

Design and Evaluation of an Experiment Integrating a Solar Heating System in Aquaculture

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ABSTRACT

The study aims to enhance the efficiency of a solar collector used for water heating in a fish tank and to prevent fish mortality during the winter season. The solar collector, positioned above the surface, absorbs solar radiation and converts it into heat, which is then transferred to a heat transfer fluid. Various experiments were conducted to improve the efficiency of the solar water heater specifically designed for aquaculture purposes. The findings indicated that weather conditions significantly influence the performance of the solar collector. Moreover, temperature variations were found to have a considerable impact on the fish's life cycle. During the experiments, the basin temperature increased by 5 to 6 degrees Celsius, resulting in an average temperature of 33.3 degrees Celsius over five days, compared to 30 degrees Celsius in the control basin.

I. Introduction

Energy plays a central role in achieving sustainable development, particularly with the growing global interest in clean and renewable energy sources such as solar, wind, and geothermal energy. The increasing demand for energy, coupled with the depletion of fossil fuels like oil and gas, necessitates the development of efficient and sustainable alternatives.

Among these alternatives, solar energy has emerged as a viable solution due to its availability, cost-effectiveness, and environmental benefits. In arid and semi-arid regions such as the Algerian Sahara, solar energy is particularly promising, given the high levels of solar radiation throughout the year.

Aquaculture, as a growing sector in food production, is significantly affected by environmental conditions, especially water temperature. During winter, the low temperature of fish tanks can negatively impact fish health, growth rates, and reproduction cycles. Ensuring thermal stability in aquaculture systems is therefore essential for optimal performance.

This study aims to evaluate the thermal performance of a solar water heating system integrated into aquaculture applications in the city of Ouargla (Algeria). The proposed system includes a solar collector and a fish tank,

working together to maintain a favorable water temperature, particularly during cold periods. This approach not only enhances fish productivity but also promotes the use of clean energy in agricultural practices

II. Research Method

The experimental study was conducted to assess the performance of an integrated solar water heating system designed for aquaculture purposes. The system was developed at the Renewable Energy Research Unit in the Saharan Region of Adrar (Algeria). It consists of a galvanized steel absorber (0.4674 m², 0.5 mm thick) with thermal insulation made of 6 cm glass wool and 4 cm polyester.

A transparent glass cover was placed above the absorber to allow solar radiation to pass through. A 6-meter copper pipe (14 mm diameter) painted in black was used to circulate water through the absorber. All components were enclosed in a wooden collector box measuring 86 cm × 61 cm × 10 cm.

Two experiments were conducted at the Experimental Desert Aquaculture Plant in Hassi Ben Abdallah, Ouargla. The first experiment used two 2 m³ fish tanks, each containing 350 L of water. One tank was integrated with the solar water heater while the other served as a control. The second experiment used two 250 L tanks equipped with water pumps. In both cases, water temperatures were monitored and compared over several days using electronic thermostats, thermocouples, and an anemometer.

Measurements included inlet and outlet water temperatures, solar radiation intensity, ambient air temperature, and wind speed. Data were used to evaluate the system's effectiveness in improving water temperature and creating a suitable thermal environment for fish survival and growth during winter.

Mathematics

The thermal efficiency and heat transfer processes of the solar water heating system were evaluated using classical thermodynamic equations.

$$Q_u = m \times C_p \times (T_{out} - T_{in}) \quad (1)$$

Where:

m is the mass flow rate of water (kg/s); C_p is the specific heat of water (J/kg·K); T_{out} is the outlet water temperature (°C); T_{in} is the inlet water temperature (°C).

$$\eta = \frac{Q_u}{A_c \times G_t} \quad (2)$$

where: A_c is the collector area (m²); G_t is the global solar radiation on the collector surface (W/m²).

$$Q_{conv} = h_c \times A \times (T_{glass} - T_{air}) \quad (3)$$

where: h_c is the convective heat transfer coefficient (W/m²·K); A is the surface area of the glass (m²); T_{glass} is the glass surface temperature (°C); T_{air} is the ambient air temperature (°C).

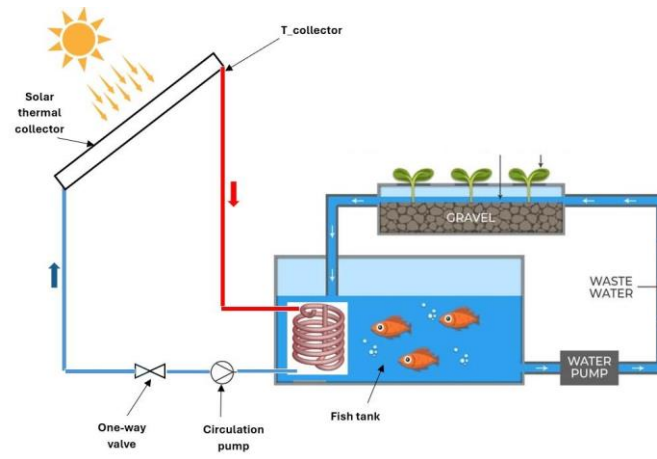


Figure 1. Solar thermal heating system schematic

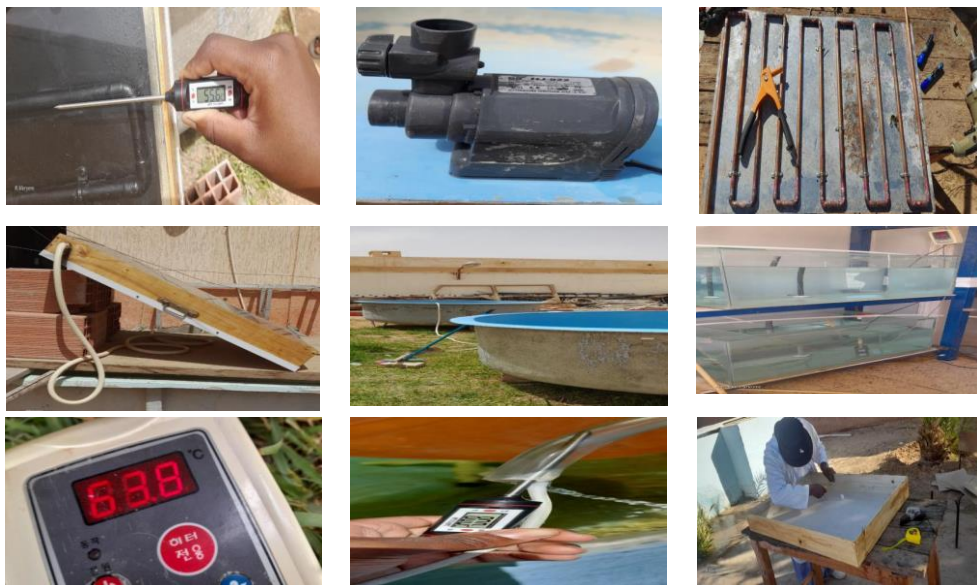


Figure 2. he pictures show the set of methods used and how

Table 1 . Primary account information

Ouargla, latitude	31.9 north
Ouargla, Longitude	5.32east
Height	170 (m)
Testing hour	From 9:00 AM to 16:00 PM
The days considered	05-06-07-08/05/2024
The specific heat of water	$C_p=4180$ (J/Kg.°C)

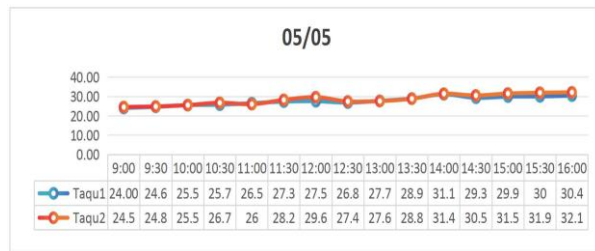


Figure 3. the variations of Taqu1 and Taqu2 as a function of t (05/05)

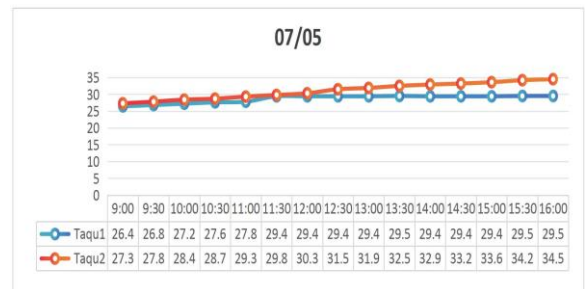


Figure 4 .the variations of Taqu1 and Taqu2 as a function of t (06/05)

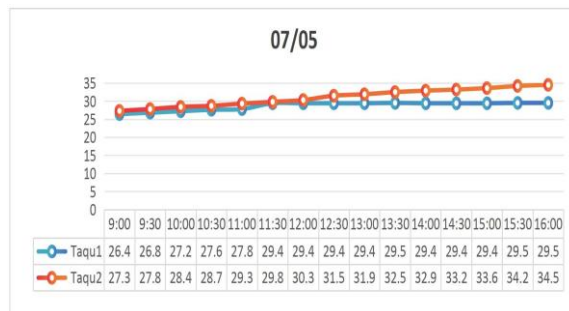


Figure 5. the variations of Taqu1 and Taqu2 as a function of t (07/05)

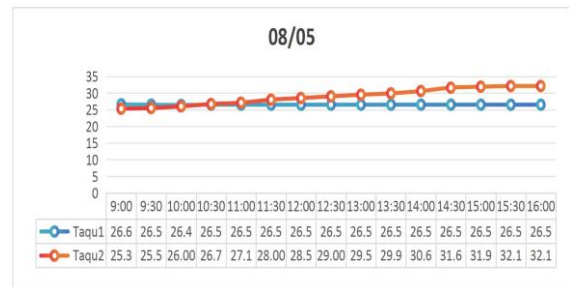
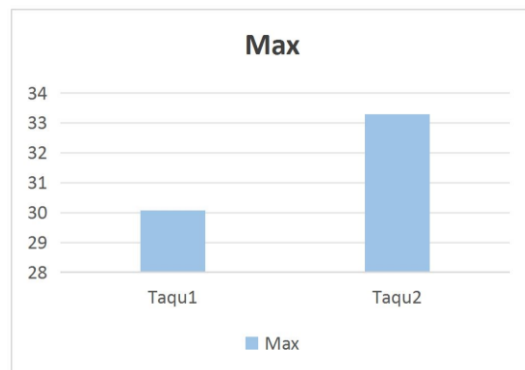


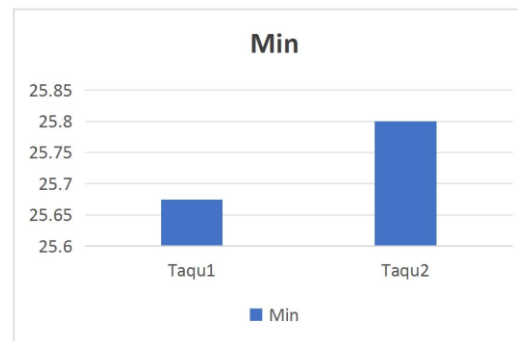
Figure 6. the variations of Taqu1 and Taqu2 as a function of t (08/05)

The figure represents the curve of the variations of Taqu2 and Taqu1 as a function of t, as we observe:

- The temperature in the two basins is very close on May 5 and 6, with a difference of one or two degrees at most.
- For the days 07 and 08 May, we record a clear increase in the temperature of the second basin (Taqu2) relative to the witness basin (Taqu1), starting at midday.
- In all curves, the temperature at the beginning of the morning is almost equal, with a difference of one to one and a half degrees at the maximum .



(a) Maximum water temperature in both tanks



(b) Minimum water temperature in both tanks

Figure 7. Max and Min Temperature Comparison Between Control and Heated Tanks.

III. Conclusion

This study focused on integrating a solar collector into an aquaculture system to maintain water temperatures suitable for aquatic life, especially during cold periods. The experimental results demonstrated the effectiveness of the proposed solar water heating system, showing that the tank temperature increased by approximately 5 to 6 degrees Celsius. Over five days, the average temperature in the heated tank reached 33.3 degrees Celsius, while the control tank remained at 30 degrees Celsius. This difference highlights the collector's efficiency in improving thermal conditions for fish.

The integration of solar thermal technology in aquaculture offers several benefits: it creates a more suitable environment for fish growth, enhances productivity, reduces reliance on conventional energy sources, and contributes to environmental protection by lowering greenhouse gas emissions. These findings support the adoption of renewable energy technologies for sustainable fish farming.

In future studies, a thermal storage system will be implemented to maintain water temperature during nighttime or periods of low solar radiation. Additionally, numerical simulations will be conducted to optimize system performance. It is also envisioned to integrate a water filtration unit, enabling nutrient recycling and the use of fish waste as natural fertilizer for crop irrigation, thus promoting a circular and sustainable aquaponic model.

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