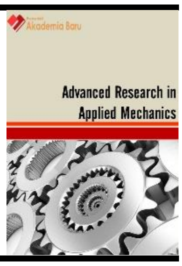
Penerbit Akademia Baru

Journal of Advanced Research in Applied Mechanics

Journal homepage: www.akademiabaru.com/aram.html
ISSN: 2289-7895



Underwater Fish Attraction LED Lamp (UFAL) for Improving Aquaculture Productivity

Open Access

Noor Zalikha Mohamed Islam[1,*], Nik Mohd Azmi Nik Abdul Aziz[1], Norhidayah Abu[1], Wedianti Shualdi[1], Khairuldin Mohd Isha[1], Tan Chin Kong[2], Tan Chin Hai[2], Mohd Muzamir Mahat[3]

[1] Industrial Centre of Innovation in Sensor, SIRIM Berhad, Lot 34, Jalan Hi-Tech 2/3,Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia
[2] Alion Nation Solution Sdn. Bhd.,1413, Solok Perusahaan Satu, Prai Industrial Estate, 13600 Prai, Penang, Malaysia
[3] Faculty of Applied Science, Universiti Teknologi MARA, Selangor,Malaysia

ARTICLE INFO

Article history:
Received 5 November 2018
Received in revised form 14 December 2018
Accepted 23 December 2018
Available online 31 January 2019

ABSTRACT

In 2014, SIRIM Berhad collaborated with a local SME to design and develop an Underwater Fish Attracting LED Lamp (UFAL). Based on a number of field studies in the open sea of Langkawi, Pulau Aman, and Kuala Muda, at northern Malaysia the green LED was found to be effective in attracting different species of fish. The light spectrum works by attracting planktons (zooplankton and phytoplankton) from the surface of the ocean to convene around it which in turn provides sustenance to the pelagic fishes. In the Malaysian aquaculture industry, the average mortality rate of fish larvae (above 3 months) after being released to a cage is around 50%. The dependency on commercial pellet and trash fish as the major components of the fish's diet aggravates the situation as these options can be costly. The effectiveness of UFAL has been reflected in the physical and growth rate of seabass and grouper in an aquaculture site at Kuala Muda. After 10 months of its application, the green LED was proven to speed up the fish's growth by 30-40 %, reducing the dependency on commercial food by 30 % and reducing the harvesting cycle by 20%. In addition, both species of the fish that thrived in cages with UFAL exhibited a lower mortality rate when compared to the control cages. This technology could offer an alternative prospect in the sea coastal aquaculture industry and help local SMEs to produce a reliable product to expand their business into new and niche markets. Based on the outcomes of this study, this promising technology could be the key to improve productivity in the sea coastal aquaculture industry.

Keywords:
Fish- green LED lamp, aquaculture, fisheries, productivity

1. Introduction

Malaysia is a maritime nation where its fisheries industry is a major source of income for 143,421 licensed fishermen in 2014. According to Fish Research Institute (FRI) the national capture of marine fish contributed 1,458,128 t.m(RM8.785 billion), where about 26% were generated by aquaculture industry with value of 520,514 tonnes (RM3.47 billion) in 2014 (summarized in Figure 1) [1]. Despite achieving a surplus in food

* *Corresponding author.*
E-mail address: nzalikha@sirim.my (Noor Zalikha Mohamed Islam)

supply since 2010, Malaysian consumers still face consistent price hike for fishes. On the other hand, the Dasar Agro Makanan Nasional (DAN) has targeted 794,000 tonnes of aquaculture production by the end of 2020. Furthermore, the Malaysian Government has identified aquaculture as one of the major sources to increase fish production that can meet the domestic and export demand. To fulfill this demand, the Malaysian aquaculture's production and growth should be increased to 12.8% and 20% per annum, respectively, in order to reach its new target of 1.443 million tonnes.

MALAYSIA FISHERIES PRODUCTION: TARGETS AND ACHIEVEMENTS

NEW PROJECTION ON FISHERIES UP TO 2020 (*000 t.m)

Year	2011	2012	2013	2014	2015	2016	2020
CAPTURE	1,373.10	1,472.20	1,482.90	1,458.10	1,415.00	1,455.00	1,577.00
Seashore	1,086.00	1,136.20	1,156.70	1,193.00	1,100.00	1,100.00	1,100.00
Deep ocean	287.1	336.1	326.2	265.00	315.00	355.00	477.00
AQUACULTURE	526.51	634.38	530.21	520.51	628.21	711.06	1,443.00
FRESH WATER	122.22	163.76	132.89	106.73	169.75	189.85	313.00
Fish	121.88	163.34	132.44	106.33	169.00	189.00	311.65
Prawn	0.33	0.41	0.46	0.398	0.75	0.85	1.35
BRACKISH WATER	164.84	139.13	127.88	168.45	168.41	191.21	400.00
Prawn	67.47	55.57	49.96	61.34	75.87	85.15	189.04
Shellfish	60.81	45.18	41.96	42.68	45.00	45.02	45.1
Seaweed	239.45	331.49	269.43	245.33	290.05	330.00	730.00
TOTAL	1,899.60	2,106.60	2,013.10	1,985.20	2,043.20	2,161.10	3,020.00

Fig. 1. Statistic on achievement and target of fish production in Malaysia

In general, fish feed constitutes 60-70% of the operating costs of aquaculture fisheries. The profit margins are largely dependent on the cost of livestock feeds and the effectiveness of the conversion of food by the reared fish. Meanwhile, improvements in aquaculture production are usually inhibited by the inflated cost of process feeds. In general, there are two categories of process feed; 30% protein content (CP30%) for freshwater fish (omnivorous species) and 40% (CP40%) protein content for carnivorous species. Currently, the market prices for these process feeds are relatively expensive with CP30 % fetching at RM4.00/kg and RM6.50/kg for CP40 %. Current projections estimate that these figures will increase up to RM5.20/kg (CP30 %) and RM8.55/kg (CP40 %)in 2020 [1-2]. One of the main factors that contributed to these increase in prices is the cost of imported raw ingredients, such as fishmeal, soy flour, and maize.

Previous research has indicated that light intensity, spectrum, and photoperiod in the rearing environment of marine fish (larvae and juvenile) are important for the fish's survival and growth [3]. Light spectrum plays an important role in the early stages of fish development by sharpening the larval fish's recognition of food by contrasting it with the environment. However, larval fish's responses to light change as they grow. Light receptivity in larval fish changes as the animals show some improvements of product quality in most aquaculture species, such as increase the growth rate [4]. By combining the knowledge of the fish's response to UFAL with precise manipulations of the light with LEDs, a better chance for survival and growth for fish is within reach.

2. Materials and Methods

2.1 Material Selection

Thermal conductive polymer was used in the second prototype of UFAL, unlike the ferrous-based metal for the first prototype. Thermal conductive polymer carries the benefit of excellent thermal properties while eliminating the problem of corrosion. The Green LED chip and thermally conductive polymer were supplied by

OSRAM and Prospector, respectively. For the second prototype of UFAL, a nanocoating solution was applied on acrylic tube outer-surface to eliminate or minimize the attachment of marine species. These newly-developed LED lighting systems came with an adjustment for light intensity and its spectrum.

2.2 Technical Specification

Green UFAL (24Vdc, 30 W) was equipped with a controller to adjust the light intensity that is appropriate for the reared aquaculture environment and fish behavior. The technical specifications of the UFAL are described in Table 1.

Table 1
UFAL technical specification

	UFAL
Design	
Weight	0.6 kg
Materials	• Thermal conductive polymer-based • Transparent acrylic side cover
Features	• Dimmable capability • Nano coating

2.3 Technology Demonstration Setup

Solar-powered UFAL was installed at the aquaculture site with a dimension of 12’ x 12’ for each individual fish cage. The requirements for the four units of UFAL were 80 A battery, 30 A charge controller and 600 W solar panel. Two ponds were used in this study; one was equipped with the UFAL and the other without it to act as the control pond. The arrangement of this study is summarized in Table 2.

Table 2
Type of fish and UFAL setup

Group		A (seabass)	B (grouper)	C (seabass)
1	With UFAL	baseline weight 100 g above	baseline weight 100 g above	baseline weight 100 g below
2	Without UFAL	baseline weight 100 g above	baseline weight 100 g above	baseline weight 100 g below

Figure 2 shows the design of the experiment to monitor the growth of seabass and grouper at the aquaculture site in Kuala Muda, Kedah. The photoperiod of UFAL ran from sunset to sunrise with an interval of 30 minutes every day. The grading process took place before the monitoring stage where similar sizes of fish were placed in the same cage. The fleet of seabass was divided into group A and C, where Group A represented seabass with baseline average above 100 g while those with baseline average below 100 g belonged to Group C. Each cage had 300 fishes and their physical size, growth and survival rate were monitored.

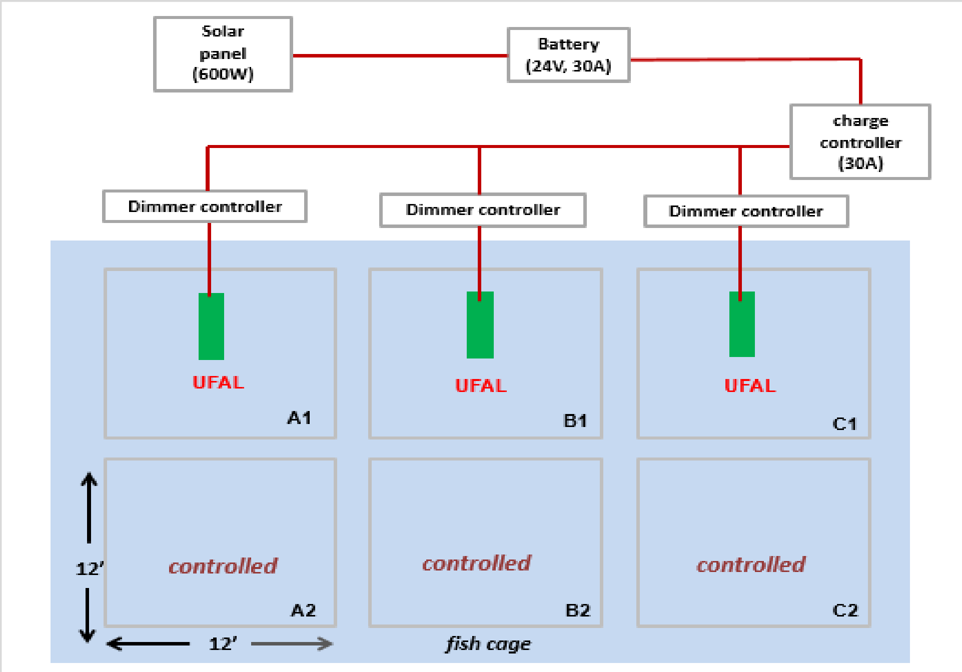


Fig. 2. Technology demonstration diagramat Kuala Muda

2.4 Characterization

The green UFAL was characterized with a Lighting Passport Pro Essence (Asensetek) for lighting color coordinate (CIE). CIE 1931 is a color matching indication that numerically specifies a measured color space.

3. Results and Discussion

3.1 Photometric Testing

From the photometric testing, the color coordinate for green UFAL was 0.18: 0.77 based on the CIE 1931 characterization. The LED color mixing for UFAL primarily came from the green LED as shown in Figure 3.

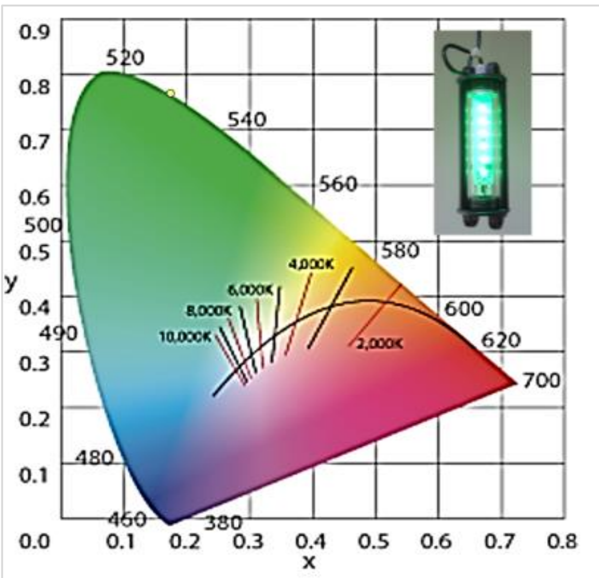


Fig. 3. CIE of UFAL

3.2 Nanocoating Advantage

In addition, UFAL’s outer acrylic tube was coated with nano-silica based materials. The nanocoating aided significantly in the post-cleaning process while inhibiting the growth of barnacles. The benefits of the nanocoating are visualized in Figure 4. To maintain its integrity against wear and tear, the nanocoating was reapplied once every three months.

(a) Without nanocoating- barnacles attached to the lamp (after seven days)

(b) With nanocoating- Free marine attached; only moss and easy to clean (after 2 months)

Fig. 4. UFAL without (a) and with (b) nanocoating

3.3 UFAL Performance at Kuala Muda, Kedah

The application of UFAL in the brackish river of Kuala Muda, Kedah was monitored since November 2017. This study began with the introduction of 3-inch larvae fish into the river followed by monthly monitoring of their weight, health, survivability, physical appearances and parasite attacks, if there were any. Photoperiod is the duration of light exposure during a 24-hour cycle. For this study, the photoperiod took place daily from sunset to sunrise. For each cage, the fish were fed twice a day (morning & evening) with either commercial pellet or trash fish. The feed management was following the recommended Feed Conversion Ratio (FCR) which generally accepted at 1.5 for optimum growth. FCR is a tool for farmers to calculate the amount of feed necessary to grow a kilogram of fish. The dimmable controller allowed the adjustment of light intensity to support optimum first-feeding activity. The LED light was coordinated with particular dimming specifications which were integrated with an IOT system so that the lighting intensity can be varied according to the changing needs of fish larva and juvenile.

Fig. 3. UFAL performance setup and visualization at Kuala Muda, Kedah

3.4 Growth and Survival Rate

The relationship between light intensity, photoperiod and the growth of seabass and grouper in Kuala Muda, Malaysia was the main focus of this study. As mentioned earlier, the photoperiod for this experiment was 12 hours with an interval of 30 minutes with a range of light intensity from 20 to 60 % of 30 W UFAL depending on the age/stage of the fish. The fish growth was monitored every month, where about 10 % sample of fish been collated to measure their weight and length. Figure 4 summarizes the growth rate for A-seabass (baseline weight 100 g above), B- grouper (baseline weight 100 g above) and C-seabass (baseline weight 100 g below) in the presence and absence of UFAL. With green LED lighting in A1, B1, and C1; the growth rate of seabass and grouper increased above 90 % after 8 months. The growth rate without the lamp in A2, B2, and C2 cages was below 65 % on average. Both species of fish grew between 30 to 40 % faster in the presence of UFAL. Based on these findings, the combination of suitable photoperiod and light intensity plays an important role in the growth rate of fish [5-6].

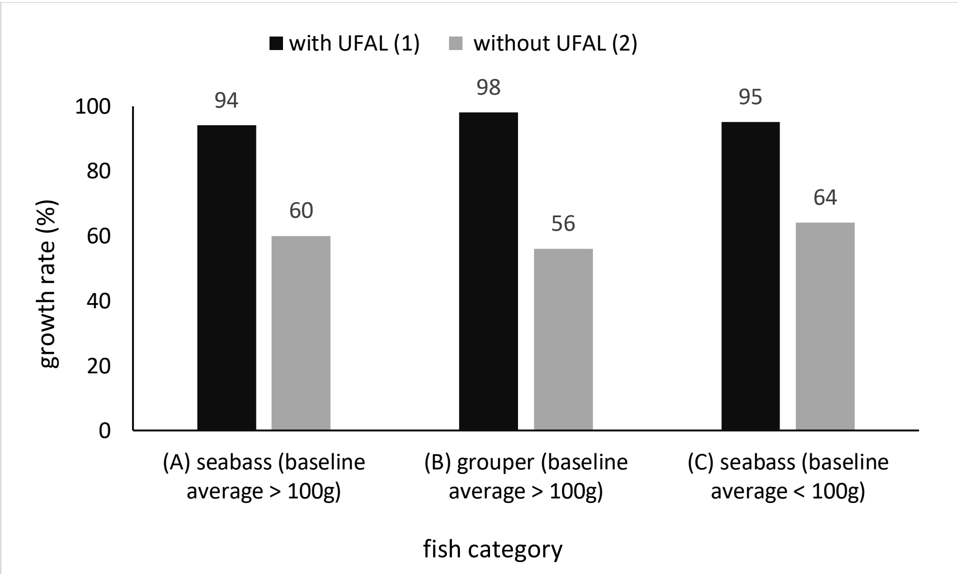


Fig. 4. Comparison of various growth rate (%) after 10 months

Light intensity prior to the first-feeding in larvae has subsequently affected the survival and led to the growth development of both species. However, survival of fish larvae may vary depending on the species and rearing conditions. For instance, seabass (both in A and C) survival rates were found to be higher as compared to grouper in post-larvae reared. This is due to the grouper that was easier to be attacked by leeches. Therefore, this has contributed to the higher mortality at the first three monthsas represented in Table 3.

Table 3
Summary on the development and survival of seabass (A & C) and grouper (B) with and without UFAL at Kuala Muda, Malaysia after 10 months

	Label	Physical appearance	Health	Mortality Rate (%) /cage	Weight average (g)
Seabass with UFAL	A1	fleshy	good	1.3	950
Seabass without UFAL	A2	normal	good	2.0	648
Grouper with UFAL	B1	fleshy	vulnerable to leech attack	3.0	925
Grouper without UFAL	B2	normal	vulnerable to leech attack	4.3	620
Seabass with UFAL	C1	fleshy	good	1.7	895
Seabass without UFAL	C2	normal	good	2.3	515

In local aquaculture practices, normally 10- 12 months are needed to complete one harvesting cycle of seabass, and it is around 12- 16 months for grouper. However, our findings showed that the application of UFAL in the Malaysian aquaculture industry can pay huge dividends in terms of cost-saving of up to RM 850-RM1200 per cage, faster growth rate of fish between 30 to 40% and reducing the harvesting cycle by 20%.

4. Conclusion

The objective of this study was to demonstrate the effectiveness of UFAL in the aquaculture industry. The characteristics of artificial light which are its intensity, photoperiod and wavelength can be adjusted to promote a higher success rate in fish rearing. By coupling the technology of UFAL with a suitable standard operating procedure, aquaculture productivity can be increased by reducing the feeding cost, harvesting cycle, dependency on manual labor and cultivating a uniform growth for the fish.

Acknowledgements
This research was supported by the Ministry of Energy, Science, Technology, Environment &Climate Change (MESTECC) Malaysia under SIRIM Industrial Innovation Model (SIIM) Fund with grant no. DF-16-1235.

References
[1] FRI, http://www.dof.gov.my/index.php/pages/view/42, 2017.
[2] Ministry of Agriculture Malaysia (2014), Annual Fisheries Statistic, Vol. 1, pp 1-52.
[3] Villamizar, Natalia, Borja Blanco-Vives, Herve Migaud, Andrew Davie, Stefano Carboni, and F. Javier Sanchez-Vazquez. "Effects of light during early larval development of some aquacultured teleosts: a review." *Aquaculture* 315, no. 1-2 (2011): 86-94.
[4] DelabbioJ., (2015) The Importance of Environmental Light to the Culture of Marine Fish Larvae. Once, Plymouth, pp 1-7.
[5] Marchesan, Mara, Maurizio Spoto, Laura Verginella, and Enrico A. Ferrero. "Behavioural effects of artificial light on fish species of commercial interest." *Fisheries research* 73, no. 1-2 (2005): 171-185.
[6] Hammerschlag, Neil, Carl G. Meyer, Michael S. Grace, Steven T. Kessel, Tracey T. Sutton, Euan S. Harvey, Claire B. Paris-Limouzy, David W. Kerstetter, and Steven J. Cooke. "Shining a light on fish at night: an overview of fish and fisheries in the dark of night, and in deep and polar seas." *Bulletin of Marine Science* 93, no. 2 (2017): 253-284.