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EFFECTS OF INTERNAL REFLECTORS ON DAILY PERFORMANCE OF DOUBLE SLOPE SOLAR STILLS WITH POROUS FIN ABSORBER PLATE

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ABSTRACT

The potential of energy and sea water in Indonesia is relatively high, but it has not been utilized massively to reduce the shortage of fresh water on the islands. Utilization of this potential can use solar stills. Solar still is a relatively cheap technology, easy to obtain materials, environmentally friendly and easy to construct, but this technology has shortcomings in its low productivity. Efforts to increase productivity have been made by many researchers, but there has not been a study of internal reflector integration in a double slope solar still using a porous absorbent plate tested for 23 hours. This study aims to examine the effect of adding an internal reflector on the performance of a double slope solar still. The performance of the double slope solar still is identified by evaluating freshwater productivity and efficiency. This research was conducted experimentally comparing with and without internal reflector. The addition of internal reflectors varies in placement, as for the placement on the north and south sides (RUS), the south side (RS), and the north side (RU). Data collection starts at 07.00 p.m. until 06.00 a.m the next day and is carried out for 5 days. Research comparing the performance of RUS, RS, RU compared to TR and concluded that there is an increase in temperature of fins, seawater and cover glass when using the addition of internal reflector. The increase in temperature has an effect on daily productivity for RUS, RS and RU between 12.88-16.13%, 8.71-12.56%, and 1.70-2.88%, respectively. In addition, the addition of the internal reflector has a positive effect on increasing the daily efficiency for RUS, RS and RU between 12.69-15.93%, 8.60-12.46% and 1.65-2.82%, respectively.

Keywords reflector; double-slope; fins; productivity; efficiency;
Paper type Research paper

INTRODUCTION

Indonesia is a country with a large population. The main need of the population is fresh water. An increase in population will require an increase in the availability of fresh water to meet their needs, but fresh water sources are relatively limited [1]. In addition, Indonesia is an archipelago, of course it will experience problems in the fresh water distribution system to meet the population living in the islands and far from water sources. The problem is more pronounced for people living in remote islands during the dry season. Such conditions require an effort to meet the needs of fresh water that adapts to the conditions in the islands. Indonesia is a country that is passed by the equator, so the availability of solar energy is almost always there throughout the year, and this energy will be even greater during the dry season [2]. In addition to the potential of solar energy, in the islands there is also the potential of sea water that can be processed into fresh water. The potential of energy and sea water can be utilized using solar still technology. This technology is relatively cheap, materials are widely available, environmentally friendly and allows for independent construction. However, this technology has drawbacks to its low productivity [3].

Various efforts to increase the productivity of solar stills have been made, for example, efforts to improve the performance of solar stills by applying double slope cover glass [4][5]. Another effort to reduce the temperature of the double slope cover glass is also done by providing water cooling on the top surface of the cover glass and the results can increase the productivity of fresh water [6]. In addition to the cover glass, development is also done by improving the performance of the solar still by increasing the surface area of the absorbent plate [7][8]. Increasing the surface area of the absorber plate can be done by adding fins that are integrated with the basin, and the results can increase the productivity of the solar still [9]. Some researchers tried to create a thin layer of water by making the absorbent plate porous and the results can increase evaporation and solar still productivity [10]. Another effort to increase the productivity of solar stills, some researchers investigated to increase the solar radiation energy that can be received by the absorber plate. Increasing solar radiation energy by adding an internal reflector has been done and the results can increase solar still productivity [11] [12].

From the literature review, respectively, using double slope cover glass, porous fins and internal reflector on the wall can improve the performance of the solar still. Investigation of previous works also revealed that the integration of double slope cover glass, porous fins and internal reflectors on the wall has not been studied. In addition, the combination has not been studied for the performance of the solar still for 23 hours starting from 07:00 am to 06:00 am the next day. To fill this gap, this research makes the following contributions: 1) Investigate the results of comparative research with and without internal reflector on double slope solar still. Internal reflectors are varied in placement, namely on the north and south sides (RUS), on the south wall (RS) and on the north wall (RU). 2) Experimental research was conducted from 7:00 am to 6:00 am the following day. 3) Provide insight into the effect of internal reflectors on the wall to produce productivity from morning to evening when the solar still is exposed to solar radiation and evening to morning when the solar still is not exposed to solar radiation. 4) In addition, a comparison of the effect of the internal reflector on the daily efficiency of the solar still was conducted. Thus the aim of this research is to investigate the effect of internal reflector on the daily performance of double slope solar still.

METHOD

The study compared the addition of internal reflector on the north and south sides (RUS), the addition of internal reflector on the north side (RU), the addition of internal reflector on the south side (RS), and without reflector (TR). The study used a double slope solar still and a porous fin absorber plate. Experimental research was conducted at the Solar and Alternative Energy Laboratory of Widyagama University Malang in September 2023. Data collection location at 7.98 south latitude coordinates and 112.62 east longitude coordinates. The experimental testing equipment can be seen in Figures 1 and 2. The basin uses mortar which is a mixture of iron sand and cement with a composition of iron sand 1, cement 1 and sufficient water. The composition of this mortar mixture is to ensure that there is no leakage in the basin. Basin with a size of 1 x 1 m and on all sides are given a barrier with a height of 0.1 m and a thickness of 0.03 m, while at the bottom it is 0.05 m thick. Above the basin are elongated fins with a length of 0.9 m, a height of 0.1 m and a thickness of 0.03 m. The distance between fins is 5 cm. The distance between fins is 5 cm. The fins use a composition with a ratio of iron sand 2, cement 1 and enough water. This composition is intended to create porous fins that will be used as a water and heat flow medium, in addition as an evaporation medium. The surface of the basin and fins is coated with matte black paint to increase the absorption of solar radiation. The cover glass uses a double slope cover glass of transparent glass with a thickness of 3 mm and a slope of 15°. The wall uses transparent glass with a thickness of 5 mm.

The reflector uses a mirror with a thickness of 5 mm. The internal reflector at the top follows the roof model with an angle of 15°, on the lower side with a length of 1.1 m and in contact with the east side wall 20 cm high. The addition of the reflector is intended to increase the solar radiation that can be received by the porous fin absorber plate, so as to increase evaporation and further increase productivity. To reduce heat loss, the glass is bonded with transparent glass glue and the wall is insulated with Styrofoam with a thickness of 5 cm. The thermocouples used are type k temperature thermocouples totaling 24 pieces. Thermocouples were installed in the water basin, on the fins, cover glass and the environment. Pyranometer using Sentec SEM228A Rs232 Solar Radiation Sensor. Anemometer was used to measure wind speed using GM816 Digital Wind Anemometer. Data from temperature, pyranometer and wind are processed using arduino mega 2560. The data obtained on the arduino is displayed and stored on the computer.

The double slope solar still using porous fin absorber plates with and without the addition of reflector is filled with seawater with a height of 1 cm. Seawater is filled every morning between 06:00 WIB. Seawater comes from Lamongan Regency with a salt content of 3.5%. Data on ambient temperature, cover glass, basin water temperature, fin absorber plate temperature, solar radiation intensity and fresh water were taken every 1 hour. Data were taken from 07:00 a.m. to 06:00 a.m. on the following day (23 hours). The distillation water channel is made of aluminum mounted on the wall under the cover glass to drain water to the reservoir.

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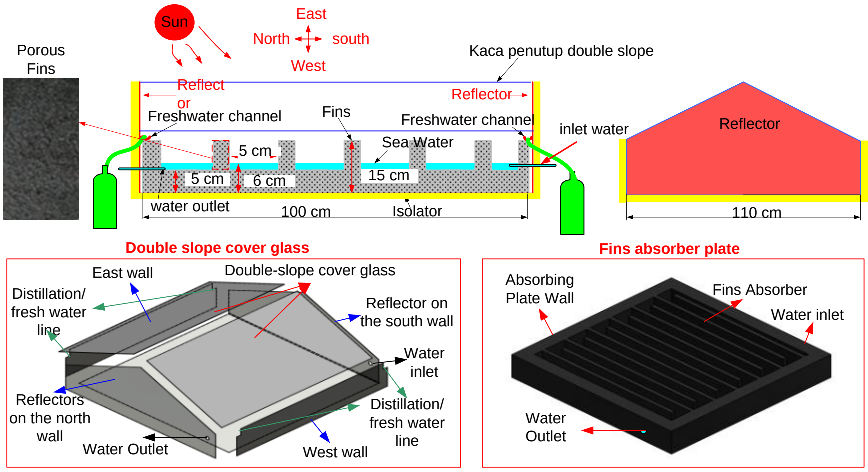

Figure 1. Schematic of testing equipment

Figure 2. Research equipment

Solar still efficiency

Solar still efficiency can be calculated using the equation from Duffie [13], as follows:

$$\eta_i = \frac{q_e}{I_{(t)}}(\%) \qquad (1)$$

To calculate the total daily radiation on the solar still, from Lempoy [14], as follows:

$$I_s = \frac{(t \times 60) \times I_{(t)}}{1000000}\left(MJ/m^2 \right) \qquad (2)$$

For the daily efficiency produced by the solar still experimentally daily [15], as follows:

$$\eta_i = \frac{m_{p.} \times L_{ev}}{I_s \times A} \times (100\%) \qquad (3)$$

Latent heat of vaporization using equation [16],

$$L_{ev} = \left(2501.67 - 2.389T_w\right)x10^3, \text{ (J/kg)} \qquad (4)$$

Where :

η_i = Solar still efficiency (%)
mp = Fresh water production per day (kg/day)
L_{ev} = Latent heat of vaporization (kJ/kg)
$I_{(t)}$= Total solar radiation (W/m^2)
I_s = Daily total solar radiation (MJ/m^2)
A = Area of the basin (m^2)
q_e = Heat for evaporation (kW/m^2)
t = Data collection time interval (minutes)

DISCUSSION

Research conducted experimentally with data collection intervals every 5 minutes for 23 hours for temperature is presented in Figure 3. In the figure, it can be seen that the temperatures of RUS, RS and RU are higher than TR, this condition is caused by the presence of an internal reflector which can increase the solar radiation energy that can be received by the absorber plate. Internal reflector besides having an effect on increasing the temperature of the absorber plate also has an effect on increasing the temperature of the cover glass and water, this is in line with previous research [17] [18].

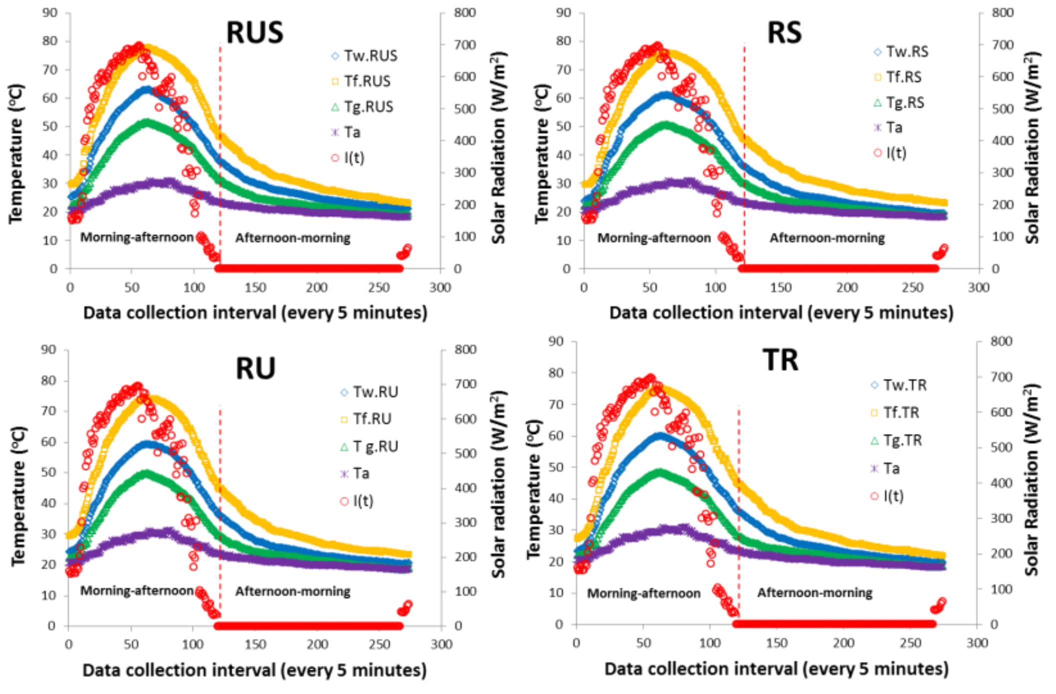

Figure 3. Temperature of the double slope solar still components during 23 hours of testing

Figure 3 also provides information on the effect of the internal reflector on the temperature of the solar still components (temperature of the absorber plate, water and glass cover) when exposed and when the solar still is no longer exposed to solar radiation. The temperature of the solar still components when exposed to solar radiation (morning-afternoon) appears to follow the pattern of solar radiation. However, when the solar still component is no longer exposed to solar radiation (afternoon-morning), the temperature on the solar still component does not follow the pattern of solar radiation. This condition is caused by the solar still when exposed to solar radiation, the components in the solar still perform heat storage. The heat stored in the solar still component will be used in the afternoon to morning. The method of utilizing the stored heat is in line with previous research [19].

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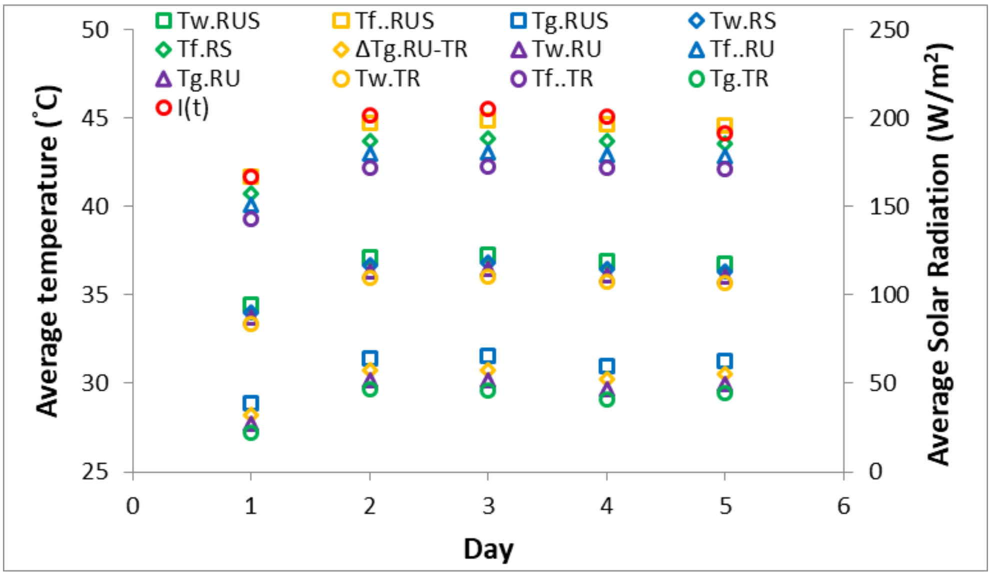

Figure 4. Daily average temperature of the double slope solar still component

Figure 4 shows the daily average temperature of the solar still component. The average temperature presented is the temperature acquired for 23 hours. The average fins temperature is higher than the average water and glass cover temperatures. This condition provides information that the absorption of solar radiation heat by the fins is higher than the water and glass cover temperatures. In addition, it can also be seen in Figure 4 that the temperature using RUS, RS and RU is higher than that of TR, this provides information that using an internal reflector can increase the temperature of the solar still components. In addition, there are conditions in the installation of internal reflectors on the north side that are not exposed to direct solar radiation which also affect the temperature increase in solar still components.

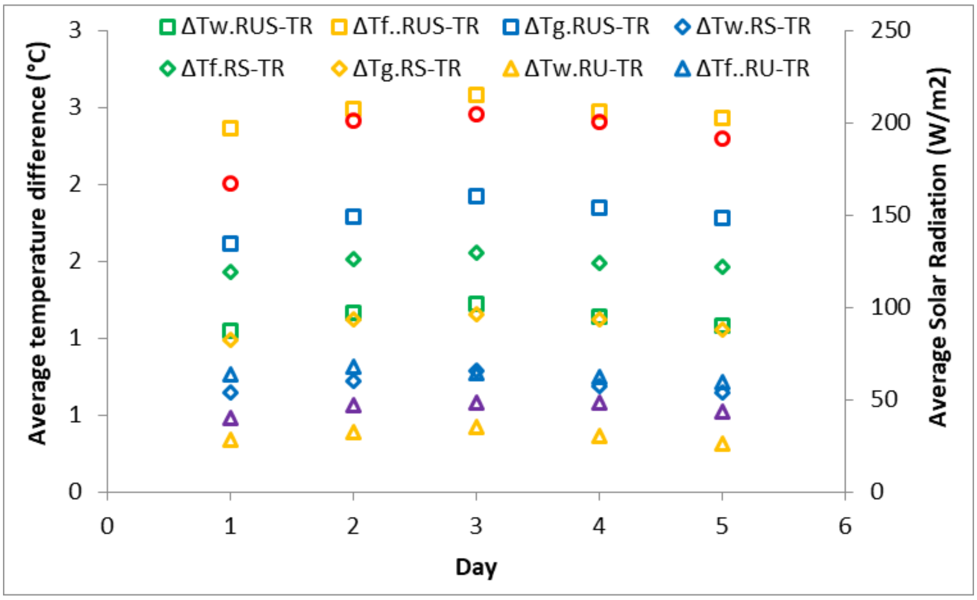

Figure 5. Daily average temperature difference in double slope solar still components

From the data taken during the five days of testing and each of which was carried out for 23 hours, then averaged and the results are presented in Figure 5. From the figure shows the effect of adding an internal reflector on the average temperature during the test. The effect of adding an internal reflector can be seen from the difference in average temperature for five days. The difference is in the temperature of the cover glass, seawater and RUS fins with TR between 1.05-1.22°C, 2.37-2.58°C and 1.61-1.92°C, respectively. The differences in the average temperatures of fins, seawater and cover

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glass RS with TR are between 0.64-0.79°C, 1.43-1.56°C and 0.98-1.16°C, respectively. While the average temperature differences of fins, seawater and RU glass cover with TR are between 0.34-0.42C, 0.76-0.81°C and 0.48-0.58°C, respectively. From these conditions, it can be seen the effect of the internal reflector on increasing the temperature of the solar still component which can be an indicator of increased energy. This increase in energy is a positive indication of the increase in solar still productivity. This temperature increase is comparable to previous research which is 0-7.24°C [12] and 0-2°C [20].

The results of experiments conducted for 23 hours and data collection of freshwater productivity in the afternoon and in the morning can be seen in Figure 6. The effect of internal reflectors can increase freshwater productivity compared to without internal reflectors. Freshwater productivity in the morning-afternoon using RUS, RS and RU increased between 11.66-17.86%, 8.26-15.38%, and 0- 4.29% respectively compared to TR. While in the afternoon-morning using RUS, RS and RU increased between 8.00-25.22%, 6.80-20.80%, and 0-8.24% respectively compared to TR. Freshwater productivity in the afternoon is more due to the energy stored in the absorbent plate and water when exposed to higher solar radiation, so that the stored energy can be utilized when in the afternoon.

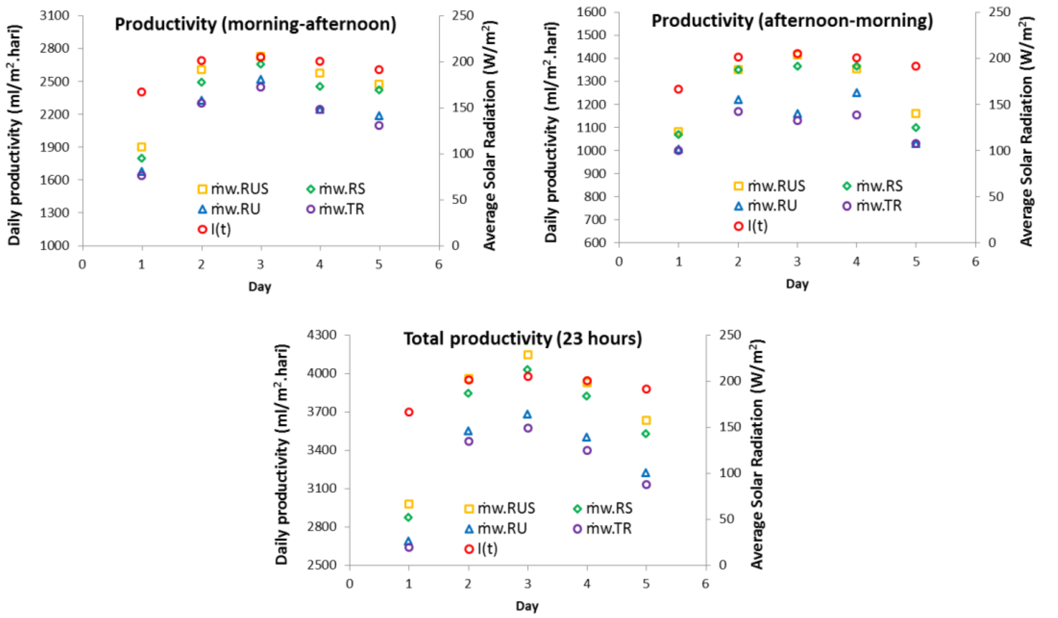

Figure 6. Daily morning-afternoon productivity, afternoon-afternoon productivity and total daily productvity

In a double slope solar still, performance can be evaluated using the productivity parameter. Figure 6 shows the total daily productivity for five days of testing with and without internal reflector which is the experimental result. The figure shows that the total daily freshwater productivity for RUS, RS, RU is higher than that of TR. The high freshwater productivity is more due to an increase in temperature in the solar still components, including an increase in fins and water temperature. Fins and water are the media for the evaporation process, so the high temperature is an indication of the increasing evaporation process. An increase in the evaporation process can lead to an increase in solar still productivity.

The increase in total daily freshwater productivity from experiments using RUS, RS and RU increased between 12.88-16.13%, 8.71-12.56%, and 1.70-2.88% respectively compared to TR. RU experienced a relatively small increase compared to TR, this condition is because the reflector on RU is not directly exposed to solar radiation. Efficiency is an evaluation of the performance of the system, where the thermal work of the system is compared to the energy input. Figure 7 presents the daily efficiency of four desalination systems with and without internal reflectors. Of the four desalination with three solar still systems with the addition of an internal reflector and without a reflector, the daily efficiency was studied. The daily efficiency obtained shows the addition of internal reflector can improve the performance of solar still compared to without reflector. The efficiencies obtained for RUS, RS, RU and TR are between 52.37-59.11%, 50.47-57.44%, 47.24-52.47% and 46.47-51.08 respectively.

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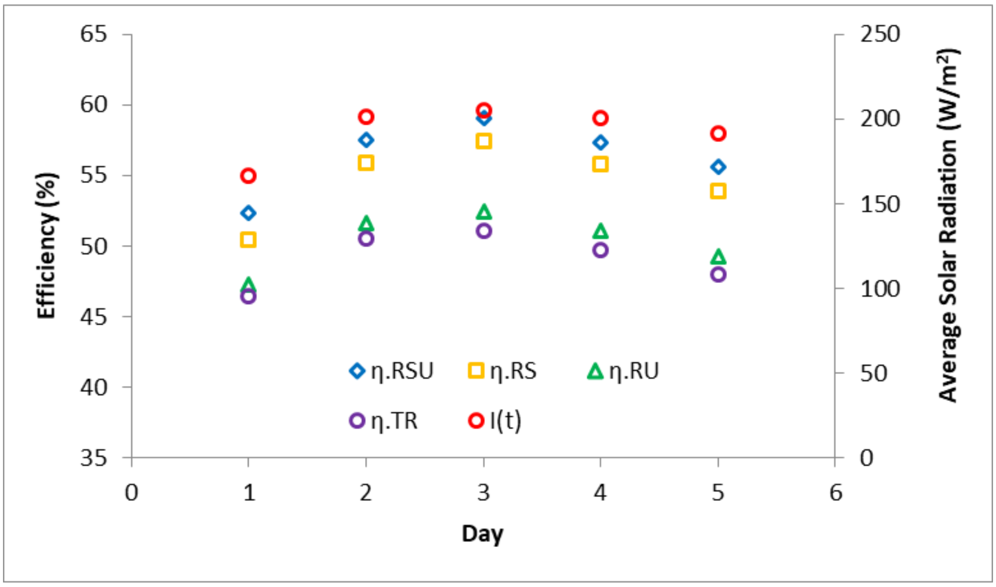

Figure 7. Daily efficiency with and without internal reflectors

Figure 7 also analyzes the daily efficiency improvement with and without internal reflector. The daily efficiency increases for RUS, RS and RU are between 12.69-15.93%, 8.60-12.46% and 1.65-2.82% respectively compared to TR. The increase in daily efficiency is due to the addition of solar radiation energy from the internal reflector. This additional energy can increase the temperature of the fins and water, thus increasing evaporation. Increased evaporation can increase freshwater productivity which in turn can increase the daily efficiency of the double slope solar still.

Conclusion

The daily performance of the double slope solar still with the addition of reflector and without reflector was investigated experimentally. The performance of RUS, RS, RU were compared with TR and tested under the same conditions. The results can be concluded that with the addition of inernal reflector, there is an increase in temperature of fins, seawater and cover glass. The increase in temperature has an effect on daily productivity for RUS, RS and RU between 12.88-16.13%, 8.71-12.56%, and 1.70-2.88%, respectively. In addition, the addition of internal reflectors had a positive effect on increasing daily efficiency for RUS, RS and RU between 12.69-15.93%, 8.60-12.46% and 1.65-2.82%, respectively.

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