Effect of the RGB Wavelengths of LED Light on Growth Rates of Nile Tilapia Fry in Biofloc Technology (BFT) Systems

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Abstract: This research evaluates the effect of wavelengths of the light on growth rates of Nile tilapia fry in the order of improving sustainability in aquaculture production. For this purpose, four tanks of water with tilapias were studied. Three tanks were illuminated with LED lamps each one with monochromatic peak wavelengths (λ): Blue light (BL) tank with $\lambda = 451.67$ nm, Green light (GL) with $\lambda = 513.33$ nm and Red light (RL) tank with $\lambda = 627.27$ nm. All tanks were illuminated with a light intensity of $0.832\ mW/cm^2$, and they had a photoperiod of 18L:6D throughout the study. Besides, the fourth tank was illuminated only by Natural light (NL) tank, which had the function of witness tank. Each treatment included the fourth, were randomly assigned to 150L tanks that were stocked with 122 Nile tilapia fry. The Nile tilapia fry had an initial average weight of $0.24 \pm 0.01\ g$, and were grown for 73 days. The average final weight for BL, GL, RL and NL treatments were 15.54 g, 16.84 g, 17.27 g and 16.22 g, respectively. The results suggest that Nile tilapia fry was positively influenced by the red light wavelength, which was represented in the greatest mass gain.

Key words: Aquaculture, color, LEDs, light, tilapia.

1. Introduction

Aquaculture is a technique that directs and encourages the reproduction of fish in both salt and freshwater, but the use of traditional fish production techniques requires a large amount of water and natural resources, generating negative environmental impacts [1]. Therefore, techniques that produce more are required, with less use of natural resources [2].

An alternative of intensive production that requires less use of natural resources is proposed by Biofloc technology, which requires zero or minimum water exchange, thus generating ideal conditions for the formation of microbial communities, called bioflocs [3]. The bioflocs, are conglomerates of microbes, algae, protozoa, detritus and dead organic particles that take the inorganic nitrogen existing in the pond, which comes from of the physiological waste of the fish and the degradation of the uneaten food. When the bioflocs are fed with carbohydrates (sugar, starch, molasses, cassava flour, etc.), they are forced to consume the inorganic nitrogen to generate the protein necessary for its growth and cell multiplication, which then becomes food for the fish [4].

The implementation of new technologies and the development of new areas of science in aquaculture is essential to improve intensive fish production. But, a little explored and implemented technology in the aquaculture is LED lightings. Although it is well known that night lighting considerably increases production in poultry farms, the advantages of LED lightings are only just being explored to create spectral and spatial distributions of light in special forms, with periods of lighting time ranging from hours until pulses of light repeated at 1Ghz [5]. This means that LED lightings systems meet the lighting requirements suitable for birds, pigs, bovines and fish. On poultry farms, the unique properties of LED light can reduce stress and mortality [6]. In addition to regulating the circadian rhythm and significantly increasing the production of eggs and meat, LED lightings may drastically reduce the consumption of electricity and the cost of aprocching inputs. On various research studies it is found that sunlight and light that is emitted by non-natural sources (such as spotlights, LEDs or other electronic devices) is an important factor that regulates the life and growth of all living beings [7]. In the case of fish, the intensity and spectrum of light influence embryonic development, and with the generation of certain photoperiods (light, duration and periodicity) the growth of fish may be altered and controlled, and in turn influences the release of reproductive hormones; thus having an important role in the reproduction and growth of fish [8]. At the same time, the effect of light should be investigated to know which properties of light could allow an optimal development and growth of the bioflocs. For example, the optimal density of bioflocs that allows the greatest amount of food available for fish.

Therefore, the effect of light should be investigated, and the objective of this study is to investigate the optimal RGB (Red, Green, Blue) wavelengths of LED light in growth rates of the Nile tilapia fry.

2. Material and Methods

2.1. Raw Materials

For this experiment, 489 Nile tilapias (O. niloticus) were acquired from a commercial hatchery of Jalisco, Mexico (AQUAMOL S.C. DE R.L.) and carried to the Prototypes Laboratory at the Autonomous University of Zacatecas. Fish were acclimatized and distributed into four tanks, each one with 150 L of water and a density of 122 fish per tank. The initial average weight of fish was $0.24 \pm 0.01\ g$.

2.2. LED Lighting

Three tanks were illuminated with RGB LED lamps, the Red light (RL) tank with a wavelength $\lambda = 627.27\ nm$, the Green light (GL) tank with a wavelength $\lambda = 513.33\ nm$ and the Blue light (BL) tank with a wavelength $\lambda = 451.67\ nm$. The light intensity in the RGB LED lamps remained constant in $0.832\ mW/cm^2$ with a photoperiod of 18L:6D during all the days of experimentation. The witness tank was the Natural light (NL) tank, which was only illuminated by the natural light.

2.3. Experimentation Setting

All tanks were filled with 150 L of potable water, and it was aerated with a blower for a week in order to dechlorinate the water. No water exchange was made, and pure cane sugar was added as source of carbon as described by De Schryver *et al*. [9] with a C/N ratio of 20:1 [10], in order to promote the formation of bioflocs from zero. Each tank was set at 29 ° C with a thermostat heater of 300 W to avoid high temperature variations throughout the entire study. The study lasted 73 days.

Temperature and Dissolved Oxygen (DO) were measured daily twice a day at 09:00 am and 8:00 pm every day with a model meter YSI 550A, in the same way, the pH was measured with a model meter Hanna HI 98127. Also, Ammonia-Nitrogen ($NH_3 - N$) was measured weekly with a model meter Hanna HI715. For its part, TAN (Total Ammonia Nitrogen) was calculated from Ammonia-Nitrogen by using a mathematically modified form of the equilibrium expression [11].

3. Results and Discussion

3.1. LED Lighting Characterization

All LED lamps were optically characterized through a spectrophotometer and radiometer, getting the properties shown in Table 1. Also, Fig. 1 shows the spectral power distribution of light emitted by each color LED lamp.

Table 1. Optical Properties of Color in LED Lamps: Blue Light (BL), Green Light (GL), and Red Light (RL)

Optical properties	LED Lamps		
	BL	GL	RL
$\lambda\ (nm)$	451.67	513.33	627.27
$\Delta\lambda\ (nm)$	23.75	32.80	16.92
Radiant intensity (mW/cm^2)	0.802	0.825	0.870

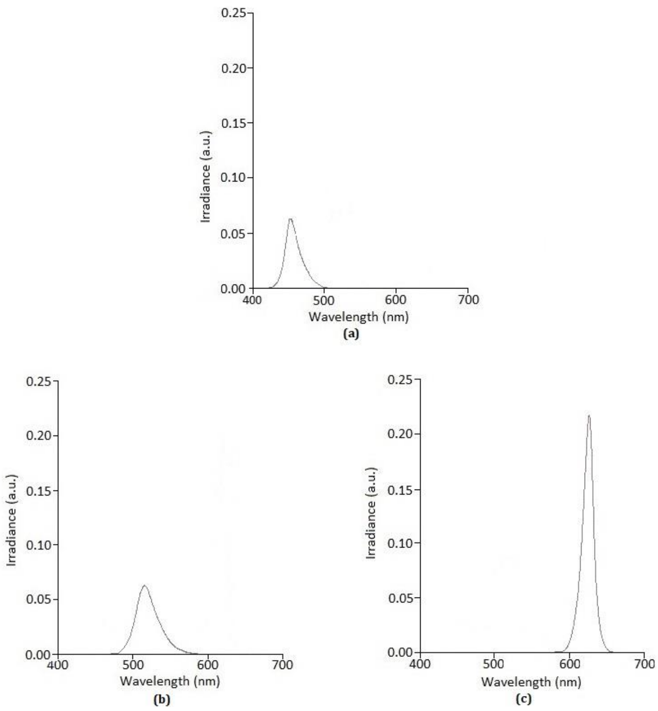

Fig. 1. Spectral power distribution of RGB LED lamps: (a) blue, (b) green, and (c) red light.

3.2. Maintaining Water Parameters

All parameters of water quality remained close to each other in all tanks, which could be seen in Table 2. The temperature did not change significantly between the tanks, and even remained under the optimal range of tilapia growth ($26°C$ - $30°C$) [12]. Meanwhile, the DO did not affect the growth performance of tilapia or the formation of microbial communities, given that it was at the level accepted by them, which is between 4-5 mg/l suggested by Evans *et al.* in [13]. The pH slightly varied between the treatments with Blue and Green light with respect to the treatment only with natural light, this small difference can be due to a greater microbial activity due to the effects of light on it. However, all the treatments were between the adequate range for tilapia (7-8) according to El- Sherif and El-Feky [14]. For its part, Ammonia-Nitrogen ($NH_3 - N$) never reached lethal levels for tilapia, this remained at levels below 0.1 mg/l recommended by El-Shafai *et al.*, in the Ref. [15], thanks to the C/N ratio of 20. TAN concentration followed a pattern similar to the pH, and remained at adequate levels for tilapia in accordance with [16].

Table 2. Parameters of Water Quality

Parameters	Tanks			
	BL	GL	RL	NL
Temperature (°C)	28.94	28.38	28.03	28.65
DO (mg/l)	4.71	4.67	4.65	4.72
pH	7.92	7.91	7.91	8.01
$NH_3 - N$ (mg/l)	0.08	0.07	0.07	0.10
TAN (mg/l)	0.79	0.76	0.86	0.93

3.3. Effect of Colored Light

The only parameter that differs significantly among all the treatments was the color or wavelength of the light, which one is the study parameter. By varying this parameter, it is possible to observe its effect on the growth rate of tilapia. The growth rates and survivals obtained in each tank are shown in Table 3.

Table 3. Parameters of Growth Rates

Parameters	Tanks			
	BL	GL	RL	NL
Average initial weight (g/fish)	0.27	0.22	0.22	0.26
Average final weight (g/fish)	15.54	16.84	17.27	16.22
Average final body length (cm/fish)	7.67	8.06	8.16	7.86
Survival (%)	84.68	59.85	95.49	74.33

We could see that tilapia growth presented the best performance in the tank with the Red lamp (See Fig. 2). Tank with RL presented the greatest gain of weight, it was noted in them a big demand for feed intake, every food that was offered was consumed immediately. Clarifying in turn, that all the ponds received the same amount of food according to the survival that they presented. For its part, the tank that was illuminated with Green light presented the second best gain in weight of all the treatments, but also this one presented the worst survival. This behavior agrees with the research carried out by Luchiari and Freire in (Luchiari & Freire, 2009), where they studied the effect of some light colors but in adult tilapia and different photoperiod. In the case of tank with Blue light, this presented the worst performance in growth rates, but it may be important to highlight that was the tank with the best homogeneity in the growth of the tilapia.

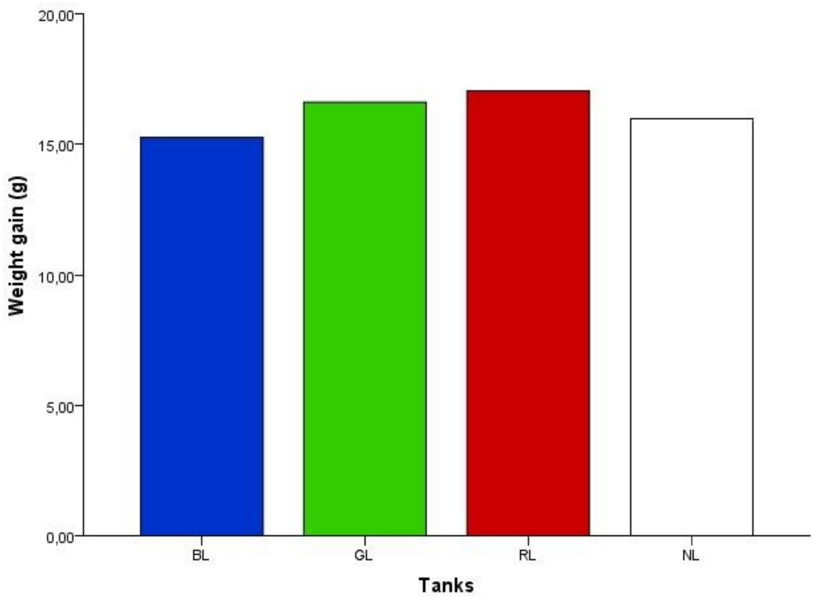

Fig. 2. Weight gain in all the treatments.

4. Conclusion

According to this research, the Nile tilapia fry showed the best growth performance under the red wavelength. Under Red LED light, tilapia presented a remarkable feed intake, the highest percentage of survivals and the best growth rate. Also, the green wavelength presented the second best growth rate but the worst survival of all treatments. Meanwhile, the blue wavelength only presented a good homogeneity in growth rates, but the worst growth rate. Future research includes to study. There are many issues for future research, for example the effect of many different LED colors [18], the effect of the light in the chemical composition of the tilapia and the effect of the light on the biofloc systems. This issues should be investigated to know the effect in the nutritional composition of tilapia.

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