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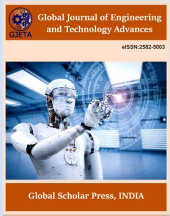

(RESEARCH ARTICLE)

Thermal study of wave plate applications for indirect method solar drying collectors

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Abstract

Cheap and easy direct solar drying is still practiced by small farmers who mostly live in rural areas. This method results in slow drying and improper heating due to sub-optimal temperatures. This only relies on the ambient temperature which has an average of 32.26oC with a range of 29.38-33.88oC. In addition, small farmers need appropriate tools at affordable prices and materials that are easy to obtain on the market. For this reason, the research was carried out by thermally studying an indirect type solar dryer using a corrugated plate collector made of zinc material. The test results show that the ambient temperature can be increased by 34.54%. This increase was measured in the drying chamber without load with an average temperature of 49.29oC with a range of 38.20-56.84oC. With this condition, it is hoped that it can be applied in the post-harvest drying process for small farmers. In addition, dryers designed with local materials and readily available on the market have received a positive response from small farmers to speed up the food drying process.

Keywords: Solar collector; Wave plate; Zinc; Indirect solar dryer; Thermal study

1. Introduction

The sun in equatorial regions such as Indonesia is very abundant, so many people use it for post-harvest preservation. The community preserves agricultural products through direct methods, namely drying in the solar. This is considered cheap and easy by the community as a result of the sun shining all year round. The process of drying agricultural products directly is a step to extend shelf life and is carried out throughout the day. This method still has weaknesses, including workers being exposed to sunlight which results in additional workloads and temperatures that are not optimal because they depend on ambient temperature. The alternative can be done through the indirect solar drying method.

The indirect method of utilizing the sun as a source of drying energy can be done through the design of a dryer with a solar collector. The solar collector is applied to absorb solar heat which functions to increase the ambient temperature which flows into the drying chamber. The drying air temperature can be increased by applying a solar collector which is up to 60% above the ambient temperature in conventional dryers [1]. The indirect solar drying method through a convection system includes fans, solar collectors, air circulation ducts, and drying units. This is a drying model that can eliminate the risk of discoloration and produce good-quality products [2, 3, 4]. The indirect solar drying method can be used as an alternative to overcome the disadvantages of direct solar drying. Drying directly in the foodstuffs in an open area is vulnerable to animal disturbance and exposure to dust and flies. Insects, animals, dirt, and dust are some of the environmental conditions which are the weaknesses of drying in the open which affects product quality [5, 6, 7]. In addition, direct solar drying puts workers at risk of continuous heat exposure and injury from working in the open and unnatural working postures. The pulse will increase due to continuous exposure to heat. This heat exposure also creates an additional workload for workers during the drying process [8]. The risk of muscle injury, fatigue, and increased rates

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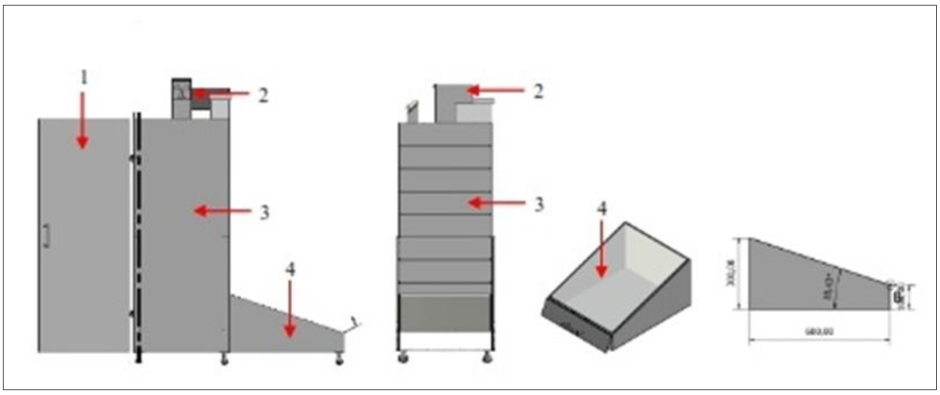
of musculoskeletal complaints, has implications for additional workloads and lower productivity, as well as expenditures for health and welfare as a result of unnatural work postures [9, 10, 11, 12]. Participation from the community, in this case, the user, is needed in the drying process to obtain appropriate and sustainable drying work tools. This principle is part of the application of ergonomics aimed at creating work with humans as the center, as well as reducing risks to occupational safety and health [13, 14]. Based on this, the solar drying process is optimized using the indirect method according to the needs and input of the user.

The indirect method through the application of a solar dryer is an approach that is environmentally friendly, improves product quality, and is practical in terms of investment costs [15]. One way is through the application of wave plates for solar drying collectors. Utilization of wave plates because they are easy to obtain by the public and widely circulated in the market. The collector plate is functioned to absorb sunlight to increase the temperature of the ambient air flowing in it. The higher the heat absorbed by the absorber plate the result of the higher the intensity which has an impact on increasing the temperature of the exit air [16]. One of the uses of abundant sunlight throughout the year in Lombok, Indonesia is for the drying process. As a sustainable and cheap energy source, people only use solar directly for the drying process. Drying only relies on ambient temperature, so we need a method so that the absorption of sunlight becomes optimal. Based on this, the research focuses on thermal testing of wave plate applications for solar collectors. The result is expected to obtain the temperature desired by the community for small-scale and continuous drying.

2. Material and methods

The research was conducted by utilizing solar energy sources through an indirect process, namely using a drying chamber and wave plate solar collectors. Wave plates use zinc material which is sold in the market so people can easily obtain this material. Dryer design and testing as shown in Figures 1 and 2.



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

Figure 1 Solar dryer design with wave plate collector

Figure 2 Research schematic

The solar collector consists of a surge plate, glass and a wall with a single passage of ambient airflow. The thickness of the clear glass is 3 mm and the corrugated plate (zinc) with dimensions 1.69 mm thick and 60 x 50 cm^2 in the area is painted black. Air is circulated by forced convection using an exhaust fan with a constant speed of 2 m/s using a battery as the driving force. Hot air from the solar collector flows into the vertical drying chamber. In the exhaust section of the drying chamber, an exhaust fan is added as a forced convection method. The drying chamber is made of aluminium with dimensions of 50 cm x 50 cm x 140 cm and is insulated using 3 mm thick rubber. Measurements were made of solar intensity, ambient air temperature, wave plate, hot air, and drying chamber.

3. Results and discussion

The indirect solar drying method by utilizing zinc as an absorber of sunlight in the collector can increase the ambient temperature. This can be shown by the increasing temperature of the drying chamber used in this study. Figure 3 to 5 presents the results of thermal testing of the application of wave plate solar collectors made of zinc.

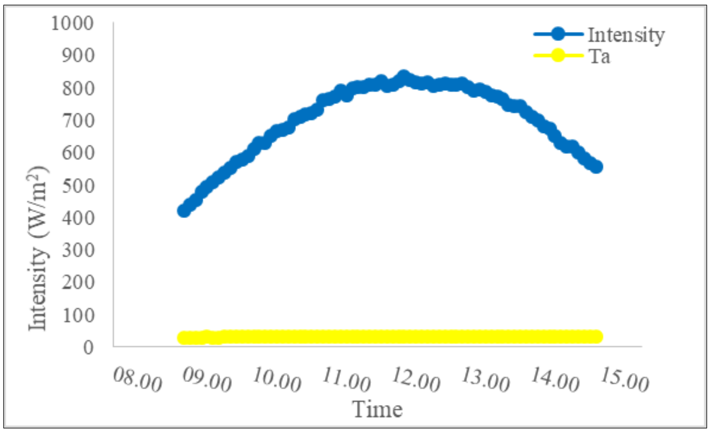


Figure 3 Comparison of ambient temperature (Ta) with solar intensity

Figure 3 shows the results of measuring the intensity of the sun starting at 09.00 and ending at 15.00. The solar intensity and ambient temperature (Ta) at 09.00 were found to be 422.2 W/m^2 and 29.38^{o}C respectively. The intensity of the sun reaches its peak at 12.10, which is 833.4 W/m^2 and the ambient temperature (Ta) is 33.35^{o}C. It was found that the intensity of the sun is directly proportional to the ambient temperature. The highest environmental temperature occurred at 10.25 at 33.88^{o}C. At 15.00, the end of the test, it was found that the ambient temperature (Ta) was 31.39oC with the intensity of the sun reaching 555 W/m^2. The average ambient temperature and solar intensity are respectively 32.26^{o}C with a range of 29.38-33.88^{o}C and 700.06 W/m^2 with a range of 422.2-833.4 W/m^2. The ambient temperature experienced an average increase of 95.87% after the use of wave plate solar collectors made of zinc material and painted black. This increase in temperature is measured on a corrugated or zinc plate. This condition can be seen in Figure 4.

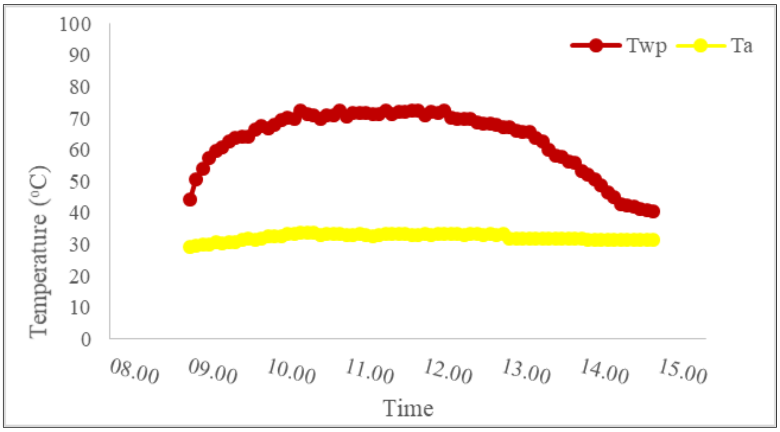


Figure 4 Comparison of ambient temperature (Ta) with wave plate/zinc temperature (Twp)

Increasing the temperature of the solar collector has an impact on increasing the temperature of the drying chamber. Tests carried out in the drying chamber by circulating hot air from the solar collector to the drying chamber found that there was an average temperature increase of 34.54%. The temperature distribution of the drying chamber is shown in Figure 5.

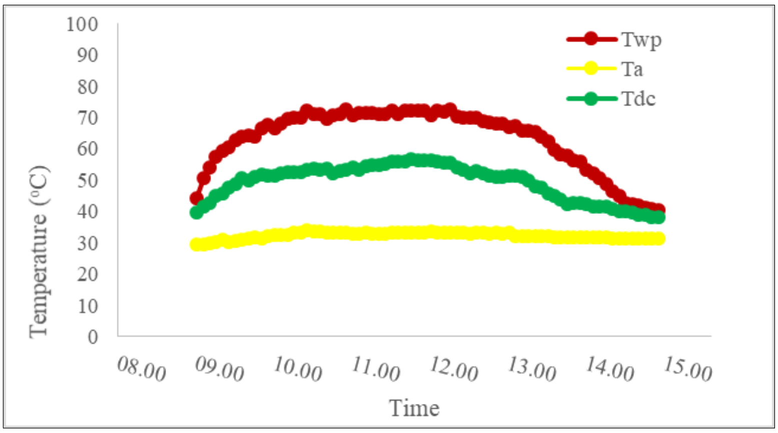


Figure 5 Comparison of ambient temperature (Ta), wave plate (Twp), and drying chamber (Tdc)

The temperature that occurs in the drying chamber (Tdc) without load is 49.29°C with a range of 38.20-56.84°C and higher than the average ambient temperature (Ta) of 32.26°C with a range of 29.38-33.88°C. This is influenced by the increase in temperature on the wave plate, which averages 63.19°C with a range of 40.30-72.54°C. When compared to the use of a flat plate solar collector, the corrugated plate solar collector made of zinc material produces a higher drying chamber temperature. This is based on previous studies using flat plate solar collectors and producing an average drying chamber temperature of 47.74°C [17]. The wave plate solar collector made of zinc material which is painted black can absorb the maximum intensity of the sun thereby increasing the ambient temperature. The wave plate temperature on the solar collector is getting higher as a result of increasing solar intensity. The application of solar collectors is to produce hot air [18]. Increasing the wave plate temperature (Twp) affects increasing the temperature of the drying chamber (Tdc).

The heat sink on the solar collector is made of zinc material which is easy to obtain on the market and has a great opportunity to be applied to smallholder drying. This is very much needed by small farmers after harvest to shorten the drying time. Indirect solar dryers can be used side by side with biomass dryers from rice husk waste energy. This is following research conducted by Alit and Bawa-Susana [19] that rice husk waste through the energy conversion process can increase the ambient temperature and is used to dry corn. A dryer for smallholder applications that are efficient, easy to operate, and affordable is urgently needed. In addition, materials for designing dryers are easy to obtain in the market and do not require high technology. Solar dryers for the community with minimum maintenance costs are done by utilizing locally available materials and do not require high technology [20]. A dryer with a corrugated plate solar collector made of zinc material for indirect solar drying can replace the direct solar drying process to shorten drying time.

4. Conclusion

The indirect method of solar drying through the application of corrugated plates made of zinc material to the collector can increase the ambient temperature to an average of 34.54% in the no-load drying chamber. The dryer is designed based on the capabilities of the users, namely small farmers. In this case, dryers are appropriate, easy to operate, and easy to obtain materials on the market, so they are affordable in terms of cost for small farmers. With the sun shining all year round, the thermal evaluation carried out obtained an average solar intensity of 700.06 W/m^2 with a range of 422.2-833.4 W/m^2. This is capable of producing temperatures on corrugated plates made of zinc material reaching an average of 63.19 °C with a range of 40.30-72.54 °C. This is obtained from the ambient temperature of an average of 32.26 °C with a range of 29.38-33.88 °C. A more optimal temperature was obtained in this study so that it has an impact on a more efficient drying time.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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