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## Design Modification of Greenhouse Effect Solar-Hybrid Rack Type Dryer

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# Design Modification of Greenhouse Effect Solar-Hybrid Rack Type Dryer

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**Abstract.** Hybrid solar-type rack dryers are modified to improve efficiency and to save the drying energy. Modifications are made to the main components, namely; furnace and heat exchanger. The dimension of dryer was 1.8 m length, 0.7 m width and 1.8 m high. The dryer was equipped by 22 racks with dimension of 0.5 m x 0.65m. The furnace was modified to a cylindrical shape instead of rectangular shape and was designed with optimization of heat utilization and comfortable to be operated. To reduce heat loss, the wall of furnace was designed contact directly the drying room. The furnace material was iron galvanized plate with a thickness of 2 mm. The foregoing design of heat exchanger was tube bank type with horizontal fins attached on tubes. In this research, the adoption of vertical fins has enlarged the heat transfer area and increase the effectiveness of heat exchanger. The smoke flow from the combustion chamber of furnace was directed at the opposite side of the ambient air inlet for drying, so that smoke does not enter the drying chamber.

## 1. Introduction

Drying of agricultural product have an important role for products preservation and make it easier for further processing, as applied to the process of making sweet potato flour. The hygienic drying process is a necessity in the sweet potato processing industry. Mechanical dryers can overcome these problems, due to the dryers can be used all the time, both day and night, when the sun is clear or cloudy, even during the rainy season, so that the continuity of production can be maintained. Hybrid solar dryer become the alternatif dryer for the need.

This research proceed of a double rack type greenhouse effect (GHE) solar dryer that has been investigated previously [1]. In order to reduce the consumption levels of drying energy, several modifications were conducted appropriate to the drying needs of sweet potatoes in small household industries. The purpose of this study is to modify the GHE solar dryer, especially in the size of the drying capacity, solar energy conversion system, heat exchanger, a small portion of the furnace and rack placement.

## 2. Method

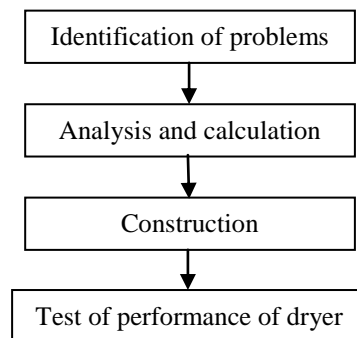
### 2.1. Material and apparatus

The apparatus used in the study consisted of workshop tools, such as electric welding, iron cutting tools, ect. While the materials needed were iron plates, iron pipes, hollow iron, aluminum perforate, wood, fans, electrical equipment, tool kits etc. The product dried was slice sweet potato.



## 2.2. Procedure

Research follows the stages as shown in Figure 1.



**Figure 1.** Research steps

## 3. Results

### 3.1. Hybrid solar dryer before the modification

Figure 2 showed the hybrid solar dryer designed in previous research [1]. The dryer utilized solar energy and biomass energy for drying of herbal product, such as roselle [1], “temu lawak” or wild ginger [2], slice of modified cassava [3]. Dimension of dryer is 4.4 m length, 1.8 m width and 3 m high. The dryer consist of:

1. Racks as product holder: There are 144 trays with dimension of 0.5 m x 0.6 m. The distance between trays is 0.12 m. The capacity of dryer is 400 kg of roselle pod or 200 kg of ginger slice.
2. Inlet: Ambient air is intake through the inlet. There are three inlets with diameter of 0.2 m which located on the center of dryer
3. Outlet: The outlet is use to stream out the vapor evaporated from the product. There are two rectangular outlets of 0.2 m x 0.3 m on the right and left side of dryer, respectively.
4. Blower: Three blowers are implemented in inlet position with a power of 80 W each.
5. Furnace: It have trapezoidal configuration and made of 2 mm thick iron plate. The furnace is equipped with the iron rod grille for placing the firewood.
6. Heat exchanger (HE): HE is consist of several vertical pipes (0.25 m diameter, 2 m length). There are two heat exchanger system; the first is air-air HE system and the second is water-air HE system. The first used combustion air, whilst the second utilized hot water from solar concentrator.
7. Chimney: It is the prolongation of heat exchanger that have a function for releasing the smoke produced from the combustion chamber of furnace
8. Solar concentrator: Pair of solar concentrator were placed on the top of dryer to collect solar radiation in the black absorber pipe to heat the water. Solar tracking is powered by 1 Hp motor. Solar tracking is controlled by light dependent resistor. The water is circulated entire the pipe (from absorber pipe to heat exchanger pipe) by two pumps motor (1/4 Hp).
9. Water tank: It used as water container made of cyllindrical iron (2 mm thick).

The problems have been identified from the several experiments of the dryer with agricultural products could be summarized below.

- 1) The dryer need the high power for solar tracking. The solar tracking is absolute requirement for solar concentrator to capture the maximum solar radiation.
- 2) The energy consumption to evaporate the water vapor from the drying product is high of 29 MJ/kg of vapor until 57 MJ/kg of vapor [2], due to the high of heat loss through the furnace wall and the heat exchanger didn't yet transfered heat optimally.



**Figure 2.** The dryer before modification [2]

### *3.2. The dryer after modification appropriated with the need of slice of sweet potato drying*

The dryer is modified to dried wet slice of sweet potato. The dimension of dryer is  $L \times W \times H = 1.8 \text{ m} \times 0.7 \text{ m} \times 1.8 \text{ m}$ , in order to obtain the dryer capacity of 100 kg of sweet potato slice. The structure of dryer modified is illustrated in Figure 3.

Below is the components and material of dryer modified:

1. Rack: The racks consist of 24 trays with dimension of  $0.7 \text{ m} \times 0.5 \text{ m}$ . The interval among the trays is  $0.1 \text{ m}$ . The drying room and racks is designed adjacent to the furnace wall, in order to make use of heat loss from the furnace wall,.
2. Inlet: One rectangular inlet is designed which placed on the opposite position with the inlet of furnace, so the smoke flow entered to the inlet could be avoided. Dimension of inlet is  $0.6 \text{ m}$  and  $0.15 \text{ m}$ . This inlet position make it possible to intake ambient air and flow it through the HE pipe longer than previous design.
3. Outlet: There are no change of outlet design.
4. Blower: There are three blower (12 W) implemented on the left and right of HE wall respectively. Temperature of drying room more uniform than previous design.
5. Furnace: Cillindrical furnace is designed consist of iron plate  $2 \text{ mm}$  and  $0.80 \text{ m}$  of diameter. The grilles is mounted for placing the firewood. The cillindrical shape could flowing combustion air easily in to HE pipe. Furnace is equipped with cover and handle for safety and to easily operated.
6. Heat exchanger: There is one system of air-air HE. The HE is crossflow type, where combustion air enter the HE pipe, while the ambient air flow across the outer wall of the pipes. The vertical fins is attached along the outer pipe to increase heat transfer area.
7. Chimney: No significant change of chimney design.
8. Drying room: Drying room is function as solar collector. Solar irradiation is transmitted by tansparent wall of dryer. The dryer floor and HE wall performe the function of absorber.



**Figure 3.** Dryer modified

### *3.3. Heat transfer analysis of furnace*

The previous design of furnace [1] have a trapezoidal shape without cover. Rahari [4] have modified a cylindrical furnace from an iron plate (3.2 mm thick). The furnace system efficiency was 27 %. In this research, design modification of furnace applied Rahari's cylindrical furnace design. The material of furnace is iron plate (2 mm thick) which is used to reduce weight of furnace. The position of furnace in dryer system is unity with dryer floor and adjacent to drying room to take advantage of heat loss from furnace wall. The efficiency of furnace system modified is 45 %.

### *3.4. Design modification of heat exchanger*

Heat exchanger is the important component of dryer to facilitate the exchange of heat between combustion air which contain smoke at high temperatures while keeping it from mixing with drying air at lower temperature, so the dried product is free from smoke.

The modification of HE in this study was carried out on the shape, dimensions and addition of fins. The number of fins, the position and the dimension in the HE pipe were simulated and compared to get the best results. HE performance with the addition of fins is expressed by the value of fin efficiency and the effectiveness of fins and the amount of heat that HE can transfer. This analysis has been submitted in a separate paper [3]. Wulandani and Arnanda [3] have added horizontal fins on the pipe wall of HE. The design have decreased energy consumption until 43 % compared to the previous design [1], however HE effectiveness still low of 4.0.

Modification have been carried out at current research was by added vertical fins along the vertical pipe to enhance heat transfer area. Based on the 10 design scenarios of HE heat transfer simulation, it was found that the best design for vertical fin shape was with 26 pipes, 3.5 cm pipe diameter, 1 m pipe length. The number of vertical fins is 64 pieces, with dimensions of 2.5 cm wide, 1 m long and 1.2 mm thick. The heat transferred by HE is 6.8 kW, with fin effectiveness of 4.9. This result is greater than that of the horizontal fin shape.

### *3.5. Drying performance*

The dryer have been tested for drying slice of sweet potato of 50 kg for 16 hours. The average fresh sweet potato water content was 69.9% bb and dry sweet potato sawut water content was 10.2% bb. Table 1 shows performance data from the results of drying of sweet potatoes slice. Dryers have an average thermal efficiency of 40%, and a drying system efficiency of 15% and energy consumption of 17 MJ / kg of vapor. The value shows drying performance improvement compared to the previous dryer [1]; [2]; [3].

**Table 1.** Drying performance of GHE hybrid solar dryer

NO	Parameters	1	2	3	4
1	Product	Roselle	Wild ginger	Modified cassava chip	Sweet potato
2	Capacity (kg)	32	60	18	50
3	Initial moisture content (% wb)	89	81.3	70	69.9
4	Final moisture content (% wb)	12	8.5	12.6	10.2
5	Drying time (hour)	28	30.5	11.5	16
6	Drying temperature (°C)	43	41.8	43.5	53.7
7	Thermal efficiency (%)	14	14.5	24.8	40.1
8	Drying efficiency (%)	3.5	8.5	9.4	15.2
9	Energy consumption (MJ/kg vapor)	55	28.6	28	17.0

Note:

1. Wulandani and Nelwan, 2009 [1]
2. Elsamila and Wulandani, 2014 [2]
3. Wulandani and Arnanda, 2016 [3]
4. This research

#### 4. Conclusion

Design modification of hybrid solar dryer have resulted better performance of drying compared to previous design. System efficiency of furnace is 45 %. This value increase 1.6 times comparing to that of previous design. Modification of heat exchanger have enlarge the heat transfer area by adding the vertical fins. Fin effectiveness is obtained of 4.9, greater than the horizontal fins.

The slice of sweet potato with a capacity of 50 kg with initial moisture content of 70% wb was dried to the final moisture content of 10% wb for 16 hour. Drying energy is supplied by solar energy and biomass during drying process simultaneously. The energy consumption is 17 MJ/kg vapor. The dryer modified have reduced energy consumed significantly about 69 % comparing to previous dryer. The drying system efficiency is 15.2 % increased about four times comparing to that of previous dryer design.

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