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Thermal evaluation of indirect type solar dryer using flat plate collector

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Abstract

Direct sun-drying has a slow drying rate and improper heating. Smallholders rely heavily on the sun because it is cheap and easy to dry post-harvest crops. This study aimed to evaluate thermally the dryer using a flat plate collector for use on a small scale. The test results show an increase in environmental temperature of 32.42%. This increased temperature is the temperature in the no-load drying chamber. The average ambient temperature is 32.26 (29.38-33.88 °C) with a solar intensity of 700.06 W/m^2 (422.2-833.4 W/m^2) increasing to 47.74 °C(38.25- 54.74 °C) in the drying chamber. By utilizing local materials for the design of indirect solar dryers, it is hoped that small farmers will be easy to operate and maintain. The dryer is designed in an efficient manner and adapted to the needs of small farmers in the post-harvest drying of foodstuffs.

Keywords: Solar Dryer; Collector; Flat Plate; Drying; Thermal

1. Introduction

The sun that shines throughout the year in tropical areas such as Indonesia becomes very important energy needed for postharvest. The most important post-harvest process is drying to extend the shelf life of the product. Small farmers are very dependent on the sun to dry their products because it is easy and cheap. Drying carried out by small farmers is direct sun drying. The product is dried in the sun in an open area. This method gives a relatively long time to produce dry products because the temperature is not optimal. To anticipate this, it is necessary to use an indirect sun drying method.

Indirect drying is carried out by converting solar energy into thermal. Solar energy is clean and freely available energy. The utilization of solar energy in an effective drying system has an impact on a fast return on investment [1]. The conversion of solar energy into thermal is generally used to dry agricultural products. Solar energy is converted into thermal using a device called a collector. The solar collector is the main device in a thermal solar system that functions to collect and absorb solar radiation. The working principle of a solar collector is that the absorber plate absorbs solar radiation and converts it into thermal. The utilization of solar collectors can increase the drying air temperature above the ambient temperature up to 60% for conventional dryers [2]. In order to function to dry a product, the solar collector is integrated with the drying chamber and is called an indirect solar dryer. According to [3] that the indirect type solar dryer is more efficient than the open sun drying. Indirect type solar dryer provides shorter time and quality product.

An indirect solar dryer generates hot air from the solar collector for drying in the drying chamber. The method can use natural convection or forced convection. Solar collectors in the form of flat plates or waves. In general, flat plate solar collectors produce hot air at low to moderate temperatures and are proven to be suitable for drying agricultural

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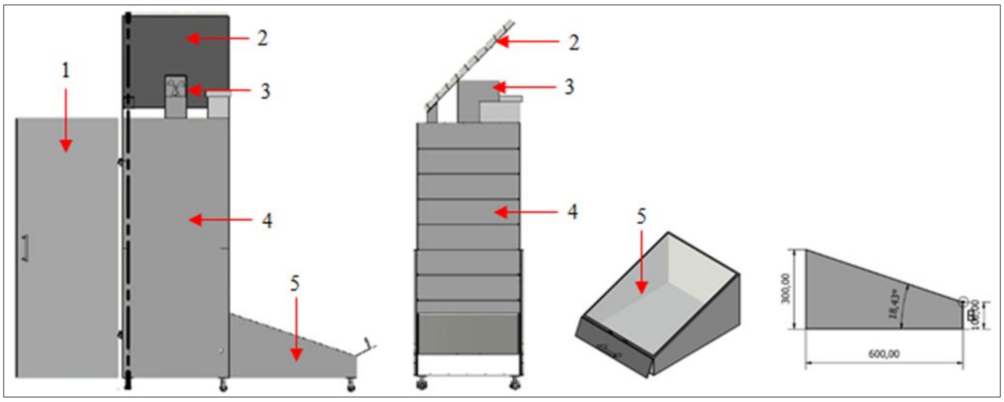
products [4]. Solar dryers with flat plate collectors with natural convection systems can reduce drying time by 34% compared to direct solar drying [5]. Flat plate solar collectors are most widely used in indirect solar drying for solar air heating [6]. The water heating test utilizes heat from a flat plate collector whose peak occurs at 14.00 [7]. An indirect solar dryer consisting of a solar collector and drying chamber as an alternative overcomes the disadvantages of open sun drying. Several drawbacks are related to the quality of the dried product due to the impact of environmental conditions such as dirt, dust, insects, animals, and rain which can re-wet the dried product [8, 9, 10]. Sun-drying creates an additional workload for workers, namely exposure to the sun's heat during drying [11]. Continuous exposure to heat causes an increase in the work pulse. Meanwhile, the use of indirect solar dryers is practical in terms of investment costs, hygiene, product quality improvement, and an environmentally friendly approach [12]. The indirect solar dryer with a convection system consists of a solar collector, drying unit, fan, air circulation duct and is a drying model that produces good quality products and eliminates the risk of discoloration [13, 14, 15].

Conditions in the Lombok-Indonesia area have sunshine throughout the year and most small farmers depend on the sun for post-harvest drying. To optimize solar energy in smallholder-scale drying, in this study a thermal test was carried out on the indirect type solar dryer design using a flat plate collector. From the test results, it is expected to obtain a temperature that is in accordance with the needs of small farmers for post-harvest drying.

2. Material and methods

Dryer design and testing as presented in Figures 1 and 2.



1. Drying chamber door, 2. Solar panel, 3. Exhaust fan, 4. Drying chamber, 5. Solar collector

Figure 1 Solar dryer design with flat plate collector

Figure 2 Research schematic

The research uses the main energy source of the sun. The sun's heat is absorbed by the flat plate collector which is painted black. The thickness of the flat plate is 2 mm and the glass is 3 mm. The solar collector is placed in a chamber equipped with a clear glass cover and environmental air inlet and hot air outlet. Hot air flows into the vertical drying chamber with a forced convection system. Forced convection by adding an exhaust fan to the exhaust duct of the drying chamber. The constant exhaust fan speed of 2 m/s and driving energy from solar panels and batteries as energy storage. The dimensions of the drying chamber are 50 cm x 50 cm x 140 cm from the aluminum plate and insulated using rubber with a thickness of 3 mm. Measurements were made on the intensity of the sun, ambient air temperature, flat plate, hot air, and drying room.

3. Results and discussion

The test results on indirect solar dryers using flat plate collectors are shown in Figures 3-6. Figure 3 shows the results of measurements of solar intensity which were carried out starting at 09.00 WITA until 15.00 WITA.

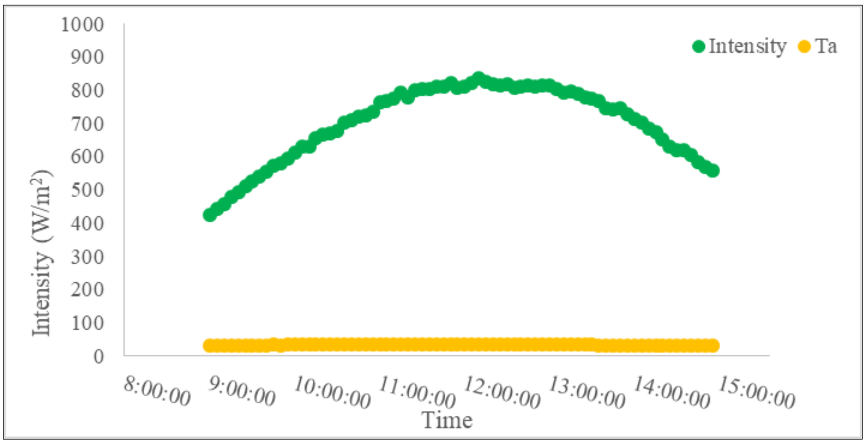


Figure 3 Comparison of solar intensity with ambient temperature (Ta)

The measurement results at 09.00 WITA it was found that the ambient temperature (Ta) was 29.38 °C and the solar intensity was 422.2 W/m². The peak of solar intensity occurred at 12.10 WITA at 833.4 W/m² with an ambient temperature (Ta) of 33.35 °C. On the other hand, the highest ambient temperature (Ta) occurred at 10.25 which is 33.88 °C. At the end of the test at 15.00 WITA, it was found that the intensity of the sun reached 555 W/m² with an ambient temperature (Ta) of 31.39 °C. Based on the average value, the solar intensity is 700.06 W/m² (422.2-833.4 W/m²), the ambient temperature (Ta) is 32.26°C (29.38-33.88 °C). The use of flat plate collectors can increase the ambient temperature as shown in Figure 4.

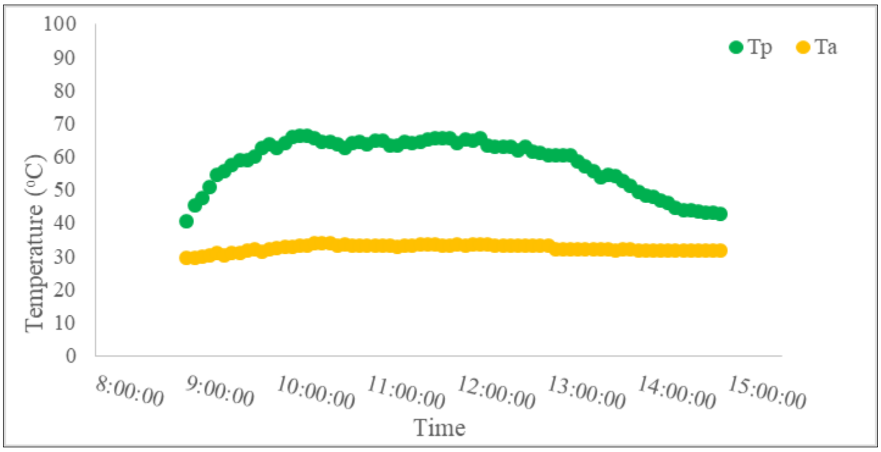


Figure 4 Comparison of flat plate temperature (Tp) with ambient temperature (Ta)

The results of measurements of the flat plate on the solar collector found that the ambient temperature increased by 79.82%, from an average of 32.26 °C (29.38-33.88 °C) to 58.014 °C (40.43-66.10 °C). This proves that flat plate collectors are suitable for weather conditions such as on the island of Lombok. The intensity of the sun is directly proportional to the temperature of the flat plate solar collector (Tp) as shown in Figure 5.

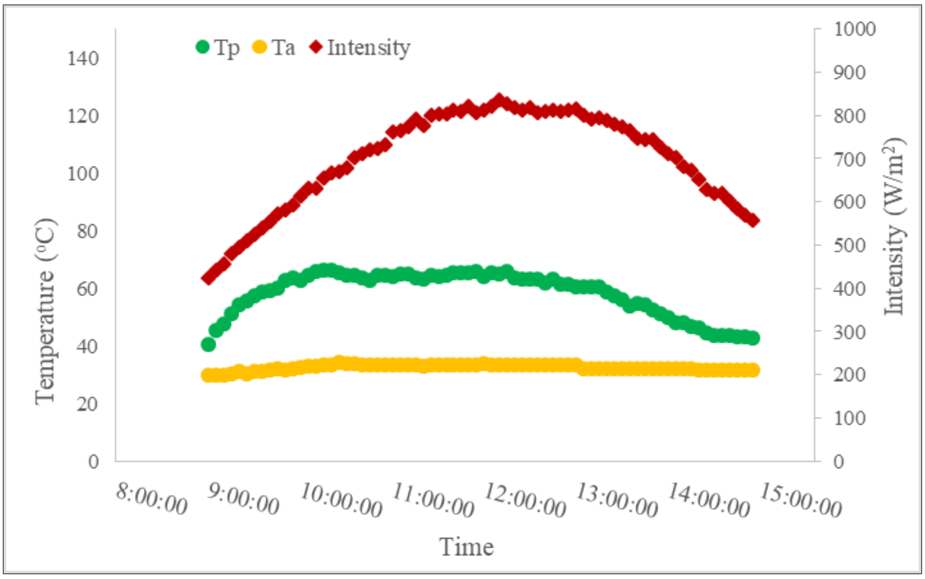


Figure 5 Comparison of intensity with ambient temperature (Ta) and flat plate temperature (Tp)

With a flat plate solar collectors are able to absorb the maximum intensity of the sun so as to increase the environmental temperature. The higher the intensity of the sun is followed by the higher the temperature of the flat plate on the solar collector. Flat plate collectors are used to generating hot air [5]. The increase in the flat plate temperature (Tp) affects the drying chamber temperature (Tdc) as shown in Figure 6. The use of flat plate solar collectors can increase the ambient temperature used for drying. The average drying room temperature (Tdc) is 47.74 °C (38.25-54.74 °C) and is higher than the average ambient temperature (Ta). There was an increase in drying chamber temperature (Tdc) of 32.42%. The temperature that occurs in the no-load drying chamber.

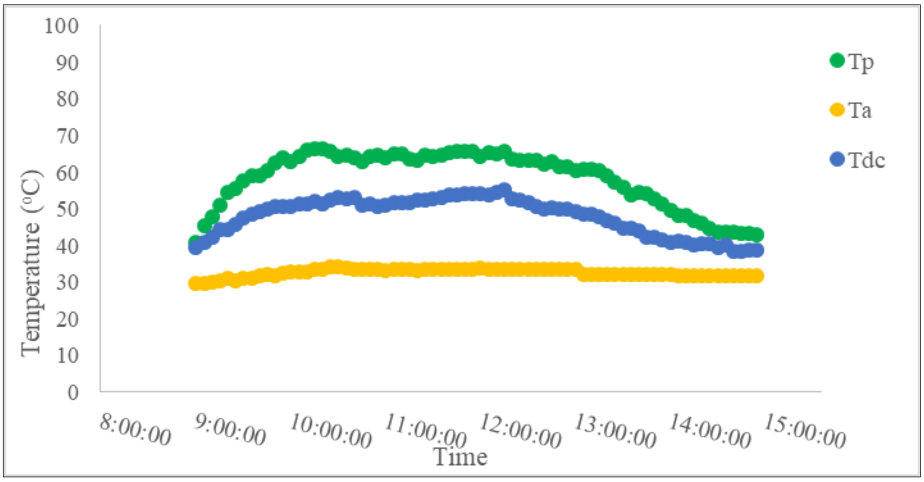


Figure 6 Comparison of drying chamber temperature (Tdc) with ambient temperature (Ta) and flat plate (Tp)

With the result that the drying chamber temperature increased significantly after using a flat plate solar collector, it has the potential to be applied to small farmers. Indirect solar dryers are urgently needed by small farmers to speed up the post-harvest drying process. Dryer with a small scale at an affordable price and easy to operate. In addition, the materials used in the design of the tool are easily available in the market and do not require high technology. Solar dryers are made from locally available materials and do not require high technology so maintenance costs are minimum [16]. Direct sunlight drying which has a slow drying rate can be replaced by dryers using flat plate solar collectors.

4. Conclusion

The utilization of a flat plate that is used as a collector to absorb solar heat can increase the ambient temperature significantly. Dryer design for smallholder scale that is easy to operate and maintain and at an affordable cost. Based on the thermal evaluation in this study, the average environmental temperature was 32.26 ^{o}C (29.38-33.88 ^{o}C) with a solar intensity of 700.06 W/m^{2} (422.2-833.4 W/m^{2}). The average flat plate temperature is 58.014 ^{o}C (40.43-66.10 ^{o}C). The average drying chamber temperature is 47.74 ^{o}C (38.25-54.74 ^{o}C). There was an increase in the temperature of the drying chamber by 32.42%. Drying chamber temperature with no drying load. With increasing drying temperature, the drying time is faster and heating is more optimal.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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