Asian Journal of Applied Science and Technology (AJAST)
Volume 9, Issue 3, Pages 39-48, July-September 2025

Solar-Powered Aerator with Integrated Lighting System for Tilapia Fishfarm at Minalin, Pampanga

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DOI: https://doi.org/10.38177/ajast.2025.9304

Article Received: 10 May 2025 *Article Accepted: 22 July 2025* *Article Published: 26 July 2025*

ABSTRACT

As renewable energy advance, the development, building, and analysis of a solar-powered aerator and lighting system, an environmentally beneficial device that improves water quality while also provide effective, energy-saving lighting for an aquatic setting. A significant problem in fishpond in Minalin, Pampanga the, cultivation is the concentration of dissolved oxygen (DO) in the water; hence, employing aeration is preferable to traditional methods of tilapia farming. To evaluate its efficiency and appropriateness for little fish, the research also looks at the length of time and efficiency of our aeration in the fishpond. Since the system runs constantly 24 hours a day is subjected to water and different weather conditions, the tests involve determining the solar panel's adequate efficiency, our battery's lifespan, and the monitoring and measurement of high-quality materials for the prototype. For our testing we the data shows how the efficiency our solar panel with a content of 39.22Volts 42.22 amperes, and total 4080 watt-hour, aeration demonstrates a 66.67% grow-out rate, significantly outperforming in just 1 month using. To ensure a higher to consistently supply the fish pond's energy needs in order to guarantee optimal system functioning, particularly during prolonged times of low solar input or increasing aeration requirements.

Keywords: Traditional; Environmentally; Tilapia Farming; Energy Efficiency; Renewable Energy; Financial.

1. Introduction

Tilapia farming in Minalin, Pampanga is a major contributor to the Philippines' aquaculture industry, with Central Luzon producing over 60% of the country's tilapia supply. They use Traditional method that cause 30%–40% survive to harvest due to poor practices. This low survival rate is partly due to the continued use of traditional farming methods, such as manual feeding and reliance on natural aeration, which often result in poor water quality and oxygen depletion. In fact, nearly 40%-50% of the fingerlings can die during the grow-out period, leading to major financial losses for pond owners. Cannibalism among fingerlings of varying sizes has been identified as a major cause of low survival rates in nursery ponds. This behavior tends to worsen when there is a significant size difference between the fish (Hafeez, A., Shamair, 2021).

However, providing an aerator especially is beneficial to significantly reduce these aggressive interactions and improve recovery rates. Tilapia culture in Philippines they build organizations like PHIL Tilapia, established in 2017 by Bureau of fisheries and aquatic Resources (BFAR) and the Philippine Alliance of Fish Producers Inc. (PAFPI), to support more than 500 stakeholders across the tilapia value chain.

In Minalin, farm operations cover 25 hectares, with stocking rates of 70,000–100,000 hectare and each production cycle lasts 5–6 months and supports both direct and seasonal workers. Tilapia farming is important for food security, rural employment, and local economies. However, farmers face challenges such as low dissolved oxygen levels, high energy costs, and poor visibility at night all of which can lead to reduced growth, higher mortality, and increased operating expenses. Addressing these issues is essential for sustaining and improving the productivity and resilience of the tilapia industry (Aypa, S. 1995).

To support the region's vast aquaculture activities and in order to fulfill the increasing demand for tilapia both domestically and abroad, to improve farm production, and ensure environmental sustainability, the PTS president imports fish breeds from other countries to avoid overkill due to weather conditions and implements a wide range of strategies for tilapia. In a study by (Sharangdhar, M. T., & Ramteke, S. U., 2024), releasing small amounts of water or thin layers into the atmosphere or by small particles by air that rise through the water, aeration helps water and air come into contact, which can help water circulation. As stated by (Kedri Janardhana, & Bhattacharya, S. 2022), the amount of oxygen required by aerobic organisms to break down organic materials in a water sample at a given time and temperature is known as biological oxygen demand, or caused by greater levels indicates greater levels of human-derived organic waste and lower oxygen availability, thus serving as an indicator of water contamination causing fish kills.

The impact of solar aerators on improving the sustainability and productivity of tilapia farming in Central Luzon and around the Philippines will be explored in this study. According to Tepy Lindia Nanta (2024) While diffuse air systems are often utilized for water de-stratification in lakes or ponds that are eight feet or deeper. Aeration systems have the capacity to provide a specific quantity of mixing in pond water. Deeper waters are brought to the surface by the diffuser system, which crucially causes constant mixing or a "destratifying" effect. The standard of the water is the primary concern in this pond. These issues arise from several variables, but the primary concern is that the water's oxygen levels are not sufficient for the various types of aquacultures at the local farm. Without proper aeration, oxygen levels in fish ponds can drop significantly, especially in deeper or overcrowded ponds. This research will also take into consideration the larger implications for the organization's aquaculture sector and its connection with national projects to develop environmentally and economically viable farming techniques, given the significance of the Philippine tilapia and the national tilapia industry.

Aerators are one of the electrical equipment for farmers, especially in fishponds. These systems also utilize aquaculture irrigation to prevent water oxygen depletion and maintain purification. Furthermore, a lot of these systems can store water for usage in the absence of sunshine, which removes the need for batteries, makes setup easier, and lowers total expenses. The semiconductor materials make up a photovoltaic (PV) module’s in solar (Ardiyansyah, N., & Wibowo, T. 2023). This study focuses on a solar-powered aerator with an integrated lighting system for energy utilization aimed at preventing financial losses and helping fish farmers save on operational costs at Minalin, Pampanga. In today’s modern world, the most commonly used aerators are electrical utilities. This research proposes a modern innovation focusing on a solar-powered aerator with an integrated lighting system for energy utilization at Minalin. This study aims to provide more cost-effective alternative electricity-powered systems. By integrating solar energy, this system seeks to revolutionize current aeration practices and contribute to the sustainable development of the local aquaculture industry. Ultimately, the goal is to improve the future prospects of fish farmers by offering an energy-efficient solution that reduces operational costs while supporting environmental sustainability. Aquaculture farming in Minalin, Pampanga, faces significant challenges due to the reliance on traditional energy sources for aeration, which results in high operational costs and insufficient oxygen levels in fishponds. Many small-scale fish farms lack access to reliable aeration systems, leading to fish mortality, reduced productivity, and poor water quality. Consequently, there is a pressing need for an innovative and cost-effective solution that utilizes renewable energy sources to enhance the efficiency and sustainability of fish farming operations.

1. What are the optimal specifications and sizes for an aerator, charge controller, inverter, and battery needed to ensure the reliable operation of a solar-powered aeration system and select an inverter size that is suitable for the lighting system and the aerator's power requirements?

2. How the traditional does compared to new method of aquaculture of a solar powered aerator in Terms of fish growth rates over the course of one month?

3. What is the cost-benefit analysis of implementing a solar-powered aeration system in tilapia farms in Minalin, Pampanga, compared to traditional aeration methods or no aeration at all, in terms of initial investment?

1.1. Specific Objectives

1. To determine the appropriate specifications and sizes of the aerator, charge controller, inverter, and battery necessary to operate the solar-powered system, this is also suitable for a lighting system and meets the aerator's power requirements.

2. To evaluate the efficiency of a solar-powered aerator compared to a setup with no installed aerator, particularly in terms of fish growth rates, over a one-month period of Tilapia fingerlings.

3. To analyze the cost-benefit of implementing a solar-powered aeration system in tilapia farms in Minalin, Pampanga, by comparing it with traditional aeration and no aeration in terms of initial investment, operational savings, and long-term productivity. To determine if the longer-term energy savings, increased profits outweigh the higher initial cost of solar-powered systems, making them more sustainable.

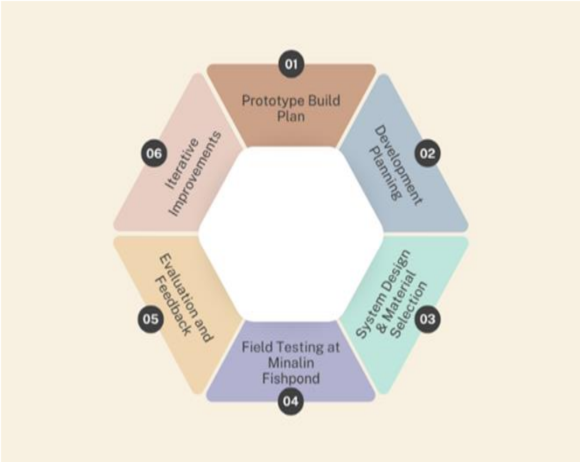

Figure 1. Cycle/Process for Solar-Powered Aerator System

2. Methods

The process begins in prototype building planning, where the core idea of the solar-powered aerator is laid out. It involves defining goals, estimating the requirements for our plan, understanding technical requirements, and outlining a rough design concept. It includes the original design and building schedule. Development planning comes next, which includes work allocations, resource allocation, and precise scheduling. The technical design is completed, and materials appropriate for the aquatic environment are selected in System Design & Material Selection. The prototype is then submitted to Field Testing at Minalin Fishpond to determine its actual performance.

2.1. Computation of Required Materials

The calculated maximum efficiency of the solar panel system is approximately 20.47%. This means that 20.47% of the sunlight energy hitting the surface of the solar panel is converted into usable electricity, while the rest is lost due to reflection, heat, and other inefficiencies. This is a solid efficiency for commercial solar panels, showing the system is performing well under standard conditions by using this formula to get the exact efficiency.

$$\eta_{max} = \frac{P_{max}}{E \times A_c} \times 100\%$$

2.2. Computation of Parameters

The researchers will use the following materials.165W aerator, (20w) light bulb, solar panel, solar inverter, and lightning outlet.

2.3. Sizing of Motor

As a general rule, you want an air pump that can move the entire volume of water in the pond at least once every two hours. This ensures that all areas of the pond receive enough oxygen [30].

2.4. Sizing of Inverter

The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting and the computed total watts is 175W × 3= 516w [29].

2.5. Total PV Array Power

FF or fill factor ratio of maximum obtainable power from the panel.

The rated maximum power of the solar panel determines the highest energy that it can produce. The fill factor for München550W monocrystalline solar panel is 0.833.

$$P_{max} = \frac{E_T}{(H_{ps})(FF)}$$

2.6. Sizing of Solar Charge Controller (SCC)

The solar charge controller rating (SCCR) depends on the maximum current that will circulate in the system and the number of panels to be utilized.

$SCCR = 1.3 \times I_{sc} \times Np$

2.7. Battery Computation

Due to the unavailability of batteries with the exact required capacity (Ah) on the market. The searchers used the next capacity available which is 200Ah 25.6V LiPo Batteries.

3. Results and Discussion

3.1. Computation of Loads

The total Load of all the component be used in solar aerator,

$E_T = \sum$ [Power Rating (W)] × [No. of Hour (h)]

Table 1. The computation of load for Phil-Tilapia

Description	Quantity	Power (W)	N0. of Hour (h)	Total (Wh)
Gf-180 Air Pump	1	165	24	3960
Ecolum LED Bulb	2	5	12	120
Total				4080Wh

Through an examination of the energy usage at Phil-Tilapia, researchers have determined that the farm consumes an average of 4080 watt-hours of energy daily while using the solar aerator. These findings provide valuable insights into the fish farm's specific energy needs, which will guide the design and development of a solar-powered system capable of fulfilling these requirements. To address these energy demands, appropriate materials have been selected for the solar-powered aeration system and analyze the system to give the exact amount needed.

Table 2. Aerator Testing April-May

Day	Duration (Hours)	Volts	Ampere
April 10	5:30am-7pm	39.31	42.24
April 12	5:30am-7pm	39.21	42.4
April 13	5:30am-7pm	39.17	42.1
April 15	5:30am-7pm	39.37	42.24
April 16	5:30am-7pm	39.22	42.32
April 18	5:30am-7pm	39.27	42.24
April 20	5:30am-7pm	38.97	41.89
April 26	5:30am-7pm	39.14	42.16
April 27	5:30am-7pm	39.07	42.15
May 1	5:30am-7pm	37.42	41.91
May 3	5:30am-7pm	39.11	42.17
May 4	5:30am-7pm	39.14	41.9

Over a 12-day testing period from 5:30 AM to 7:00 PM, the solar-powered aerator system for a tilapia fish farm demonstrated stable performance, with an average peak voltage of 38.02V and an average peak current of 42.14A, peaking between 11:00 AM and 2:00 PM. Despite having only three peak sun hours, the system was able to continuously support both the load and battery charging for 24 hours a day. The setup includes three 550W solar panels, a 24V 200Ah $LiFePO_4$ battery, a 1000W inverter, and a 60A MPPT charge controller. Under no-load conditions, the battery can be fully charged in about five hours, while under load, it can be fully charged in

Asian Journal of Applied Science and Technology (AJAST)
Volume 9, Issue 3, Pages 39-48, July-September 2025

approximately six hours—reaching 63.83% capacity during the three peak hours alone. When fully charged, the system can operate a 165W aerator and two 5W LED bulbs for around 20 hours before complete discharge.

Table 3. Size of Tilapia in Traditional and New Methods

Duration	Traditional	New Methods
Week 1	3cm to 4cm	3cm to 5cm
Week 2	4cm to 5cm	5cm to 6.2cm
Week 3	5cm to 6.2cm	7cm to 8.5 cm
Week 4	6.2cm to 7cm	9 cm to 9.5 cm

This actual size of the fingerlings in the span of 1 month of testing for the aerated and non- aerated have a 66.67%
This actual size of the fingerlings in the span of 1 month of testing for the aerated and non- aerated have a 66.67%
grow out rate rather than the direct seeding of the fingerlings in to the grow out pond in the new system with aeration the cycle is hatching next into nursery into grow out pond that have a significance in the size of the fingerlings in fish pond at Minalin, Pampanga to maximize the tilapia.

3.2. Research Locale

The research locale, located on Cul-Cul San Bartholome Road, Minalin, Pampanga, serves as the foundation for a groundbreaking exploration of a solar-powered generation system. This community provides a setting for the potential of renewable energy sources. The researchers aim to be suitable for the efficiency of solar energy systems for powering agricultural farming. This study seeks to emphasize the direct impact of clean energy solutions on local economies as well as the preservation of the environment. Through its examination of solar-powered generation system adoption, enactment, and consequences, this study seeks to make scalable and reproducible models available for incorporating clean energy in similar agricultural settings throughout the world.

Figure 2. Research Locale

4. Conclusion

In conclusion, implementation of a solar-powered aerator system for tilapia fish farming has proven to be an effective, eco-friendly, and sustainable solution for improving aquaculture operations. Based on the results, the solar panel system producing 39.22 volts, 42.22 amperes, and a total of 4080 watt-hours achieved a 66.67% fish grow-out rate within just one month, indicating a significant improvement in performance.

5. Recommendation

To further improve the performance and reliability of the solar-powered aerator system, it is recommended to use batteries with higher capacity—ideally up to 400Ah—to sustain energy needs during prolonged periods of low sunlight or heavy cloud cover. If higher-capacity batteries are not available, using batteries with a higher Depth of Discharge (DOD%) is advised to maximize usable energy while maintaining battery health. Since the system operates continuously and is exposed to environmental elements, the use of high-quality materials for construction is crucial. Regular inspection of the enclosure is also necessary to ensure durability and protection. Future improvements could include increasing battery capacity if solar output is high, enabling the integration of additional farm loads. Although the system already reduces the fish pond's energy consumption by 100%, enhancing battery storage can further improve its efficiency and expand its functionality of the prototype using in 24 hours.

Declarations

Source of Funding

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare that they have no competing interests related to this work.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Authors are willing to share data and material on request.

Institutional Review Board Statement

This study was approved by the Institutional Review Board of Don Honorio Ventura State University, Philippines.

Informed Consent

Not applicable for this study.

Acknowledgments

The authors acknowledge all involved parties in this study.

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