Performance analysis of an improved solar dryer with hybrid system

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Abstract. This study describes the development of a solar dryer system by using the hybrid photovoltaic solar dryer. The study also compares the conventional solar dryer collector system and the solar dryer hybrid system. Measurements under the same conditions of temperature, humidity, solar radiation, and moisture ratio were performed for both systems. The results showed that drying by using the hybrid solar dryer collector system is 10% faster than by using conventional solar dryer system. The result of current study is beneficial to increase the drying performance of the solar dryer on the future.

1. Introduction
The use of solar energy in drying is becoming an important and viable alternative since it decreases the consumption of conventional energy. In many parts of the world, awareness on renewable energy has an important role to play in improved technologies in developing countries like Indonesia, to increase their productivities. The solar drying system helps to get over the disadvantage of open sun drying. Especially, Indonesia is a tropical country that has average temperature of 27-30 °C and humidity of 50-70% [1]. Many benefits in utilizing the solar radiation for drying, for instance, the drying time can be shortened by about 65% compared to the open sun drying [2], solar dryer increases the farmer commodity to a superior quality. It produces more colorful product compared to the open sun drying [3].

Solar dryer has been studied in existing works [4-6]. Many literatures developed the solar drying systems for the purpose of improving the performance of the system. Lyes Bennamoun [7] reported that thermal energy storage can shorten the time required in drying process. The storage absorbs the surplus of energy during high radiation. Alqadry et al [8] studies the effect of desiccant CaCl2 for solar dryer. In his study, the desiccant CaCl2 can maintain the humidity of the drying box during the evaluation. Purnomo and Indarti [9] modified the solar dryer by using double collector dryer. It compared the system to the conventional single collector dryer.

This work tried to integrate photovoltaic with the solar collector for improving the drying performances and referred to as a hybrid system. Besides drying purpose, this method decreases global warming impact and mitigates the environmental pollution by reducing the use of fossil fuel.
Photovoltaic is a friendly and renewable energy source that can contribute significantly to sustainable development.

In this case, the commodity object to be dried is the ginger. The solar dryer hybrid system was designed, and its performance was measured and compared to the conventional solar collector dryer. Moisture content, weight, blower velocity, the voltage of photovoltaic was discussed.

2. Solution Method

2.1. Climatic data collection
The experimental was done at College of Engineering, Universitas Sumatera Utara, Medan with location of 3°34’ North and 98°40’ East, Indonesia.

2.2. Materials
The raw material used in this study is red ginger, they were taken from Medan, Sumatera Utara. Total 1 kg of red ginger are divided into two solar dryer systems. The choice of red ginger because they are most widely consumed for healthy. After they are washed, gingers were sliced with 2 mm of thickness.

2.3. Hybrid solar collector system
The dimensions of the solar collectors are 1.50 m x 1.0 m. Conventional solar collector consisted of a transparent cover, absorber plate, and insulation while the solar collector hybrid system consisted of a transparent cover, absorber plate, insulation, blower (fan), and photovoltaic. The cover collector used a two-layer transparent cover with a 5 mm thick clear glass and supported by 17 cm profile aluminium as a frame. The absorber plate is fixed below 100 mm of the first glass cover. Both collector tilt had 30 degree. In addition, three pieces of photovoltaic modules were used for activating the blower with capacity 10 WP per pieces as depicted in Figure 1.

2.4. Experimental procedure
The experiments were performed to compare drying performances of the conventional solar dryer system and the hybrid solar dryer system for red ginger. Peeled red ginger was cut into 2-3 mm slices and then placed them on the drying trays in the dryer. Each dryer tray has 0.4 kg weigh of fresh red ginger. Before starting the experiment, the whole apparatus was operated for at least 1 hour to stabilize the air temperature and the air velocity in the dryer.

Figure 1. The schematic diagram of the complete experimental setup
2.5. Measurements
Throughout the drying process, moisture content was calculated by weight difference at time interval 30 minute. Reducing the moisture content was recorded by measuring weight during the drying process. The moisture content was calculated on dry bases as follows:

Initial moisture content,

\[ M_o = \frac{W_o - W_d}{W_d} \]  \hspace{1cm} (1)

Final moisture content,

\[ M_f = \frac{W_{wet} - W_d}{W_d} \]  \hspace{1cm} (2)

At time interval, the moisture content \( M_t \) of red ginger on wet bases is expressed as:

\[ M_t = \frac{W_i - W_d}{W_t} \]  \hspace{1cm} (3)

The PV system is considered as a source of electricity to operate the DC fan, hence the total energy consumed by the fan is taken as input source of energy. The power output (\( P_{output} \), W) of PV module is given by:

\[ P_{output} = V_{oc} \times I_{sc} \]  \hspace{1cm} (4)

3. Results and discussion

3.1. PV Performance
Since the performance of hybrid solar dryer system is quite different from the conventional solar dryer system. Results indicated that photovoltaic power output and module temperature were directly proportional to insulation and ambient temperature. The specifications of photovoltaic were showed in Table 1.
### Table 1. PV module specification

| Model No | VISERO-10WP |
|-----------|-------------|
| Polycrystalline | 10 WP |
| Rated Maximum Power ($P_{\text{max}}$) | 17.5 V |
| Voltage at Maximum Power ($V_{\text{mp}}$) | 0.571 A |
| Current at Maximum Power ($I_{\text{mp}}$) | 21 V |
| Open Circuit Voltage ($V_{\text{oc}}$) | 0.66 A |
| Short Circuit Current ($I_{\text{sc}}$) | 1000 |

#### 3.2. Experimental drying rate

The hybrid solar dryer system and conventional solar dryer collector system were tested, and the ginger was the tested commodity. In this research, PV is utilized to generate electricity to operate the blower. The radiation becomes one of the main factors to determine drying performance. It determines the hybrid solar dryer collector to work optimally. The solar radiations were recorded by using HOBO.

![Radiation record by using HOBO Ware during experiment](image)

**Figure 3.** Radiation record by using HOBO Ware during experiment

During the drying period, the average of solar radiation was 268.40 W/m², and the highest global solar radiation was 533.1 W/m² at 14.50 WIB.
The drying temperature and humidity varied depending upon the solar radiation. Figure 4 and Figure 5 showed the comparisons of the temperature and humidity on the dryer boxes of hybrid solar dryer collector and conventional solar dryer collector. The average of temperature and humidity on conventional dryer box were 43.35 °C and 42.6% subsequently, while the average of temperature and humidity on hybrid dryer box were 50.05 °C and 35.9%.

The most significant difference of conventional and hybrid solar dryer collector systems was the humidity on both systems. With the hybrid system the humidity decreased up to 15 % lower than conventional system. Figure 3 shows that the temperature and humidity on hybrid system are more stable than on conventional system. Effect of the radiation, ambient temperature (as inlet temperature collector) and wind velocity made the temperature and humidity on box solar dryer fluctuated overtime.
Figure 6 shows the moisture decrement rates for both systems overtime. Final drying is at moisture content of 10 % from 81 %. Effect of the blower from hybrid solar dryer shortened the drying time. The required drying time of hybrid system is 10% shorter than conventional system. The moisture content of the red ginger decreased earlier in the drying process as the effect of convective force in hybrid solar dryer system.

4. Conclusions
The solar dryer of flat plate collector was constructed in this research. The drying performances were measured through experiments. The measurement compares the drying performances between conventional and hybrid solar dryer systems. The use of photovoltaic system as additional energy to activate blower to generate force convection make s the drying process occurred faster. With the hybrid system, the humidity on the solar dryer box decreased about 15 %. The result of current study is beneficial to increase the drying performance of the solar dryer in the future.

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