination time regimes: a) illumination time 24 h, b) illumination time 16 h and c) control treatment 11.62 h.

The results indicated that the relationship between the fish weight (g) and the illumination time (day) was exponential function (Fig. 4). The improvement in the performance of Nile tilapia the present study with increasing illumination time may also have been related to the reduction of standard metabolic rate. In support, (Biswas et al., 2003) studied the effects of illumination time on the metabolic rate of fed and unfed young and adult Nile tilapia. They found that metabolic rate and energy loss were negatively correlated with illumination time. They concluded that Nile tilapia conserve energy when raised under illumination time with longer light phases. However, these authors suggested that growth studies must be conducted under different illumination time cycles in order to further evaluate the effects of photoperiod regimes on these fish. The reduction of fish metabolic rate with increasing light phases has also been reported with marine fish species.

3.3. Fish growth performance under different illumination color:

Data illustrations on growth patterns of Nile tilapia exposed to three types of illumination colors and two long-day illumination times are presented in Fig. 5, Fig. 6 and Fig 7. The results of experiment indicated that illumination colors (whit, red and blue) significantly affected fish growth performance (Fig. 5 and Fig. 6).

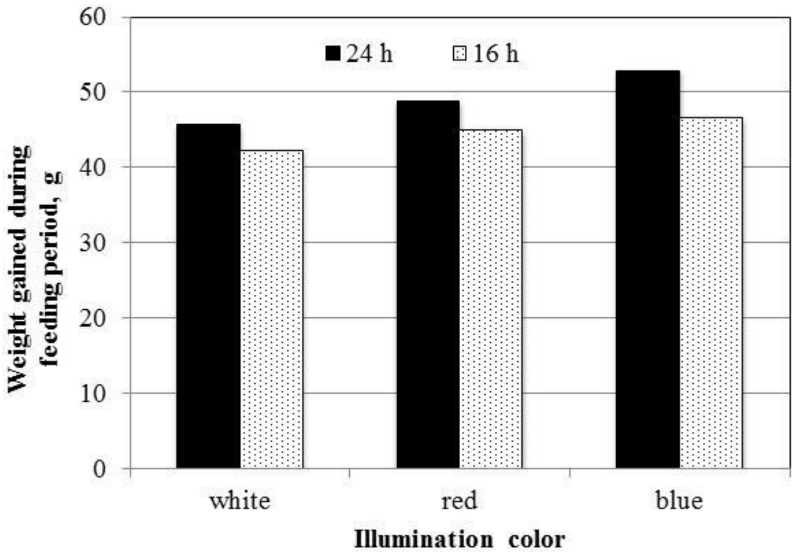


Fig. 5. Weight gained during feeding period (WGDFP) of Nile tilapia under different illumination colors and illumination time regimes.

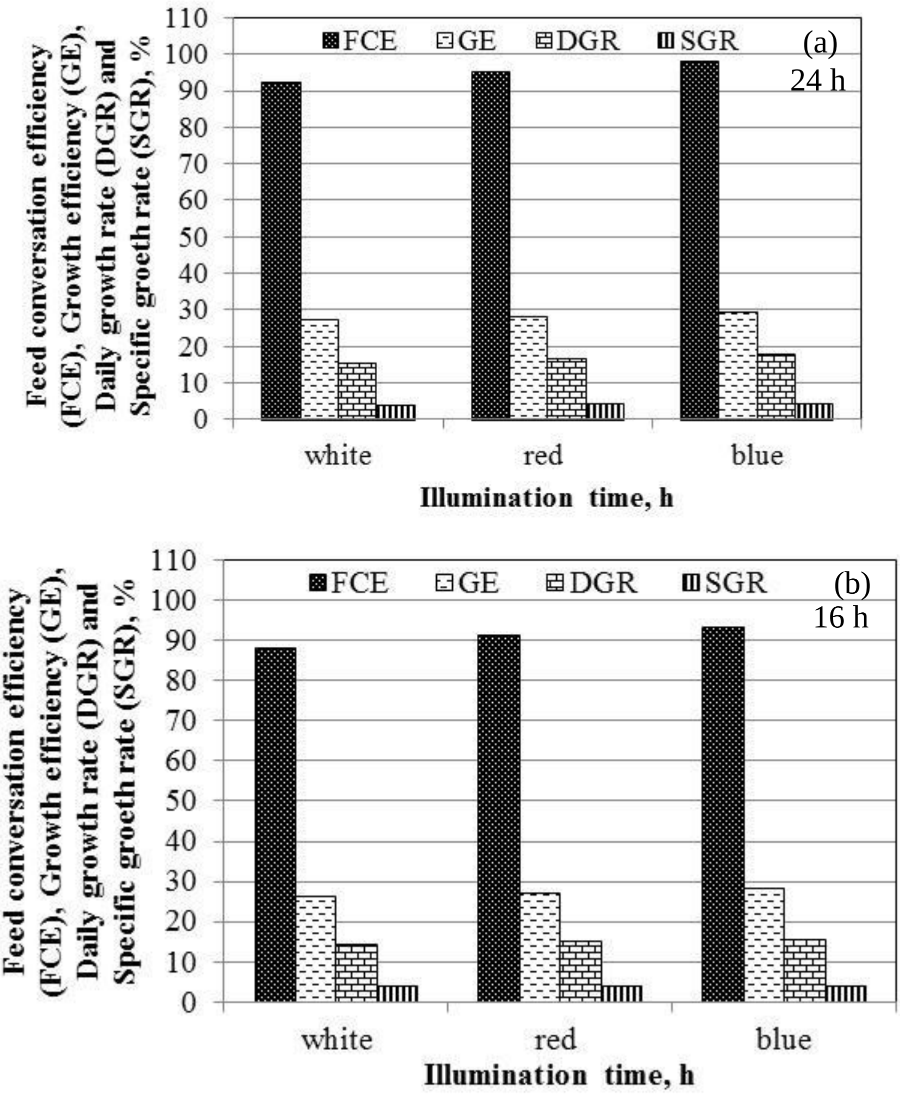


Fig. 6. The growth performance (FCE, DGR, GE and SGR) of Nile tilapia under different illumination color and illumination time regimes (a) 24 h and (b) 16 h.

The fish maintained under blue illumination and continuous illumination time (24 h) created the top mean value of final weight (57.9 ± 0.4 g). While the mean final weight for fish exposed to blue illumination and 16 h was 51.5 ± 0.4 g. Mean final weights of fish exposed to white and red illumination under 24 h illumination were 50.6 ± 0.3g and 53.8 ± 0.5g respectively. On the other side, the mean final weight of fish exposed to white and red illumination under 16 h were 47.3 ± 0.2 g and 49.9 ±0.4 g respectively. There are significant differences between light colors ($p < 0.05$). Throughout this experiment, mean body weight of fish at blue light was significantly different and higher than that of other light colors ($p < 0.05$) both at two photoperiods.

The results indicated that illumination colors significantly affected fish growth performance. At both different illumination times, the blue illumination was best of other illumination colors. The blue illumination and long illumination phase (24 h) created the best fish percentage weight gain during feeding period (WGDFP = 52. 9 g), specific growth rate (SGR = 4.08 %), daily growth rate (DGR = 17.6 %) and growth efficiency (GE = 29 %). On the other hand, the blue illumination and illumination time 16 h gave weight gain during feeding period (WGDFP = 46.5 g), specific growth rate (SGR = 3.89 %), daily growth rate (DGR = 15.51 %) and growth efficiency (GE = 28 %). The highest mean values of feed conversation efficiency (FCE = 98 %) was observed in blue illumination and long illumination time. While, the lowest mean values of feed conversation efficiency (FCE = 88 %) was observed in white illumination and 16 h illumination.

The present study demonstrated that the growth and feed efficiency of Nile tilapia were significantly affected by illumination colors. Mean final weights and growth performance (SGR, WGDFP, DGR and GE) of fish exposed to different illumination colors in this study reveal that growth in Nile Tilapia is enhanced under blue illumination when compared to white and red illumination. Light colors have been reported to stimulate growth in a number of fish species (Strand et al., 2007 and Luchiari and Freire, 2009).

It has been suggested that freshwater fish species are more sensitive to photoperiod than marine and diadromous species. However, the response of marine species to photoperiods has been well investigated, while less information is available on freshwater species.

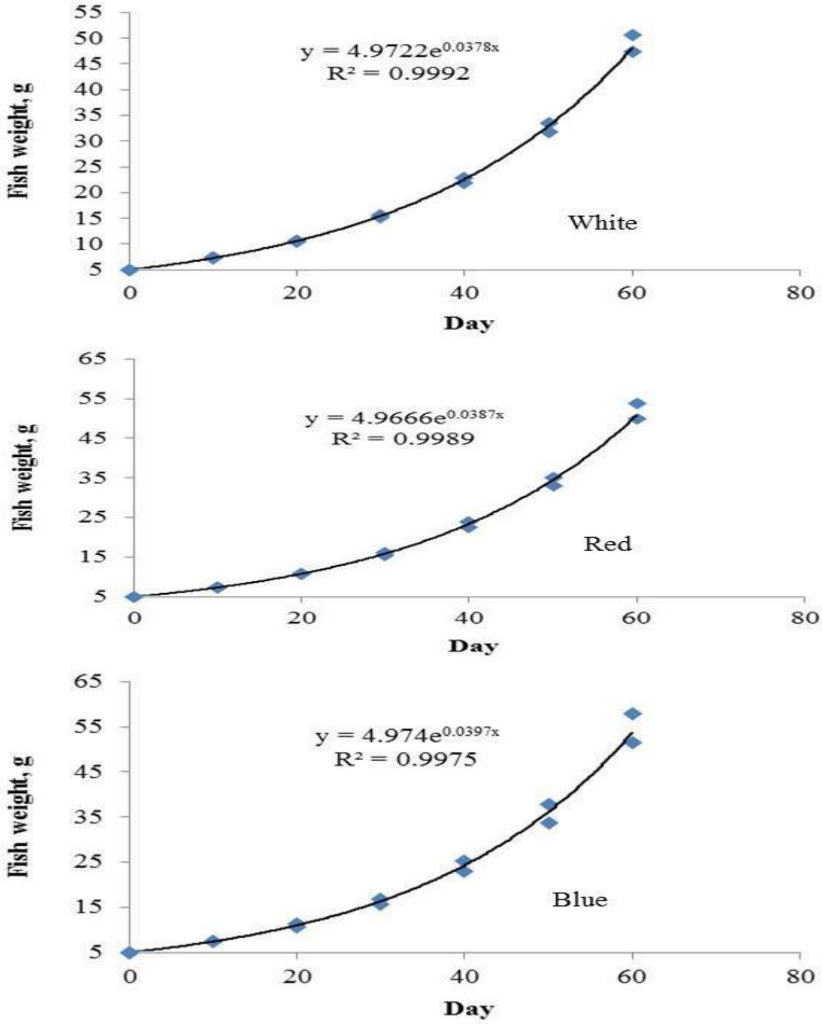


Fig. 7. The growth rate fitting curve of Nile tilapia under different illumination color (white, red and blue).

3.4. Fish flesh quality:

There were significant differences in crude protein and crude fat contents among fish exposed to different photoperiod regimes (Table 1). Fish exposed to (24 h) illumination time regime had significantly lower crude fat and ash than those of the other. Fish exposed to 16 h illumination time regime had higher body ash and crude fat but lower body protein compared to fish exposed to the 24 h. According to the results, the highest content of protein 55.88% was found in group blue illumination and long illumination time (24 h).

Table: 1. Effect of different Photoperiod and Light Color on the proximate composition (dry weight %) of Nile Tilapia at the end of the photoperiod trial

Component %	Illumination time regime						
	Control	24 h			16 h		
		white	red	blue	white	red	blue
Moisture	75.59	77.80	74.32	72.94	75.45	74.96	74.28
Protein	50.64	53.59	55.14	55.88	51.92	52.14	54.82
Crude fat	23.70	23.52	21.95	21.74	23.81	23.67	23.32
Ash	2.04	1.97	2.01	2.12	2.00	2.05	2.10

(Table 2) shows the effect of different illumination time regime and illumination colors on amino acid composition of Nile Tilapia flesh. It could be noticed that, all investigated samples contain almost all types of amino acids. It can be also found that glutamic and Aspartic were the most predominant amino acids. Generally, the highest values for all amino acids were found in fish group blue illumination and long illumination time (24 h).

Table: 2. Effect of different Photoperiod and Light Color on amino acids content of Nile Tilapia at the end of the photoperiod trial

Component %	Illumination time regime						
	Control	24 h			16 h		
		white	red	blue	white	red	blue
Lysine	7.67	6.93	7.54	8.92	7.13	7.23	7.21
Iso-leucine	3.93	4.30	3.96	3.84	3.77	4.20	3.55
Leucine	7.03	7.65	8.21	7.98	7.21	7.82	7.40
Methionine	1.60	1.56	1.21	1.71	1.68	2.60	1.68
Phenylalanine	3.33	3.98	3.30	3.46	4.12	3.28	3.75
Threonine	3.93	4.20	3.99	5.01	4.08	3.66	3.72
Tryptophan	1.07	1.43	1.07	4.19	1.92	3.48	2.88
Valine	4.50	4.62	4.50	6.50	4.50	4.50	4.50
Histidine	2.80	2.97	2.80	2.91	2.80	2.80	2.80
Arginine	4.76	4.92	5.76	4.83	4.71	4.56	5.03
Aspartic	7.94	8.21	8.02	8.31	8.00	7.99	8.23
Serine	3.73	3.76	3.14	2.92	3.73	3.73	3.29
Glutamic	15.9	16.22	16.84	16.92	16.27	15.98	16.82
Proline	3.73	3.98	3.73	3.69	3.91	3.73	3.73
Glycine	4.50	4.79	4.22	6.35	5.76	4.71	4.74
Alanine	6.44	6.83	6.44	6.21	6.83	6.44	8.65
Tyrosine	2.41	2.95	2.41	2.38	2.80	2.39	2.52

4- CONCLUSION

In conclusion, the present results revealed that illumination time regime and illumination colors were significantly affecting the growth of Nile tilapia. A 24 h illumination and blue illumination were suggested for optimal performance of fish. These results have a significant application in tilapia aquaculture in indoor recirculating systems, as they improve our understanding of the role that illumination time and illumination colors plays in fish growth and metabolism. Adopting the optimum illumination time in case of tilapia will also reduce the amount of energy used for standard metabolism, and in turn increase fish growth and profitability.

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الملخص العربي

تأثير ألون الاضاءة الصناعية وفترات الاضاءة علي معدل النمو وجودة لحم السمك البلطي النيلي

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تهدف هذه الدراسة الي اختبار تأثير الفترات الضوئية وكذلك لون الضوء علي نمو ونشاط وجودة لحم اسماك البلطي (Tilapia Niloticus) . حيث تم تغذية الاسماك اثناء التجربة علي العليقة التجارية لمدة ٦٠ يوم. وتم عمل التحليل الاحصائي(ANOVA) باستخدام برنامج SPSS . اظهرت النتائج ان الفترات الضوئية (٢٤ ساعة اضاءة و ١٦ ساعة إضاءة والمعاملة الكنترول) وكذلك لون الاضاءة (ابيض و احمر و ازرق) ذات تأثير معنوي علي معدل نمو أسماك البلطي. حيث حقق اللون الازرق افضل معدل نمو لكل فترات الاضاءة تحت الدراسة. اعلي معدل نمو تحقق عند استخدام اللون الازرق وفترة اضاءة ٢٤ ساعة حيث كان الوزن المكتسب خلال فترة التجربة ٥٢.٩ جرام ومعدل النمو النوعي ٤.٠٨ % ومعدل النمو اليومي ١٧.٦٣ % وكفاءة النمو ٢٩ % . وعلي الجانب الاخر، عند استخدام اللون الازرق وفترة إضاءة ١٦ ساعة ، كان الوزن المكتسب خلال فترة التجربة ٤٦.٥ جرام ومعدل النمو النوعي ٣.٨٩ % ومعدل النمو اليومي ١٥.٥١ % وكفاءة النمو ٢٨ % . وأوضحت النتائج انه عند استخدام اللون الازق كانت القيمة المتوسطة لكفاءة التحويل الغذائي (٩٨ % و ٩٣ %) عند استخدام فترات الاضاءة الطويلة (٢٤ ساعة) و فترة الاضاءة ١٦ ساعة علي الترتيب . بينما انخفضت القيمة المتوسطة لكفاءة التحويل الغذائي عند استخدام اللون الاحمر فكانت ٩٥ % و ٩١ % عند استخدام فترات الاضاءة الطويلة (٢٤ ساعة) و فترة الاضاءة ١٦ ساعة علي الترتيب . اوضحت النتائج ايضا ان هناك اختلافات كبيرة في البروتين و الدهون بين الأسماك المعرضة لفترات الاضاءة المختلفة. حيث كان نظام الفترات الضوئية الطويلة (٢٤ ساعة) الاقل في نسبة الدهون والاقل في نسبة الرماد والاعلي في نسبة البروتين.

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