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Effects of Led Light Color on Fish Growth in Aquaculture

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Abstract: In this study, we investigated the effects of colored Light-Emitting Diode (LED) light on the growth of fish. Fish farming is a business based on aquaculture, the art of culturing aquatic organisms. To determine optimal fish farming conditions, we experiment with various colors of LED fish tank lighting and monitor the effects of this artificial environmental control on fish growth. We show that the use of LED light control as an eco-bred technology can lead to a reduced production period.

Key words: LED, light color, growth, fish farming, artificial, business

INTRODUCTION

As a business, fish farming needs to operate as a well-structured, profit-making unit, producing competitive yields and quality. This is achieved through the use of engineering technology to construct modern and controlled ponds.

Freshwater aquaculture when compared with mariculture is relatively cheap. It uses ponds, dams and occasionally in-stream cages to grow species such as carp, tilapia, catfish, crayfish and eels. Freshwater species often tolerate poorer water quality than saltwater species and are better adapted to surviving in small areas and at high densities. Furthermore, most farmed freshwater species are vegetarian or omnivorous and therefore do not require large quantities of fishmeal for food (Kamisetti *et al*., 2012).

With the advancement of information technology, various applications of such technology to aquaculture have been developed such as water environment monitoring systems, production history recording systems and telediagnosis of fish diseases (Kang *et al*., 1995; Park and Kim, 2015; Atoum *et al*., 2015; Chang *et al*., 2005; Li *et al*., 2006; Ceong *et al*., 2007; Conti *et al*., 2006; Costa *et al*., 2006).

A potential infrastructure for an automatic aquaculture system (Kang *et al*., 1995) has been proposed. This included a visual fish farm monitoring system (Park and Kim, 2015) as well as the development of an automatic feeding controller (Atoum *et al*., 2015; Chang *et al*., 2005) and a fish disease diagnosis system (Li *et al*., 2006). In addition an IT convergence application system (Ceong *et al*., 2007) was suggested to contribute to eco-friendly aquaculture.

In this study, we investigated the effects of various colors of Light-Emitting Diode (LED) light on the growth of freshwater fish. We tested red, green, blue and yellow light using the snakehead as a test subject. Growth was assessed by taking weight measurements 2-3 times per week over a 4 weeks test period. The test results showed that light color does affect growth and that the use of optimally colored light can reduce the production period in fish aquaculture.

MATERIALS AND METHODS

Snakehead with led light in fish farming: In Korea, a fisheries white paper is submitted to the Parliament annually by the government under fisheries law which describes Fishery-related policy measures and associated trends. In 2012, the white paper included a special article titled “Sustainable Development of Aquaculture” which dealt with fisheries management, aquatic steady supply and healthy development of fisheries. It highlighted challenges facing the aquaculture industry as well as describing the sale and consumption of a food-supply fishery. Furthermore, it suggested solutions for the ongoing development of aquaculture including supply system establishment, promotion of a good fishing environment, development of technology to protect climate and natural resources and improving the safety of the industry, thus contributing to food security. And it covers for the international situation surrounding fisheries as shown in Fig. 1.

Building upon these proposed solutions, this paper elucidates the effects of various colors of LED light on fish growth as a possible technique for promoting fish resources that are declining because of overfishing and

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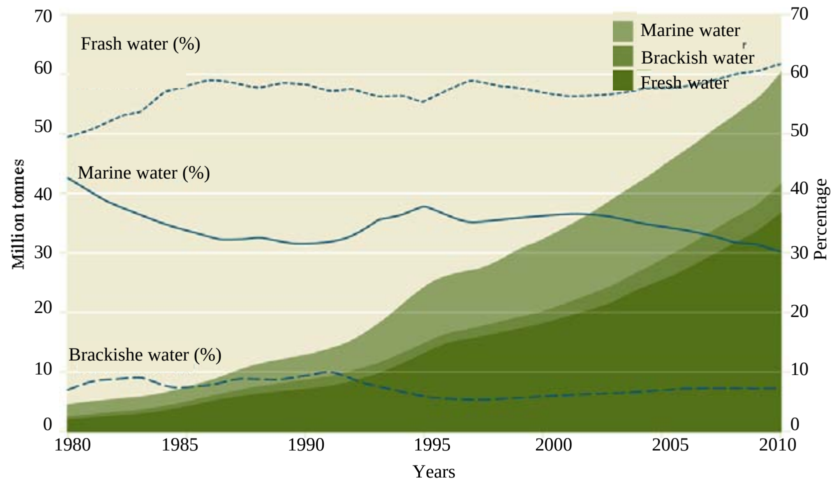

Fig. 1: Aquaculture production

indiscriminate fishing. As shown in Fig. 1, freshwater aquaculture production is increasing particularly rapidly. This study used colored LED lighting in snakehead culturing and tested the effects.

LED light characteristics: Recently, there has been much talk in the media about LED technology and information on LEDs can be easily accessed through television, newspapers and magazines. The LED is a next-generation light-source technology which can replace traditional light bulbs and fluorescent lighting, dramatically reducing power consumption. For example, LEDs can be used as an alternative light source in Liquid Crystal Display (LCD) technology, resulting in reduced power consumption and a sharper image in devices such as smartphones, televisions, computers and monitors.

An LED is a semiconductor diode. When electric current flows through the LED, electrons are recoupled with electron holes, leading to an energy gap. The energy from this gap is released in the form of light. This phenomenon is called electrical light emission and various colors of light are generated according to the magnitude of the energy gap.

LEDs possess a high luminous efficiency in energy conversion, resulting in low power consumption. An LED has a long life expectancy and a fast on/off response because it is a solid-state light emitter. LEDs have no filament or glass bulb and therefore, they are sturdy and can withstand impact which combined with their lack of mercury, makes them both safe and eco-friendly. These attractive properties are leading to a gradual expansion in the market for LED technology.

Snakehead in fish farming: Snakehead and related species are distributed worldwide with only slight variations in body shape and form. The snakehead found in Korea, Japan and China lives mainly in ponds, reservoirs and swamps where the water is murky and the bottom is muddy with many weeds. Unlike most fish, which obtain oxygen exclusively via. their gills, the snakehead has an auxiliary breathing organ which gives it the ability to breathe air. This allows the snakehead to survive in warm or stagnant waters that have low oxygen content.

The snakehead is a relatively large fish. It is usually 50-60 cm in length but it can grow up to 1 m. Its dorsal side is dark brown in color whilst the ventral side is yellow or white with a gray tinge. The spawning period is from May-August and the snakehead's main habitat is in mud under muddy, stagnant water or rankly grown weeds. The fertilized eggs hatch within 45 h temperature is approximately 20°C. The newly hatched snakehead is approximately 3.8-4.3 mm in length, only opening its mouth on reaching 5.5 mm. Approximately 37 h after hatching, it reaches 6.5 mm and the gills appear. At 8-9 mm, the young snakehead has completely absorbed the yolk sac and tail and pectoral fins appear. The remaining fins begin to form at 13 mm and patterning appears on both sides of the body at 27 mm with the scales being fully developed by around 30 mm. The snakehead eats plankton at the water surface until it reaches 40 mm by which point it is already able to breathe air. After that time, it starts to catch and eat young fish.

Female snakeheads grow faster than do the males, therefore, females are usually cultivated preferentially in fish farming to maximize profitability. The young snakehead will grow up to 25 cm in a year and reaches its adult size of 35 cm within 2 years, 45 cm at 3 years and 50 cm at 4 years. Snakeheads rarely live for more than 10 years, very rarely living for as long as 20 years. Although such a long cultivation period is not ideal for aquaculture, the snakehead has advantages of good survivability and adaptability and the production rate is generally sufficiently high for cultivating snakehead for medicinal supplement.

RESULTS AND DISCUSSION

In this study, the growth of fish under light of different colors was observed. The test colors were yellow, red, green and blue. Five water tanks were used, with dimensions of 300 mm (L)×160 mm (W)×225 mm (H). The central tank of the five was used for the white light test and each tank was capped with a box lid in order to control the extraneous light reaching the tank as shown in Fig. 2. The tank size was selected on the basis of cultivation period. Usually, a larger tank is required for cultivation periods of 1 year or longer. However, the test period in this study was considered to be approximately 2 months therefore, the smaller tank was adequate. The practicality of removing a snakehead from the water tank for measurement was also taken into account when determining tank height.

Snakehead has 5 growth periods. In this study, 5 snakeheads in the 2nd period of growth (10-15cm in length and 15-18 g) were cultivated in 5 water tanks and observed for 4 weeks as shown in Fig. 3. In order to optimize the snakehead habitats, each tank had an aquatic plant (water hyacinth) and 2-3 stones. Chlorine (disinfectant) in the water was dissipated by setting the tap water aside for a day before water changes and filters were also installed in each tank. Water temperature was maintained at 24°C.

Luminous intensity is the power emitted by a light source in a specific direction per unit solid angle. It has units of cd (candela). It is calculated as light flux (unit: l m) divided by the solid angle (unit: sr, steradian) which indicates a specific direction. 1[cd] means that the light flux in 1[sr] is 1[lm] (Fig. 4). The wavelength and light intensity of each color light is given in Table 1.

Studies in humans have shown that exposure to short wavelength light produces lower levels of fatigue than longer wavelengths and human subjects feel more comfortable in such light as its brightness increases and intensity decreases (Baek *et al*., 2011).

To measure growth, each fish was weighed three times per week in a wet state (there is a difference of <0.5 g in weight between wet and dry states) as shown in Fig. 5. From Monday-Friday, 7 g of Novo Stick (fish food) was fed to the fish at the same time each day and no food was given on Sunday. The weight measurement was taken 1 h after feeding on Monday.

Fig. 2: Water tank outside

Fig. 3: Water tank inside

Fig. 4: LED lights

Fig. 5: Weight measurement

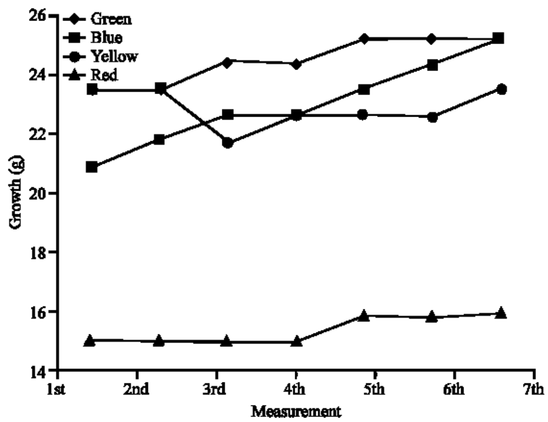

Fig. 6: Growth (weight)

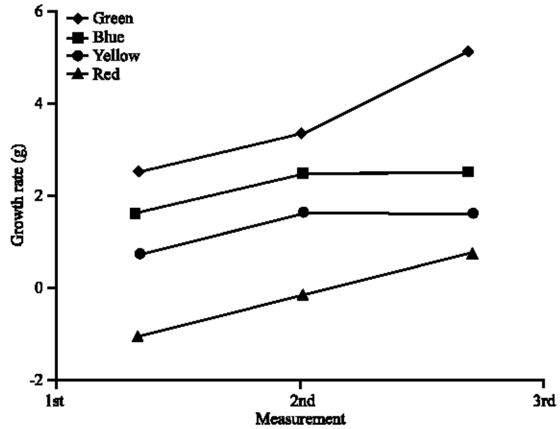

Fig. 7: Growth rate

Table 1: Color light

Colors	Wavelength [nm]	Intensity [cd]
Red	620	175
Green	460	168
Blue	520	329
Yellow	590	594

Table 2: Activity degree

Variables	Red	Yellow	Green	Blue
1st	Low	Medium high	Medium high	Medium high
3rd	Low	Medium high	Medium high	Medium high
5th	Low	High	High	Medium high
7th	Low	Medium high	High	Medium high

Figure 6 shows the weight measurements taken during the test period. Initially, it was difficult to observe any effect of light color on snakehead growth. However, after 2 weeks, we began to observe an effect. By observing fish growth for 4 weeks under the four colors of light, the most favorable impact on the growth was seen with the green light.

We then considered the growth rate and the accumulated growth rate for every second measurement (1st, 3rd, 5th, 7th measurements) is shown in Fig. 7. The green light graph shows a continuous increase in growth rate and the difference in the final growth rate between red and green color is 5 g which is 5 times greater than yellow color and 2.5 times greater than blue color.

Table 2 shows the effect of light color on fish growth from an activity perspective and supports the above results. In particular, green light has been associated with high stress levels, therefore, it is expected to assist in developing a strong immune system and to promote growth.

Our observations of food intake and swimming activities revealed that food intake rate is particularly good in the water tank illuminated with green light. This suggests that light color in the growth period affects hormone secretion, leading to an increase in food uptake.

CONCLUSION

In this study, the effect of light color on the growth of freshwater fish was investigated. Snakehead aquaculture tanks were set up and tests were carried out to examine the growth of fish under different light colors. LED technology was used as a light source and young snakeheads at 10-15 cm in length were raised in the water tanks, under red, green blue or yellow light. Weight measurements were taken for 4 weeks and as a result, the green and blue light were found to produce a higher growth rate than the red or yellow colored light. This is especially apparent in the growth rate where growth rate under green light showed a continuous increase. Therefore, control of light color in artificial growth environments is shown to have a substantial effect on the growth and feeding efficiency of the fish. We expect this study result to lead to significant improvements in productivity within snakehead aquaculture farms.

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