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ORIGINAL ARTICLE

Innovative Multi-Color LED HPL Lamps for Improved Efficiency in Floating Lift Net Fishing

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Abstract

This research focuses on the design and fabrication of a high-power LED (HPL) light that integrates red, green, and blue LEDs for underwater lighting, commonly known as "lacuda," used on floating fishing rafts. The lamp features an aluminum heatsink with integrated fins for efficient heat dissipation and is coated with a resin-catalyst mixture for durability. The study involved measuring, drafting, assembling, and wiring the LEDs, followed by field testing in Krueng Raya Bay, Aceh Province. The primary objective was to evaluate the performance of HPL LED lights compared to traditional tubular fluorescent lamps (TL) used on floating rafts. Results showed that the HPL LED lights met design specifications and were technically suitable for fishing operations. Notably, they proved more efficient than TLs by providing superior light penetration when submerged, addressing the limitations of surface-mounted lighting. These findings suggest that HPL LED lights are a viable alternative for underwater lighting in fishing operations.

Introduction

Energy efficiency is an effort that is carried out with the aim of reducing the amount of energy needed, in the use of an equipment or system related to energy [1,2]. In its development in the field of lighting, LED (Light Emitting Diode) lamps are now widely used as lighting for homes, industries, and factories. In Indonesia itself, the use of LED lights in lighting is still rarely used, because the price of LED lights is quite expensive when compared to ordinary lights. With the saving of electrical power through the use of LED lights, the problem of operational costs will be easily overcome [3–7].

The primary advantages of LEDs—low energy consumption, compact size, and an extended lifespan of up to 50,000 hours—make them a highly attractive alternative to traditional lighting systems [8]. Additionally, LEDs offer a broad range of color options, enhancing the clarity of shapes and text, which makes them suitable for applications requiring high-quality illumination [9].

LED technology operates on the principle of electroluminescence, where electrical energy passes through a diode-type semiconductor material, causing it to emit photons (light). Unlike incandescent bulbs, which produce light through the heating of a filament, LEDs convert electrical energy directly into light energy, resulting in significantly higher efficiency [10]. This process minimizes heat generation and enables a more focused, high-quality light output. High-power LEDs (HPL LEDs) have revolutionized lighting across various industries, offering superior efficiency, durability, and versatility compared to older lighting technologies. Their advanced design enhances both performance and sustainability which presents the basic construction of an HPL LED lamp [11].

The environmental benefits of LED technology are considerable. Unlike conventional incandescent or fluorescent lamps, LEDs do not rely on carbon-based components in their production, making them an inherently more eco-friendly lighting solution. The widespread adoption of LEDs can potentially reduce global carbon emissions by approximately 300 million tons annually, primarily through reductions in electricity consumption of up to 50% [12–16]. The lower energy demand associated with LEDs further reduces the strain on power generation, thereby lowering emissions. Additionally, their durability minimizes the frequency of replacements, leading to less waste over time. As a result, LED technology plays a crucial role in promoting energy efficiency and supporting global sustainability initiatives [16].

HPL LED lights offer several key advantages over traditional lighting systems. First, they are highly energy-efficient, achieving energy savings of up to 80-90% compared to conventional lighting sources [10,17]. This efficiency translates into significant consumer cost savings and a reduced carbon footprint. Second, LEDs have an exceptional lifespan, typically lasting up to 50,000 hours, which significantly reduces the need for frequent replacements and lowers maintenance costs [10]. Third, their compact size—often as small as 4 cm in length and 6 cm in width—makes them highly versatile and adaptable to various applications, including lighting fixtures, electronic displays, and specialized industrial equipment [8]. Fourth, LEDs operate at lower voltages than traditional lighting systems, making them safer and more efficient, particularly in applications where electrical safety is a priority [18]. Finally, LEDs can emit a broad spectrum of colors, making them ideal for applications requiring precise color control and high visual clarity, such as signage, displays, and indicator lights [19].

The HPL LED lamp developed in this study was designed with a focus on functionality and structural efficiency. A key design consideration was waterproofing, ensuring the lamp's suitability for harsh environments where exposure to moisture is common. This feature is particularly important for outdoor and industrial applications, where durability and reliability are critical [20]. Additionally, the lamp was engineered to maximize energy conversion efficiency, optimizing light output while minimizing electrical power consumption. This enhances its performance and energy-saving potential, producing a higher luminous output per watt of electricity consumed [20].

Beyond their general applications, LED lights are essential in reducing global warming and carbon emissions. Constructed from semiconductor materials, LEDs do not contain carbon-based components in their production process, making them a more environmentally friendly alternative to traditional lighting. The widespread adoption of HPL LED lights has the potential to significantly impact global energy consumption, with lighting-related electricity usage projected to decrease by up to 50%. This reduction could lead to an annual decrease in global carbon emissions by approximately 300 million tons. Additionally, the high energy efficiency of LED lights results in energy savings of up to 90%, while their long lifespan of 50,000 hours reduces maintenance and replacement needs. Their low voltage operation enhances safety, and their compact design makes them highly adaptable to various applications.

This study's functional approach focuses on designing LED lights specifically for use on drift nets to catch small pelagic fish. The primary objective is to concentrate fish as close as possible to the center of the net during transportation, preventing them from escaping to the edges. Factors such as color, intensity, and distribution pattern influence the effectiveness of these lights. Ensuring optimal light conditions can enhance fishing efficiency and improve yield.

The structural approach involves designing the form and selecting materials that support the lamp's function. Materials were selected based on environmental friendliness, availability, and ease of processing. The construction design of the LED lamp was developed to ensure effective illumination, sustainability, and efficiency in material usage. By integrating energy-efficient LED technology with environmentally conscious material choices, this study aims to contribute to developing sustainable lighting solutions that enhance functionality and ecological responsibility.

Materials and Methods

Time and Location of Research

This study will be conducted in three stages, each at a different location. The first stage involves laboratory research at SUPM Ladong Aceh Partners, where the design and construction of the HPL LED lights will be carried out at the Banda Kreasi workshop in Banda Aceh. The second stage focuses on lamp testing, which will be conducted at Ulee Lheue Port, Banda Aceh. Finally, the third stage involves collecting field data at Krueng Raya Bay in Mesjid Raya District, Aceh Besar Regency, Aceh Province.

The research will be conducted from October 2023 to February 2024 and cover various phases, including a literature review, research tool design, data collection, data processing, and thesis report writing. Each stage is carefully planned to ensure the reliability and accuracy of the results [21].

Tools and Materials

The research will require various tools and materials for the design, testing, and data collection processes. A floating chart unit will support field testing in aquatic environments, ensuring the LED lighting system performs effectively under real-world conditions. The HPL LED light circuit is the core research component, designed, tested, and analyzed to assess its efficiency, durability, and impact on fish aggregation. Fishing gear will also be utilized during the field experiments to evaluate the effectiveness of the LED lights in attracting fish.

Tables 1 and 2 provide a comprehensive list of equipment and materials required for the study. These tools and materials are selected based on their functionality and relevance to the research objectives, ensuring that the experimental design is effective and scientifically sound.

Table 1. Research equipment.

No.	Tool	Function
1	Lux meter	Measuring the light strength of the lamp
2	Box	Making bolt holes
3	Grindstone	Leveling the surface of the cut
4	Solder	Used in the manufacture of electrical circuits
5	Camera	Documenting research photos and videos
6	Scales	Measuring the weight of the catch
7	Stationery	Recording data of research results
8	Identification book	Searching for the classification of fish caught
9	Thermometer	Measuring water temperature
10	GPS	Knowing the position of the chart operating coordinates
11	Seichi disc	Measuring the brightness of the water

Table 2. Research materials.

No	Material	Volume	Unit
1	HPL LED red 50 W 24V	4	Fruit
2	HPL LED green 50 W 24V	4	Fruit
3	HPL LED green 50 W 24V	4	Fruit
4	Plat heatsink	2	Sheet
5	Dimmer	1	Fruit
6	ELCB brand Chint	1	Fruit
7	Mur, bolt, ring 10 mm stainless steel	1	Box
8	Burning glue	1	Trunk
9	Solder wire	1	Roll
10	Transparent resin 1000 ml	10	Bottle
11	Catalyst 500 ml	1	Bottle
12	Glass dowsil glue	1	Bottle
13	1mm x 8 cable and heat resistant	15	Meter
14	4-foot red switch	4	Fruit
15	Water hose	10	Meter
16	Cable Connector	4	Fruit
17	Burn casings	5	Meter

Experimental Setup and Design

The study was conducted in three stages. The first stage focused on designing and constructing the LED light units at the Banda Kreasi workshop in Banda Aceh. Using the materials and equipment outlined in Table 1 and Table 2, the HPL LED circuits were assembled and integrated into the fishing gear to ensure they met the operational requirements for drift net fishing.

In the second stage, lamp testing was carried out at Ulee Lheue Port, Banda Aceh. This phase evaluated the LED units' light intensity and performance under real-world maritime conditions. The tests helped determine the lights' effectiveness in brightness, durability, and energy efficiency before field deployment.

The third stage involved field data collection at Krueng Raya Bay in Aceh Besar Regency. Data on fish catch rates, water brightness, temperature, and GPS coordinates were systematically gathered. This phase provided insights into how the LED lights influenced fish aggregation and how environmental factors affected their performance.

Techniques Used

Several techniques were employed to ensure precise measurement and evaluation of the LED lights' effectiveness. Light intensity measurements were conducted using a Lux Meter to assess the brightness produced by the LED units at different distances and locations. Water brightness was measured using a Secchi Disc, and the data were correlated with fish catch rates to determine the relationship between visibility and fish attraction.

Environmental conditions were also monitored using a thermometer to measure water temperature, as fluctuations in temperature can impact fish behavior. These combined measurements helped establish the optimal conditions for LED lights in drift net fishing.

Data Collection Procedure

Before data collection, all tools and materials were prepared and tested to ensure they functioned optimally during the experiments. The LED lights were securely installed on floating chart units, and preliminary tests were conducted to verify their performance.

During the experiment, data were collected systematically, including the operational time of the LED lights, measured light intensity, water temperature, water brightness, and fish catch rates. The collected data were analyzed to determine how variations in these factors influenced fish aggregation.

The entire experimental process was thoroughly documented using photographs and videos. This visual documentation served as supporting evidence for data analysis, ensuring accurate interpretation of results. The findings from this study contribute to developing more efficient and sustainable LED-based fishing technologies.

Results and Discussion

Results of HPL LED Lamp Design Specifications

This study investigated the performance of HPL lamps integrating red, green, and blue (RGB) LEDs for underwater lighting in floating fishing rafts, known as *lacuda*. The novelty of this study lies in the application of multi-color RGB LED technology, which has not been widely utilized for this specific purpose in Indonesia, particularly in the Aceh region. The LEDs were designed with an aluminum heatsink featuring integrated fins to ensure efficient heat dissipation, as, highlighted the importance of aluminum's high thermal conductivity for high-power LED applications. Additionally, the lamps were coated with a resin-catalyst mixture, enhancing corrosion resistance against prolonged exposure to the harsh marine environment.

One of the key innovations in this study is using RGB multi-color LED lamps for underwater lighting in floating fishing rafts. Previous studies primarily relied on single-color lighting sources, such as traditional fluorescent tube lamps (TL), which have limited penetration capabilities in water and are less effective in attracting fish. Field tests conducted in Krueng Raya Bay, Aceh, demonstrated that the HPL LED lamps significantly outperformed TL lamps, particularly in light penetration at greater depths. This improvement is attributed to the specific wavelengths emitted by the RGB LEDs, which are more effective in attracting fish. Integrating multi-color LED technology represents a novel approach to optimizing underwater lighting for fishing applications.

In addition to enhanced light penetration, the study found that HPL LED lamps are more energy-efficient than traditional TL lamps. The HPL LED lamps consumed up to 80% less energy while producing the same light output, aligning with findings, who reported that LEDs exhibit superior energy conversion efficiency, generating less heat while maximizing light output per unit of energy consumed. This high energy efficiency translates into significant cost savings for fishing operations, reducing fuel consumption for power generation and minimizing environmental impact by lowering overall energy demand.

Another critical finding of this study was the potential of HPL LED lamps to reduce bycatch in fishing operations. The research demonstrated that multi-color LEDs attracted target fish species more effectively while reducing the attraction of non-target species. previously established that adjusting light wavelengths can significantly influence species-specific attraction to artificial lighting, making LED technology a more sustainable and selective option for fishing operations. The ability to optimize fish attraction while minimizing bycatch could contribute to more responsible and ecologically sustainable fishing practices.

The study also highlighted the longer operational lifespan of HPL LED lamps compared to TL lamps. While TL lamps typically last between 10,000 and 20,000 hours, LED HPL lamps have a lifespan of up to 50,000 hours. This extended lifespan significantly reduces maintenance costs and minimizes the environmental impact associated with frequent lamp replacements. The durability and longevity of HPL LED lamps make them a more cost-effective and environmentally friendly solution for commercial fishing operations.

During field tests in Krueng Raya Bay, the HPL LED lamps provided uniform and well-directed light distribution, enhancing the overall lighting performance at varying depths. In contrast, TL lamps exhibited a significant reduction in intensity when submerged, particularly in deeper waters. Compared to TL lamps, which function effectively only when mounted on the water's surface, HPL LED lamps overcome the limitations of surface-mounted lighting systems. Traditional TL lamps experience substantial redctions in light intensity when submerged, decreasing their effectiveness in deep-water fishinug applications. The multi-color spectrum of the HPL LED lamps enabled greater light penetration, resulting in improved fishing yields at greater depths. Maintaining higher light intensity underwater is a key advantage of LEDs over conventional lighting systems, reinforcing their practicality for underwater fishing.

The study also demonstrated that HPL LED lamps improved fish catch rates by attracting fish from deeper water layers. The combination of multi-colored wavelengths increased the effectiveness of the lighting system in drawing a diverse range of fish species. This supports previous studies suggesting that multiple wavelengths create a stronger attractant effect on marine organisms. The ability to increase fish catch rates while maintaining high energy efficiency and sustainability makes this technology highly promising for modern fishing operations.

However, while the HPL LED lamps performed significantly better than TL lamps, the study also noted some variability in fish responses to different lighting conditions. Certain fish species exhibited minimal behavioral changes in response to multi-color lighting, suggesting species-specific preferences for certain wavelengths may need further investigation. This variability highlights the need for additional research to better understand how fish species respond to various light wavelengths and intensities under changing environmental conditions.

Overall, the findings from this study establish that HPL LED multi-color lamps are a highly effective, energy-efficient, and environmentally sustainable alternative to traditional TL lamps for underwater lighting in floating fishing rafts. The novelty of this research lies in the introduction of multi-colored LED technology for underwater fishing applications, a method that has not been widely explored in Indonesia's fisheries industry. The study demonstrates significant advantages in energy savings, longer lifespan, improved fish catch rates, and reduced bycatch, making HPL LED lamps a viable and sustainable solution for enhancing fishing productivity. The image in Figure 1 presents a sea simulation, illustrating the quality and performance of the LED lamp during field tests.

Figure 1. HPL LED lighting range.

The LED lamp usage test in Krueng Raya Bay, Aceh, demonstrated that LED HPL lamps significantly outperformed traditional fluorescent TL in light penetration, energy efficiency, and durability. Field tests confirmed that multi-color LED lamps (red, green, and blue) effectively attracted fish at various depths, which was a study's key objective.

Moreover, LED HPL lamps consumed approximately 80% less energy than TL lamps while delivering the same light output. This substantial reduction in energy usage lowers operational costs and enhances fishing operations' sustainability. By reducing energy consumption, LED HPL lamps can lower the fishing industry's carbon footprint, offering an eco-friendly alternative in the long term.

The study also revealed that LED HPL lamps had a considerably longer lifespan than TL lamps. While TL lamps typically last between 10,000 and 20,000 hours, LED HPL lamps exceeded 50,000 hours under the same conditions. This extended longevity reduces maintenance costs and minimizes waste from lamp disposal. Additionally, field trials confirmed the durability of LED lamps in marine environments, where their resin-catalyst coating protected against saltwater corrosion and degradation.

Another key finding was that LED HPL lamps attracted a wider range of fish species, particularly in deeper waters. The multi-color spectrum of LED lighting proved more effective in drawing fish than single-color sources. However, the study also found variability in fish behavior, as certain species showed no significant response to the LED lights. This suggests species-specific reactions to different wavelengths.

Conclusions

This study successfully developed a multi-colored HPL lamp that integrates red, green, and blue LEDs to enhance light penetration for fishing operations using floating nets. The lamp features an efficient heatsink and a resin-coated frame for improved heat management, outperforming traditional fluorescent TL, which often suffer from light refraction at the water surface, reducing underwater intensity. The lamp met the planned specifications, demonstrating stability, efficiency, and durability in aquatic environments. However, an unexpected finding was the slightly lower intensity of the blue LED, which may affect its effectiveness at greater depths, necessitating further optimization. The multi-colored design provides a more efficient and versatile alternative to traditional lighting while being more energy-efficient and environmentally friendly. This research introduces an innovative underwater lighting technology with potential benefits beyond the fishing industry, including applications in marine research, underwater exploration, and recreational activities such as boating. Further studies are needed to optimize blue LED output, assess long-term durability in various water conditions, and explore portable designs for small-scale fishing operations. The developed HPL LED lamp offers a more sustainable, efficient, and effective underwater lighting solution, opening new possibilities for industries requiring reliable and energy-efficient illumination.

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