Experimental Investigation of the Thermal and Productive Performance of a Single-Slope Solar Still

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ABSTRACT

This study evaluates the thermal and productive performance of a single-slope solar still enhanced with combined rectangular and hollow square fins. Five absorber configurations were tested under real outdoor conditions, including one conventional and four finned designs. The best configuration A52 reached a peak absorber temperature of 66 °C and increased cumulative freshwater production to about 2280 mL/m², compared to 1600 mL/m² for the conventional still. The maximum energy efficiency achieved was nearly 24%. Results show that rectangular fins have a stronger influence than square fins, making A52 the most effective design for improving heat transfer and productivity.

Keywords: solar still, absorber plate, rectangular fins, square fins, DOE, energy efficiency

1. INTRODUCTION

Solar distillation is a simple and low-cost solution for producing freshwater in arid regions. However, the conventional single-slope solar still suffers from low productivity due to limited heat-transfer area and low evaporation rates. Several enhancement strategies have been studied, including fins, phase-change materials, and nanoparticles.

The aim of this study is to evaluate the impact of combined rectangular and hollow square fins on the performance of a single-slope solar still. A design of experiments (DOE) approach was used to quantify the effect of fin dimensions and to identify the optimal configuration for maximizing productivity and exergy efficiency.

2. METHODOLOGY

2.1 System Description

The experimental device is a single-slope solar still with internal basin dimensions of 0.71 m × 0.81 m. The steel absorber plate 0.71 m × 0.71 m is coated with black matte paint to maximize solar radiation absorption. The 4 mm-thick glass cover is inclined at 34° to facilitate condensate flow toward the collection gutter. The basin walls are insulated with wood to minimize conductive heat losses and ensure stable operation. The water depth was kept at 10 mm in all tests to maintain comparable thermal conditions. Distilled water was collected through a channel placed at the lower end of the glass cover.

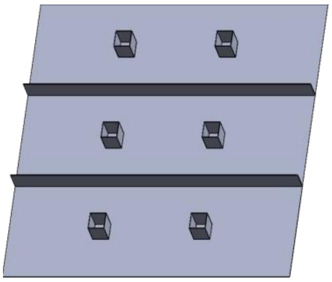
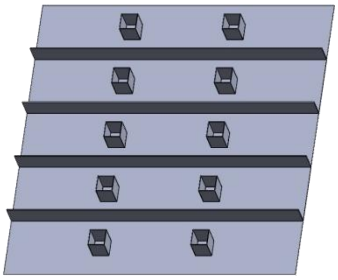
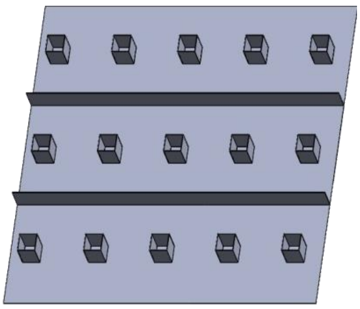
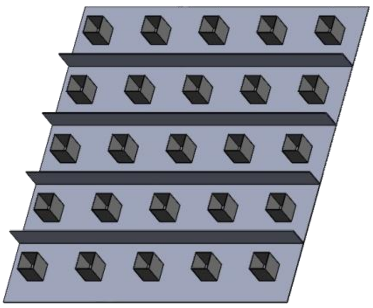
The experimental campaign was carried out in September 2025 at the National Engineering School of Gabes (ENIG), Tunisia. During each test day, solar radiation, ambient temperature, and wind speed were monitored, while absorber, glass, water, and vapor temperatures were measured to assess the thermal behavior and productivity of the system. A photograph of the constructed setup is presented in Figure 1.

Figure 1: Photograph of the single-slope solar still

2.2 Solar Still Configurations

Five absorber configurations were investigated: one conventional plate A00 and four finned plates combining hollow square fins X_1 and rectangular fins X_2. The fin densities length and width distribution were selected using the design of experiments (DOE) to study their influence on heat transfer and freshwater productivity.

Tableau 1: Experimental Absorber Configurations and Corresponding Figure

A22: 2 rectangular fins and 2 square fins 	A24: 4 rectangular fins and 2 square fins 
A52: 2 rectangular fins and 5 square fins 	A54: 4 rectangular fins and square fins 

3. RESULTS AND DISCUSSION

3.1 Temperature evolution

The absorber temperature increased throughout the morning and peaked around midday. Among all configurations, A52 reached the highest temperature, confirming its superior heat absorption. A24 and A54 followed with slightly lower values, while the conventional still A00 remained the coolest. After midday, temperatures declined consistently as solar radiation decreased. Overall, A52 demonstrated the most efficient thermal behavior.

3.2 Daily productivity

Figure 2 shows the cumulative freshwater production of all configurations. The conventional still produced the lowest amount 1600 mL/m², while fin-based designs performed better. Configuration A24 and A52 gave the highest yields about 2225 and 2280 mL/m², and even Configuration A54 2084 mL/m² remained well above the baseline.

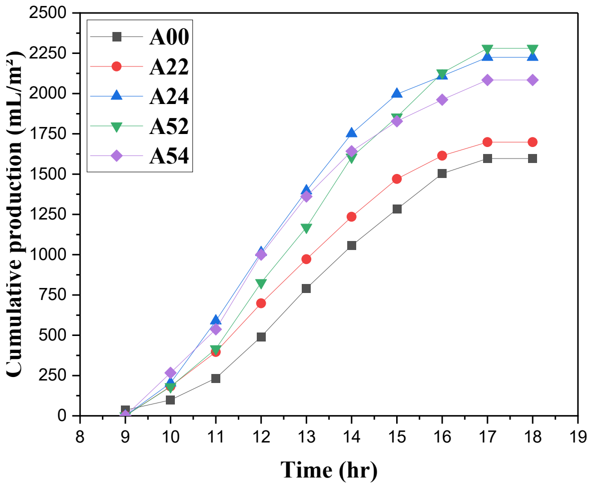


Figure 2: Comparative Cumulative Freshwater Yield of All Configurations

3.3 Energy efficiency

Energy efficiency was calculated using:

$$\eta = \frac{\sum m_{ew} \times hfg}{\sum I(t) \times A_s \times 3600} \qquad (1)$$

The energy efficiency ranged from 17 % for A00 to 24% for A52. The integration of fins increased the heat-transfer surface, enhancing absorption and evaporation.

3.4 Iso-response curve

The iso-response curve shows that efficiency increases from about 18.6% up to nearly 24% as X_2 becomes larger while X_1 remains small. The highest efficiency 24% occurs when X_2 is at its maximum 5.5–5.6 cm and X_1 is low. This confirms that X_2 has the strongest influence on improving efficiency.

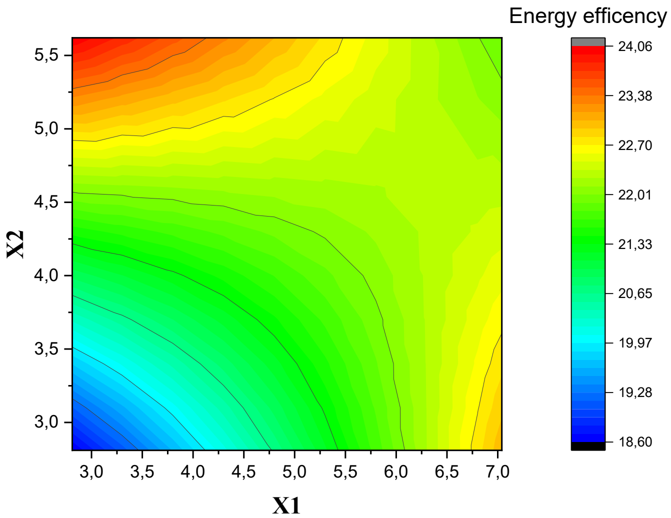


Figure 3: Variation of X_1 and X_2 as a function of the response level

4. CONCLUSIONS

The experimental study confirms that integrating fins significantly improves the performance of the solar still. The best configuration A52 increased the freshwater yield from 1600 mL/m² to about 2280 mL/m² and raised the efficiency to nearly 24%. The rectangular fin dimension X_2 proved to be the dominant factor, providing a stronger enhancement in heat transfer than the square fin. Therefore, combining larger rectangular fins with smaller square fins offers the most effective design for improving thermal behavior and productivity

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