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Performance analysis of solar photovoltaic thermal (PV/T) dryer for drying moringa leaf

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Abstract: Though its considerable solar energy potential prevents equal distribution throughout the region, Indonesia has not made the best use of it, particularly when it comes to integrated drying and electrical technologies. There are a number of drawbacks to traditional direct drying, particularly with regard to food goods. These include the possibility of contamination, discolouration, and animal disturbance. The purpose of this research is to develop, build, and evaluate an integrated drying technology—a solar photovoltaic thermal (PV/T) dryer—that can generate heat and electricity at the same time. The dried material used in this dryer is moringa leaves. This study employs an experimental design methodology, first developing and building a greenhouse-style PV/T dryer with three levels of shelves. Second, a test of the tool's functionality was conducted using 1000 grams of material on each shelf. Measuring devices such digital thermocouples, multimeters, solar power meters, and humidity meters are utilized to get test parameter data. The average daily solar intensity, according to the research findings, is 436.60 watts/m^2. Shelf 1, which is next to the collector outlet, had the highest average temperature (53.9 °C), whereas shelf 3 had the lowest average temperature (37.1 °C). With an average voltage of 30.89 volts and an average current of 4.08 amperes, solar panels generate an average power of 85.65 watts. In the meantime, the material's mass decreased after drying for nine hours, on average by 72%, according to the drying data. With an average power of 86.65 watts, an average temperature on the third shelf between 37.1 °C and 40.6 °C, and an average mass reduction of 72%, it can also be stated that this PV/T dryer is quite successful for drying.

Keywords: PV/T; moringa; solar dryer

1. INTRODUCTION

Indonesia possesses a considerable amount of potential for new and renewable energy, particularly solar energy, which can reach 3,200 Gigawatts. There is potential for solar power plants (PLTS) with an average power of up to 4 kWh/m^2 in almost every region of Indonesia [1]. To fulfill government initiatives linked to Net Zero Emission 2050, solar energy consumption must be further developed. Solar energy heat is typically used to dry agricultural and fisheries products in addition to producing power. Open drying has a number of drawbacks, including the possibility for product degradation from dust, animal disturbance, and unexpected rain. Developing a drying technique that can simultaneously produce heat and electricity is essential to solving the issues of electrical energy and drying agricultural products. Agricultural products can be dried most effectively with photovoltaic thermal (PV/T) drying technology, especially in rural locations [2]. The goal of this project is to design and create a PV/T drier that can be used to dry moringa. The plant known as moringa, or Moringa oleifera, offers a variety of nutritious properties that are good for human health. According to earlier studies, solar dryers achieve higher temperatures—80°C—while solar dryers with natural circulation only reach 60°C [4]. Similarly, solar dryers with natural circulation have an efficiency of about 10-15%, but those with artificial circulation can achieve 50–60% efficiency. In terms of controlling drying parameters, other researchers came to the same conclusion: solar dryers with artificial circulation are preferable to those with natural circulation [5], [6][7]. Artificially circulating solar dryers need electricity. Because of this, the research will create a solar dryer that combines solar panels, a technology known as photovoltaic thermal (PV/T). Heat and electricity can both be produced at the same time by this PV/T dryer. Additionally, it is anticipated that this tool for drying moringa will be more hygienic, able to preserve the content's quality and avoid color changes in the dried material.

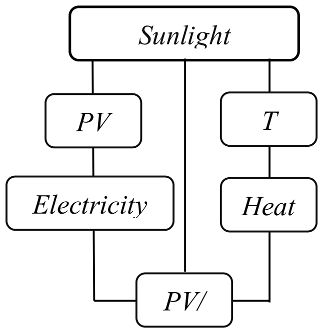

Figure 1. PV/T Scheme

A dryer with solar panels attached to it allows for the simultaneous production of heat and power, known as a PV/T (Photovoltaic Thermal) dryer [8]. More than 80% of solar radiation will be absorbed by a solar panel, but only 20% of that energy can be turned into electricity [4]. The residual heat energy received by the solar panels will raise their temperature and may result in a reduction in the efficiency of the electrical energy they generate [9]. This combo design, as seen in the side view image, can lower the solar panels' temperature and use the heat generated for drying, heating, and other purposes. Researchers from several nations have created PV/T dryers in a variety of forms and designs. Creating greenhouse-style PV/T through experimental and numerical research [5]. The findings showed that the actual and theoretical thermal energy values were 2.03 kW and 1.92 kW, respectively. The quality of the dried material samples is an additional benefit as it might lessen the material's color fading. The theoretical and experimental results correspond with r = 0.98 and e = 10.76. PV/T drier featuring a second pass collector and fins added as extra absorbers. Experiments and mathematical models were used in the investigation. The findings highlight how crucial it is to use fins as an integral component of the absorber surface in order to maximize the thermal and electrical efficiency of the PV/T dryer output [10]. A study on the performance analysis of a no-load PV/T solar dryer in Padang City, West Sumatra, has also been carried out by the author in the meantime. The created PV/T dryer is greenhouse-style, with the drying chamber and collector integrated. The outcomes demonstrate that this instrument performs admirably in both sunny and gloomy situations. On tray number one, the temperature can reach its maximum [11]. Quantitative and experimental hybrid PV/T vertical dryer. Fins have also been added to the vertical collector to improve heat transfer to the absorber. According to their research's findings, vertical PV/T collectors with fins have thermal efficiency values between 47.46 and 54.86% and 50.25 and 58.16%, respectively [12]. Comparing the effects of drying cassava slices in the sun versus using a PV/T solar dryer. In terms of physical and chemical composition, cassava dried with a PV/T dryer has a higher quality than cassava dried in the sun, according to the findings of structural, morphological, and proximate composition analysis. They came to the conclusion that PV/T dryers can boost the economic worth of drying products by producing them to high standards suitable for export [13]. Next, using a 60-watt spot heating lamp, Bina Age and Awang Surya tested the effectiveness of a solar energy drier for drying bananas. The findings demonstrate that in an average of 3 hours 32 minutes, the device can dry bananas to a water level of less than 40% [14]. The interesting aspect of this study is the way the author created a PV/T dryer with tiered shelves inside and a collector integrated into the drying chamber. The dryer will have two fans for air circulation that run on installed solar panels for power. Then, a light steel frame will be utilized in terms of frame material. The goal is to provide materials that are more mobile when carried or built in the field, stronger but lighter, and easier to install. Researchers in Indonesia are currently only very loosely exploring the potential benefits of PV/T dryers, despite the technology's enormous potential—particularly for drying marine fisheries and agricultural products. The purpose of this study is to develop and evaluate the functionality of a solar photovoltaic thermal (PV/T) dryer using dried moringa leaves or moringa as a component of beverages made with moringa tea.

2. METHOD

As shown in Figure 1, this study was conducted in multiple phases, beginning with the design, manufacturing, testing, and data gathering and analysis of the PV/T. There are multiple steps involved in creating a PV/T dryer: gathering equipment and materials, drilling, cutting, connecting to assembly, and finishing. Testing the PV/T drier to dry Moringa leaf material is the next step. Several procedures are run in this test, including a). Gather supplies or specimens of Moringa leaves off the tree, then cut the leaves from the stem. After that, it is weighed, uniformly distributed into one kilogram of drying trays, and placed inside the drying cabinet. b). The measuring instruments required for testing are then set up using the test plan, as shown Figure 2.

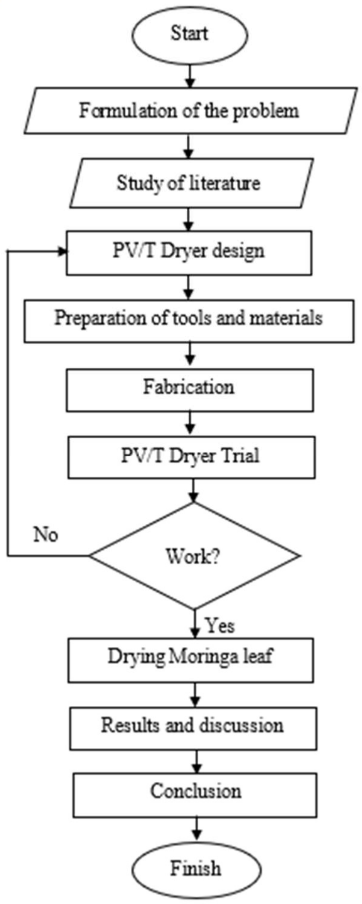

Figure 2. Flowchart of research

The parameters observed and measuring instruments used in this research are as follows:

1) Solar Radiation (G), measured using a solar power meter (watt/m^2) and its variation with time during drying;
2) Temperature (T), the measured temperature includes ambient temperature ($T\infty$), collector air temperature (T. Collector), solar panel temperature (T. Panel), air temperature on the tray (T. tray 1, T. tray 2, T. tray 3), and measured using a thermocouple with an output of °C;
3) Relative air humidity (RH), ambient air humidity, and drying room outlet humidity as measured by a humidity meter (%);
4) Current (I) and voltage (V) output of the solar panel, measured using a digital multitester (amperes and voltage);
5) Changes in mass of ingredients, weighed once every 1 hour, using a digital scale with an accuracy of up to 5 grams.

On the grounds of the Unihaz campus in Bengkulu City, testing will take place. The Moringa leaves are tested from 8:00 AM to 7:00 PM, or until they are completely dry. Data recording and collecting will occur once every hour. After that, to ensure that the sample material of moringa leaves dries evenly, it will be turned back and forth every hour. Figure 3, the PV/T washer is displayed. Figure 4 to get a better idea of how this test methodology is implemented. Next, apply the following equation to determine the material's water:

$$Water\ content = \frac{\text{Final weight}}{\text{Original weight}} \times 100\% \quad (1)$$

Then to calculate the output power of the solar panel, use the formula:

$$P = V \times I \quad (2)$$

Where: P = Power (watt); V = Voltage (volt); I = Current (ampere)

Figure 3. PV/T solar dryer

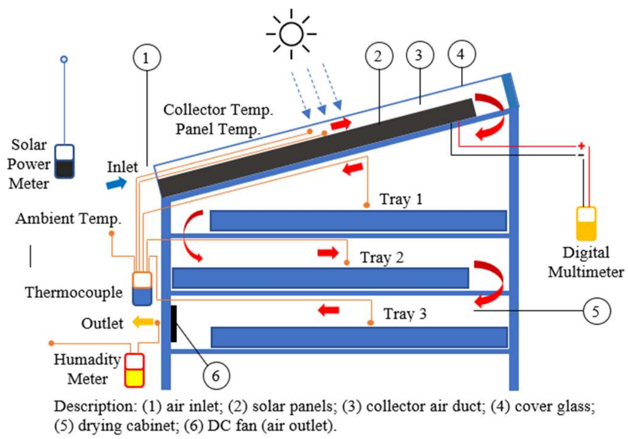

Figure 4. PV/T dryer test scheme

3. RESULTS AND DISCUSSION

Tests conducted in sunny weather on a solar photovoltaic thermal (PV/T) drier for drying moringa reveal a correlation between variations in solar radiation and the temperature inside the dryer and the surrounding air. Figure 5 illustrates that the average ambient temperature is 28.1°C and the average solar radiation is 436.60 watts/m^2. The maximum sun radiation of 703.37 watts/m^2 was recorded at 12:00 PM. The average temperature of the solar panel was found to be 45.1°C, the average temperature of the collector was found to be 41.9°C, the average temperature of tray 1 was 40.6°C, tray 2 was 38.4°C, and tray 3 was 37.1°C based on the temperature readings at different points on the dryer, as depicted in Figure 6. This demonstrates how variations in temperature within the drying cabinet occur in response to an increase in solar energy. Figure 7 in the meantime, a downward trend from tray 1 to tray 3 is visible when comparing the temperature on the panel and collector with the temperatures on trays 1, 2, and 3. Still, only a one to two-degree variation in temperature exists. This demonstrates that drying Moringa leaves with a dryer can be successful. Because tray 1 is positioned very next to the collector output air, its temperature is higher than the other trays' temperatures. This means that variations in solar radiation are followed by variations in delta T temperature at different locations in the dryer.

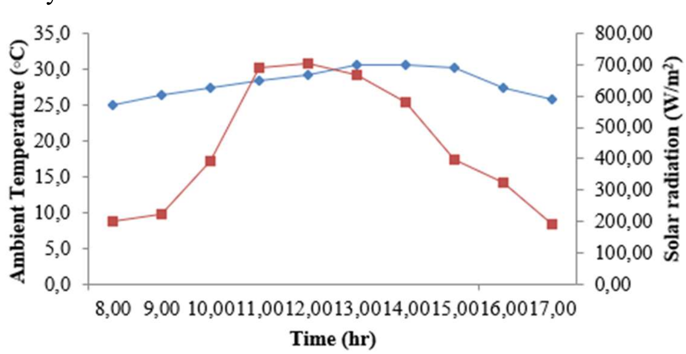

Figure 5. Ambient temperature fluctuations with solar radiation

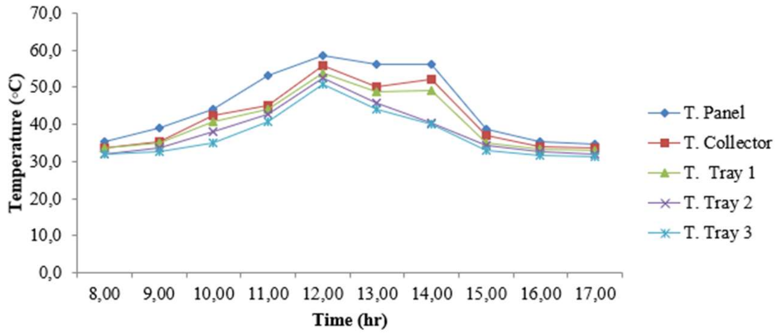

Figure 6. Relationship between solar radiation and panel temperature, collector temperature, temperature of trays 1, 2, and 3

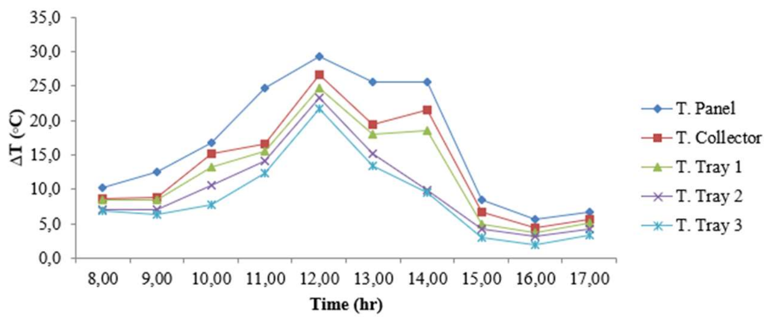

Figure 7. The value of the increase in panel temperature, collector temperature, and temperature of trays 1, 2, and 3.

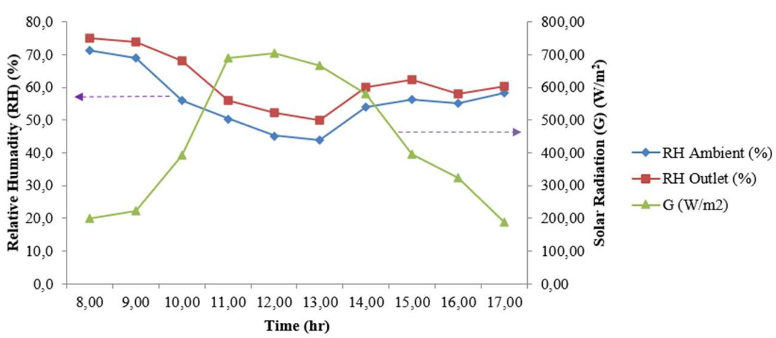

Figure 8. Relationship between solar radiation and ambient humidity and PV/T dryer outlet

The humidity profiles of the surrounding air and the air exiting the drying room that are linked to solar radiation are displayed in Figure 8. The findings demonstrate that variations in solar radiation also affect the air's relative humidity. Air humidity is one of the factors that affects drying. Figure 8 shows that the drying room outlet air humidity is 61.6% and the average ambient air humidity is 55.9%. The larger drying chamber's air humidity exit indicates that the dried Moringa leaf material inside has evaporated.

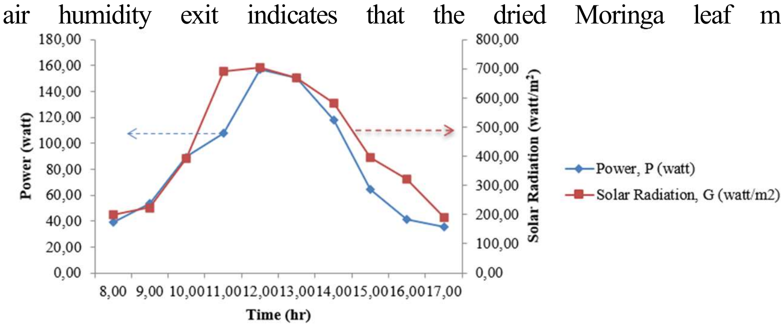

Figure 9. The relationship between solar radiation and solar panel output power

Next, an average power of 85.65 watts with an average voltage of 30.89 volts and an average current of 4.08 amperes was collected from the solar panels' output. The solar panels produced a maximum power value of 156.57 watts at 2:00 PM and a minimum power of 35.78 watts at 7:00 PM. This demonstrates that the power output of the photovoltaic system is directly correlated with the amount of radiation that the solar panel receives, [15]. The power generated by the solar panels demonstrates that this photovoltaic thermal sun dryer collector is capable of producing electrical energy in addition to thermal energy. Only two DC fan units are being powered by the generated electricity for the drying room outlet. Of course, this power can be utilized in the future for various purposes, such as charging batteries for nighttime lights.

Moreover, excellent results were obtained from drying Moringa leaves that had been in the drying room. The profile of the mass loss of the dried moringa material on each plate over time is displayed in Figure 10. After 9 hours of drying, the ultimate weight of tray 1 was 265 grams, tray 2 was 276 grams, and tray 3 was 300 grams, based on a mass of 1000 grams of moringa per tray. This demonstrates that the material mass loss on average was 72%. Outstanding results while drying things like leaves.

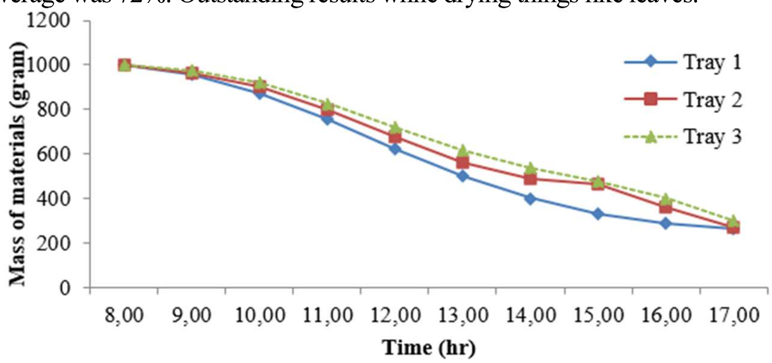

Figure 10. The rate of decrease in the mass of a material concerning time

3 CONCLUSION

In light of the research findings, it can be said that solar radiation fluctuates between 199.02 W/m^2 and 703.37 W/m^2 at 12.00 PM, while the ambient temperature is between 25°C and 30.6°C. The drying room temperature and solar panel output power are subject to variations in solar radiation. The maximum power of the panels is 156.57 watts at 1:00 PM, with a beginning power of 39.37 watts. Tray 1 had the highest average drying room temperature, 40.6°C, followed by trays 2 and 3, which had the lowest and 38.4°C and 37.1°C, respectively. In the same way, after eight hours, the three drying trays with Moringa leaves demonstrated an average mass reduction of 72.1%. Because of its good performance, this PV/T dryer is useful for drying a variety of agricultural and fisheries products, particularly in remote locations or on plantations without access to electricity.

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