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Development of a Solar Assisted Drying System Using Double-Pass Solar Collector with Finned Absorber

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Abstract. The Solar Energy Research Group, Universiti Kebangsaan Malaysia, International Islamic University Malaysia and Yayasan FELDA has designed and constructed a solar assisted drying system at OPF FELDA Factory, Felda Bukit Sagu 2, Kuantan, Pahang. The drying system has a total of six double-pass solar collectors. Each collector has a length of 480 cm and a width of 120 cm. The first channel depth is 3.5 cm and the second channel depth is 7 cm. Longitudinal fins made of angle aluminium, 0.8 mm thickness were attached to the bottom surface of the absorber plate. The solar collectors are arranged as two banks of three collectors each in series. Internal manifold are used to connect the collectors. Air enters through the first channel and then through the second channel of the collector. An auxiliary heater source is installed to supply heat under unfavourable solar radiation condition. An on/off controller is used to control the startup and shutdown of the auxiliary heater. An outlet temperature of 70–75 °C can be achieved at solar radiation range of 800–900 W/m^2 and flow rate of 0.12 kg/s. The average thermal efficiency of a solar collector is approximately 37%.

1. Introduction

Malaysia lies entirely in the equatorial region. On average, Malaysia receives of 4.21 to 5.56 kWh/m^2 of solar radiation a year. Solar energy has been identified as one of the most potential alternative energy resources as Malaysia receives abundant sunshine all year long [1]. This solar energy has great potential for low temperature applications, particularly for drying of agricultural products. Various types of solar systems for drying agricultural products have been reviewed and studied in the literature [2–6]. The solar

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assisted drying systems mainly for agricultural produce are developed with compact collector design, high efficiency, integrated storage, and long-life drying system.

One of the most important components of a solar dryer system is the solar collector. Various designs of solar collectors have been proposed including multi-pass collectors. Satchunanathan and Deonarine [7], Satchunanathan and Persad [8] and Persad and Satchunanathan [9] performed the experiments and conducted analytical studies involving double-pass solar air collector. They concluded experimentally and analytically that the double-pass design with air flow between the two glass covers and under the absorber plate had a thermal efficiency about 10-15% higher than the single-pass design. They also concluded that reduced top loss improves the performance since the outer glass cover separating the collector from ambient temperature is cooled by the working fluid.

In addition, the use of a double-pass resulted in an increase in the pressure drop a cross the collector. Mohamad [10] conducted theoretical studies of a double-pass solar collector with porous media in the second channel. Sopian et al. [11] performed the experimental studies on the performance of a double-pass solar collector with porous media in the second or lower channel. The second or lower channel of the solar collector is filled up with porous media which acts as heat storage system. This will increase the outlet temperature and the performance of the system.

However, the low thermal conductivity of air results in poor heat transfer between the absorber plate and the flowing air; hence, the air collector efficiency is low. Several designs have been suggested to increase the heat transfer coefficient between the absorber and the flowing air. These include finned absorber [12,13], corrugated absorber [14], multiple passes [15] air collector, etc.

In this work, we have investigated the performance of a double-pass solar collector in which fins are introduced in the second channel flow passage parallel to the length of the collector. Air enters through the first channel formed by the glass cover and the photovoltaic panel and is heated directly by the sun. Next it enters the second channel formed by the back plate. The fins on the back plate will increase the heat transfer to the air and enhance the efficiency of the system.

A solar assisted drying system that incorporated the double-pass solar collector with fins has been designed, constructed and tested in the OPF Factory, Felda Bukit Sagu 2, Kuantan. The followings present the design and preliminary performance results of the solar assisted drying system.

2. The Solar Assisted Drying System

The main components of the solar assisted drying system are (a) the collector array, (b) blower, (c) auxiliary electric heater with on/off controller, (d) the drying chamber, and (e) data acquisition system. Figure 1 shows the schematic of the solar assisted drying system. Air flows into the collector by using blower into the drying chamber. An auxiliary heater is used to supply heat when the drying chamber temperature reached a lower setting temperature.

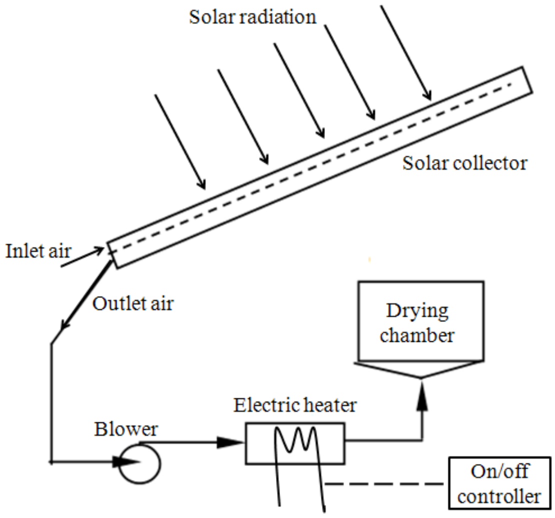

Figure 1. Solar assisted drying system.

This double-pass solar collector with fins consists of the glass cover, absorber plate, finned absorber and insulator. The upper part of the collector was covered by tempered glass, 5 mm thickness. The absorber plate was made of aluminuim sheet, 2 mm thickness and was painted black. Fins are used to increase heat removal from first channel to the second channel and improved the overall efficiency of collector. The side walls and the bottom floor of the collector were thermally insulated with 2.5 cm thick fiberglass to minimize heat losses. The schematic of the double-pass solar collector with fins is shown in figure 2.

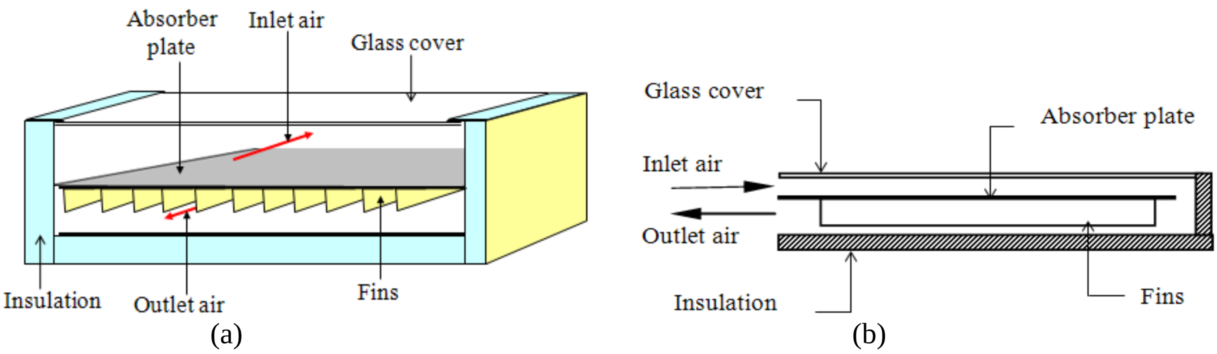

Figure 2. The schematic of a double-pass solar collector with fins in the second channel (a) front view (b) side view.

This solar collector was fabricated with a double channel configuration. The length of the collector is 480 cm and the width is 120 cm. The first and second channel depths are 3.5 cm and 7.0 cm respectively. These collectors have been arranged to form an array. The array has a total six collectors. Figure 3 shows the array for the solar drying system.

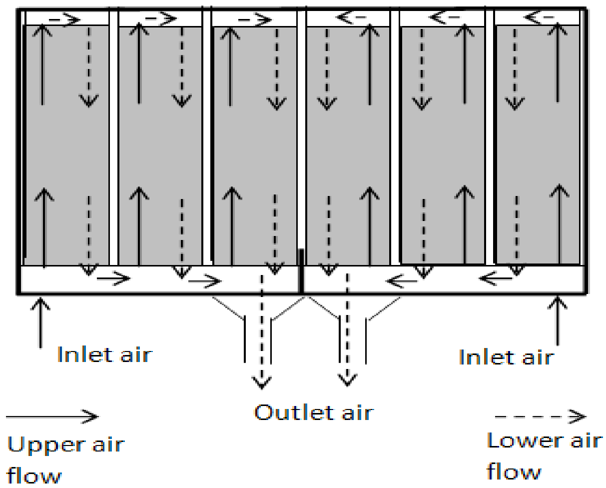

Figure 3. The array for the solar drying system.

The blower is used for sucks the hot air from the collector, because it is no natural convection flow in the double-pass solar collector. By using blower, the air flow may be varied. The electric heater is used for supply heat if the drying chamber temperature falls below a set temperature of 50 °C. Using the on/off controller, the electric heater is on if the temperature of drying chamber lower than 40 °C and off if higher than 50 °C. The electric heater is finned air heater with power supply is about of 5 kW. The drying chamber is batch type, it is used for dry oil palm frond, with capacity of about 400 kg wet dried. Data acquisition system, the data acquisition or computer interface system feed data from the thermocouple and pyranometer to the computer. The main components of the data acquisition system for the experimental setup consists of the following (a) the personal computer, (b) the data acquisition card, and (c) the personal computer application program.

3. Data Analysis

The thermal efficiency of a solar collector, η_c is the ratio of useful heat gain to the solar radiation incident on the plane of the solar collector. It is defined as

$$\eta_c = \frac{mC(T_o - T_i)}{A_c I} \times 100\%$$

where,
m = mass flow rate (kg/s)
C = specific heat of air (J kg^{-1} ^{o}C^{-1})
A_c = collector area (m^2)
T_i = inlet air temperature (^{o}C)
T_o = outlet air temperature (^{o}C)
I = solar radiation intensity (W/m^2)

4. Results and Observations

The solar drying is tested under varying environmental conditions for several days. The system is activated at about 9:00 in the morning and terminated at around 5:30 in the evening. Global solar radiation is measured by pyranometer. The inlet, outlet and ambient temperatures are measured by type-K thermocouple wire. These sensors are connected to the data acquisition system. The velocity in the outlet duct is recorded using a hand held air flow meter and the flow rate can be determined. The data are recorded and averaged for a period of one minutes and stored in the hard drive of the personal computer. The data can be retrieved using a spreadsheet program.

During five days of the experiment, the diurnal variation of solar radiation (I), ambient temperature ($T_{ambient}$), inlet air temperature (T_{inlet}), and outlet air temperature (T_{outlet}) for solar drying system were plotted and are shown in figure 4–8. An output temperature range of 40–60 °C can be obtained at solar radiation levels of 500–600 W/m^2. Figure 4 is a typical result for a cloudy day. It is also observed that the finned absorber in the second channel of the collector acts as the storage medium. This is also obvious from the fact that for the cases where the solar radiation falls to a lower level, the output temperature still be maintained. Figure 7 shows a typical result for a clear day in the morning and afternoon but rainy in the evening. The average solar radiation level from 9:00 am to 5:30 pm is about 540 W/m^2. The maximum outlet air temperature is about 76 °C for inlet temperature and air flow rate of 35 °C and 0.12 kg/s respectively.

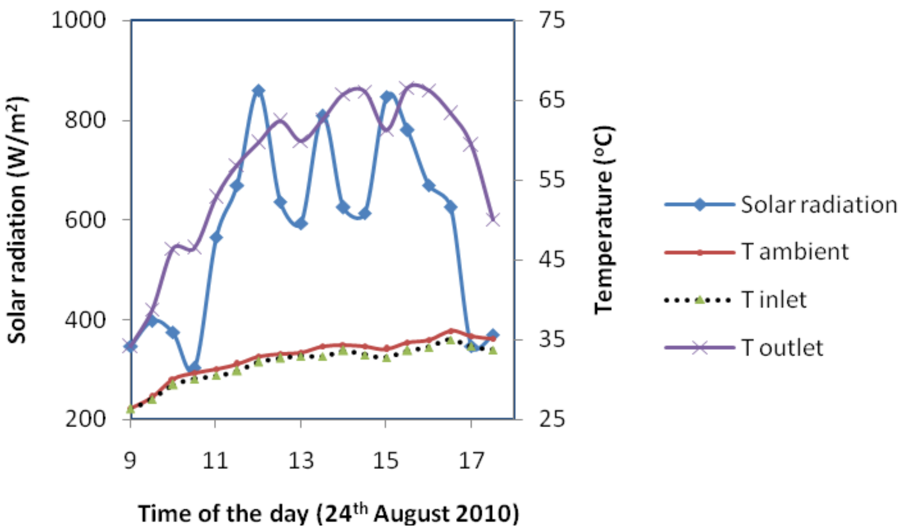

Figure 4. The solar radiation, ambient and inlet temperatures and the resulting outlet temperature for 24th August 2010.

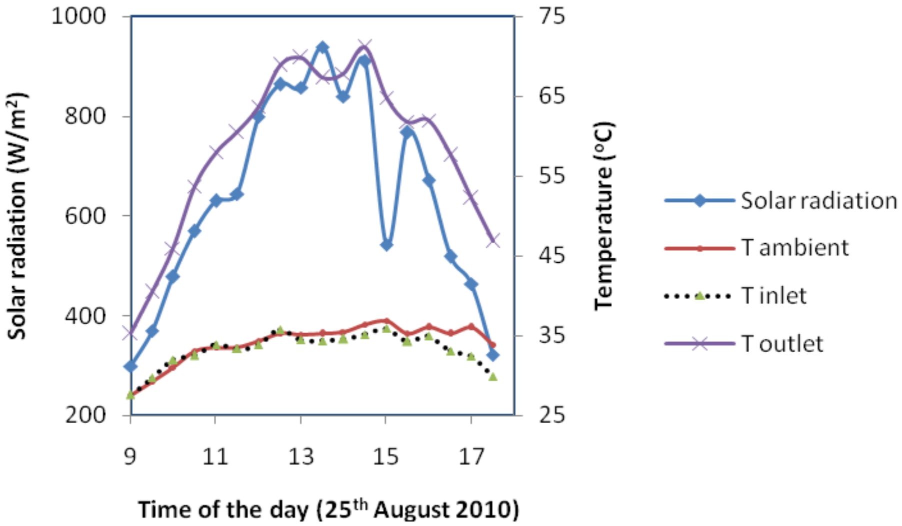

Figure 5. The solar radiation, ambient and inlet temperatures and the resulting outlet temperature for 25th August 2010.

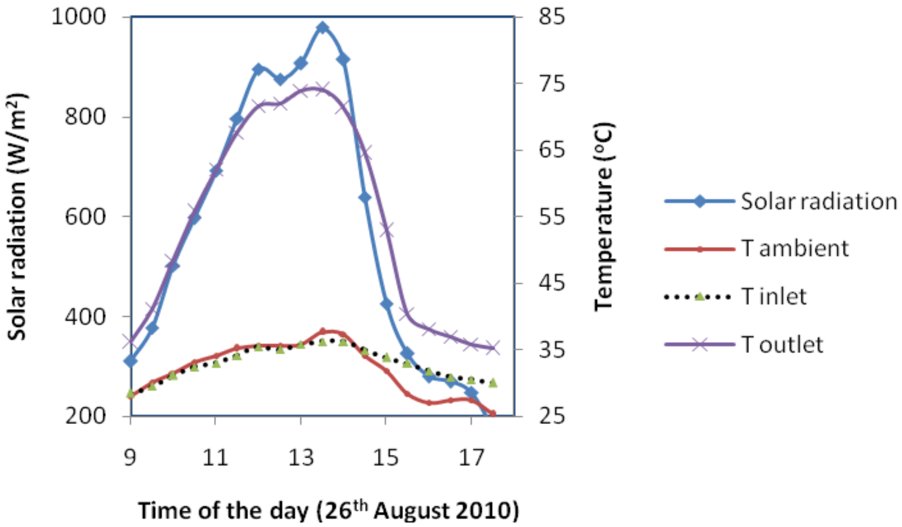

Figure 6. The solar radiation, ambient and inlet temperatures and the resulting outlet temperature for 26th August 2010.

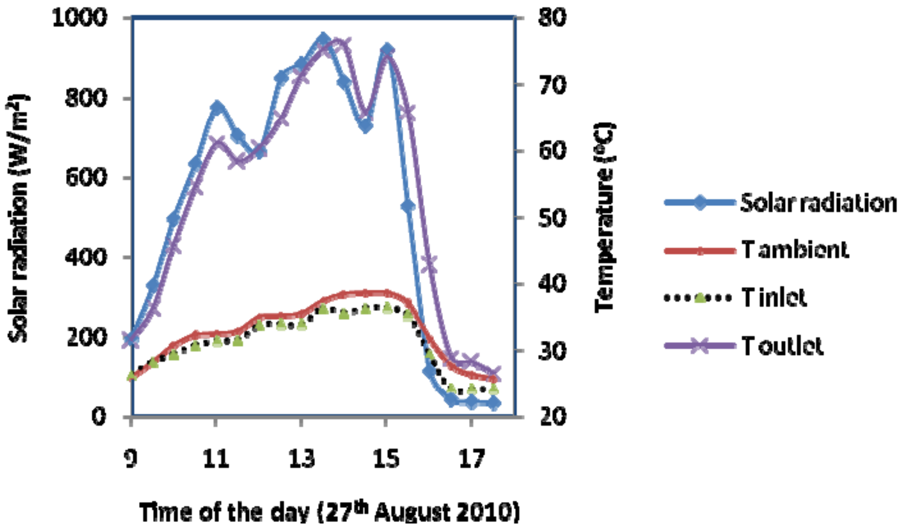

Figure 7. The solar radiation, ambient and inlet temperatures and the resulting outlet temperature for 27th August 2010.

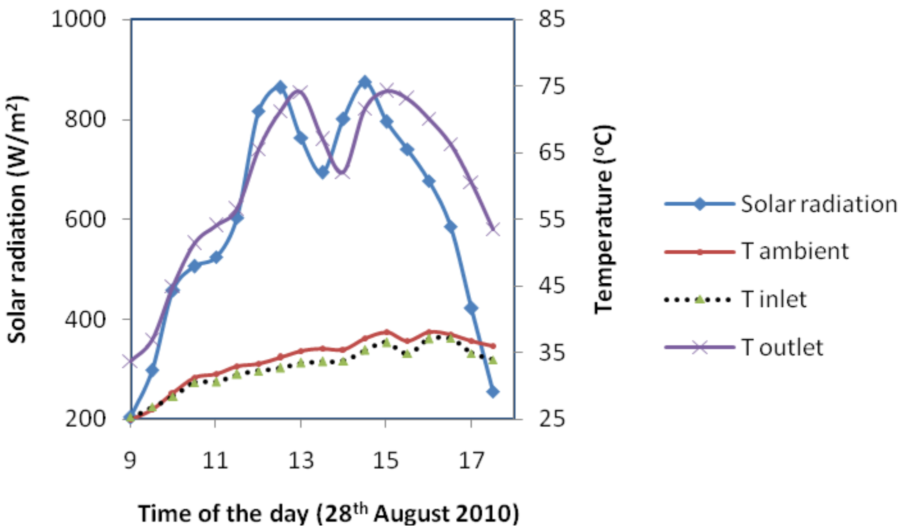

Figure 8. The solar radiation, ambient and inlet temperatures and the resulting outlet temperature for 28th August 2010.

Figure 9–13 shows the results of solar radiation and thermal efficiency of solar collector for the day. The average thermal efficiency of a solar collector varies from 25% to 37%. The higher thermal efficiency of a solar collector shows the result of the experiment for 27th August 2010. The fins acts as increase heat removal from first channel to the second channel and improved the overall efficiency of collector.

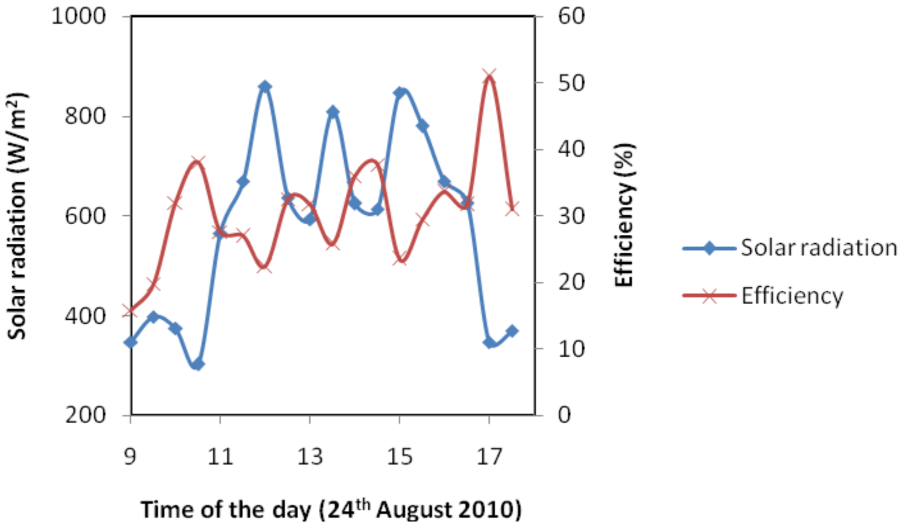

Figure 9. The solar radiation and thermal efficiency of solar collector for 24th August 2010.

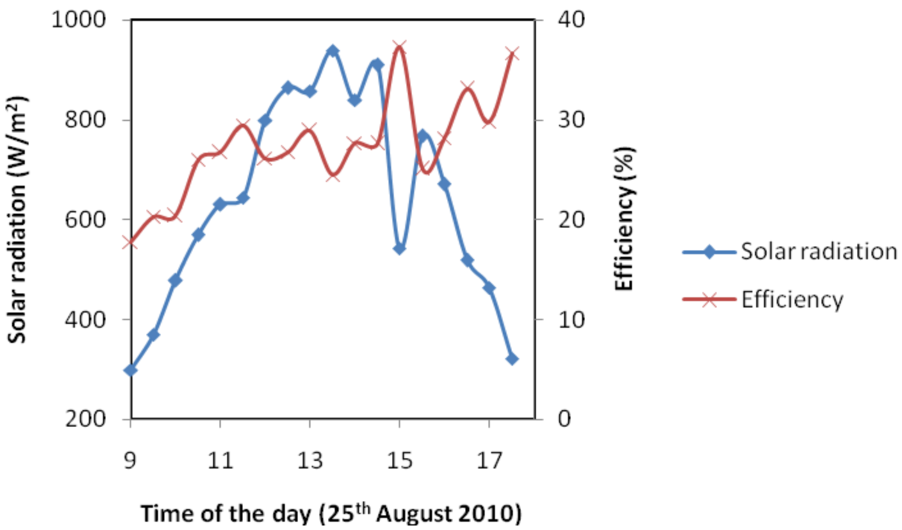

Figure 10. The solar radiation and thermal efficiency of solar collector for 25th August 2010.

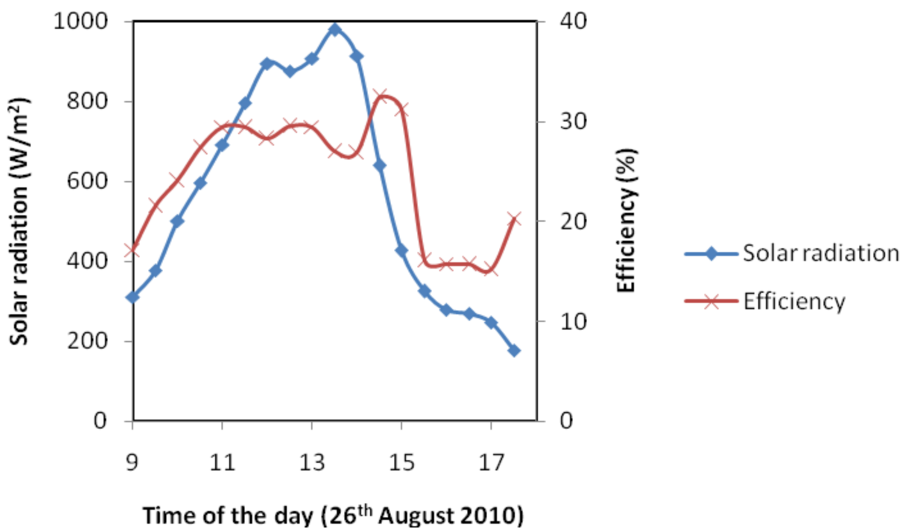

Figure 11. The solar radiation and thermal efficiency of solar collector for 26th August 2010.

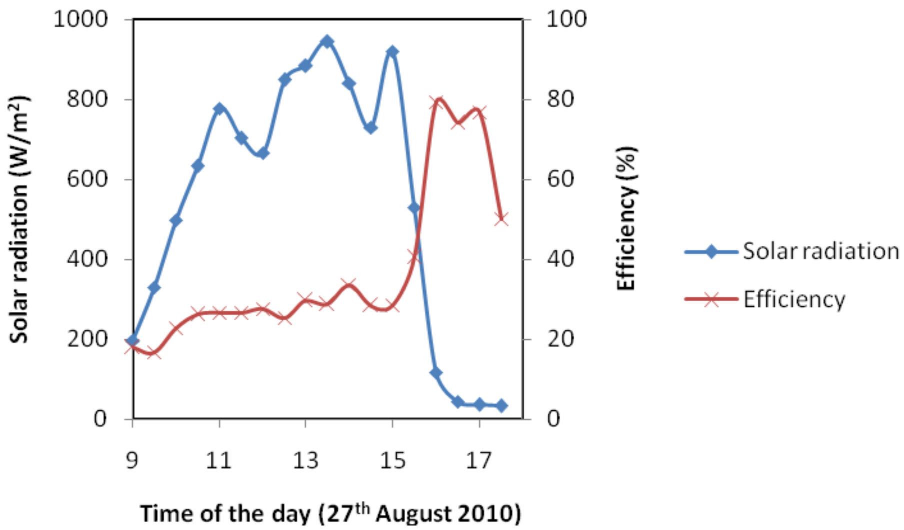

Figure 12. The solar radiation and thermal efficiency of solar collector for 27th August 2010.

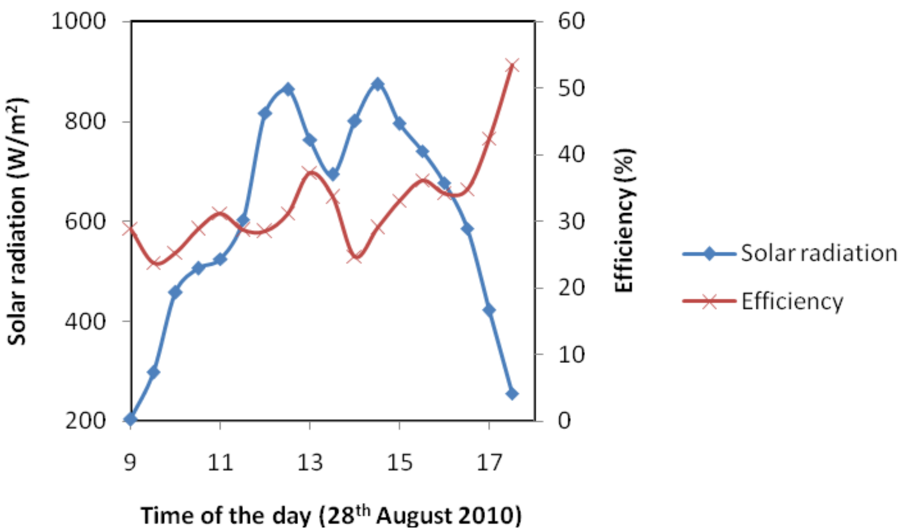

Figure 13. The solar radiation and thermal efficiency of solar collector for 28th August 2010.

5. Conclusions

The solar assisted drying system using the double-pass collector has been constructed and tested. The six collectors with a length of 4.80 m and width of 1.20 m is connected using internal manifold. Fins are added in the second channel of the collector. The fins acts as increase heat removal from first channel to the second channel and improved the overall efficiency of collector. Therefore, the higher and steady outlet temperature can be obtained even under intermitted solar radiation conditions. The outlet air temperature can reached 75 °C for average 800 W/m^2 and air flow rate of about 0.12 kg/s. The average thermal efficiency of a solar collector is 37%.

6. Acknowledgement

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