Experiemental study on solar dryer with extended flat plate collector

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Abstract. These study relates to coffee dryers sourced from solar energy, the main objective of these experiements are make solar drying tools more effective, save time, and get good quality coffee beans, so that they can be received by the community. The parameters that are used in this combustion are temperature, rh, sun intensity, weight, and Mr. the results obtained are that the temperature can vary between 40-60^{o}C, with a maximum rh is 5%, weighing 4.291 kg, and finally getting the drying rate. The main conclusion are these temperatures are very suitable for drying coffee beans, the higher the intensity of solar radiation will reduce the drying Moisture ratio and can be reduce of mass coffee.

1. Introduction

Indonesia is located in the equator, which is at 6^{o}LU - 11^{o}LS and 95^{o}BT - 141^{o}BT, so that it has a large source of solar energy and the shinshine is relatively longer. The national average solar energy potential is 16 MJ / day with temperature is 35 °C [1]. The sun is the largest available carbon-free energy resource for human being. Many investigations have been conducted to learn how to harvest and apply solar energy as a primary source of energy [2]. To take advantage of these potential, one of them is on drying, especially on agricultural products. In agricultural products in the form of granules such as peanuts, coffee, rice and others the drying process plays an important role in its preservation. The drying process aims to reduce the water content to certain limits, so as not to cause damage due to metabolic activities by microorganisms [3]. Drying helps in reducing the moisture content to a level below which deteriorationdoes not occur and the product can be stored for a definite period [4].

The traditional method of solar drying in the Asia-Pacific region is by open air drying where the product to be dried is exposed directly to the sun. Having visited a number of countries, Ong studied the numerous designs available for solar drying in this region. Three types of solar dryers considered by Ong as having the best potential for development in Asia-Pacific region, namely, natural convection cabinet type solar dryer, the forced convection indirect solar dryer and the greenhouse type solar dryer [5]. Drying of coffee beans can be done using a dryer or by conventional means. However, the conventional method has many disadvantages because it produces low quality products, prone to contamination with impurities, requires a long drying time, according to weather requirements, and requires extensive land [6].

These problem can be overcome by using a dryer. Dryers must have the ability to dry products that are safe and of good quality [7]. Therefore, the feasibility of solar energy can be added by using solar energy technology, one of which is by using a flat plate collector dryer, these tool can increase the temperature of 40-60 ^{o}C during the daytime. These work aims to

design coffee dryer used to reduce Moisture content of levels coffee, so that can be reduce mass of coffee.

2. Solution Method

2.1. Sample Preperation

Coffee fruit were collected from Berastagi regency of North Sumatra Province of Indonesia. Before drying, soak the fresh coffee for one night. The coffee Beans placed in drying room with has three batch, every batch has 3 kg coffee Beans with initial moist content varies from 65% to 75%.

2.2. Method

KnowingThese solar dryer has been fabricated and used in experiments as shown in Figure 1. It consists of three main components: the box dryer with dimension 113cm x 113 cm x 120 cm, the drying chamber made of perforated aluminum sheet an area of 100 cm x 100 cm; and there are two solar collector with dimension are 113 cm x113 cm with the other side have angle of 20^{o}. A chimney-dependent solar dryer combined with an inclined roofdrying chamber was designed by [8] in order to improveventilation in the solar dryer, the addition of a chimney was believed toimpproved the ventilation in the dryer and also the drying rate of the cropalthough this assumption was proven wrong from the sensitivity analysis ofbuoyancy effect [9].

The basic function of a solardryer is to rise the vapor pressure of moisture found inside the product and increase moisturecarrying capacity of the drying air by decreasing its relative humidity [10]. During solar drying,warm air captures moisture from the dried product [11]. Drying system efficiency takes into account the weight of moisture evaporated from the product and the energy input to the drying system during the drying time. However, the efficiency of a dryer is often reported individually as collector efficiency, pick-up efficiency, and drying efficiency. Collector efficiency is a common measure of collector performance generally ranging between 40 to 60% for flat plate collectors [12].

As a note, drying is a simultaneous heat and mass transfer process and is followed by evaporation. The drying process can be driven by temperature difference and/or concentration difference. Alower vapor concentration of drying air above the surface can provide drying process, even though the temperature of the object is relatively low.

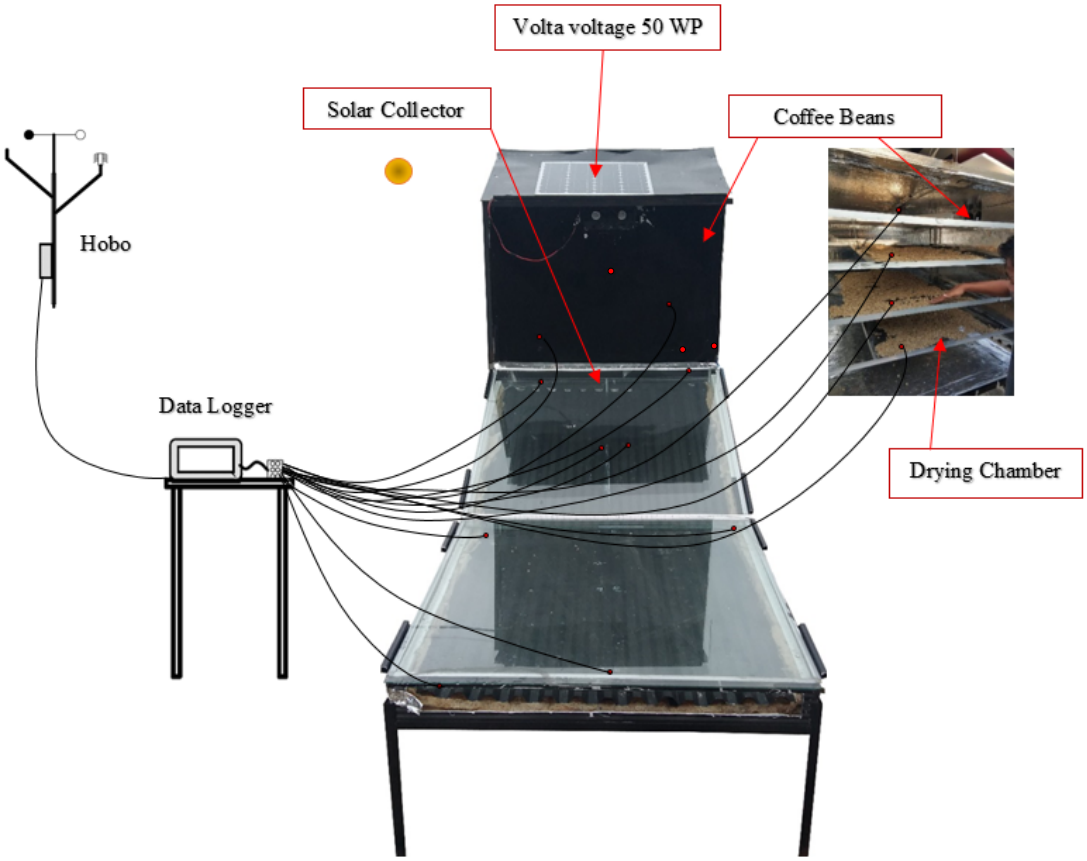


Figure 1. Experiemental of solar dryer

The solar dryer was operated in the daytime, the coffee beans is dried inside the drying chamber by usinghot air resulted by the solar collector. The parameters of these work are temperatures, mass of the coffee beans, relative humidity, wind velocity, and solar radiation were recorded every minute. Thermocouples of J type with an accuracy of 0.4% were used to measure temperatures. An Agilent 3497A data acquisition system with a 20 Channel multiplexer was used to record measurements. To measure the humidity inside the drying chamber, 2 USB Temperature Humidity Logger were used. The mass of measured using a load cell weight system data logger with an accuracy of 0.01 kg. A HOBO micro station data logger was used to measure the weather conditions. They are ambient temperature, RH, solar radiation, and wind velocity.

2.3. Drying effectiveness

The final moisture content of the material is the ultimate goal of the drying process, the final moisture content will determine the length of the drying process the drying time is defined as the total time needed from the beginning until the equilibrium is reached.

$$M = \frac{(W_t - W_d)}{W_t} \times 100\% \quad (1)$$

The energy received by solar collectors comes from solar radiation:

$$Q_r = F'(IA\tau\alpha) - Q_l \quad (2)$$

Where F" is the factor efficiency of the collector that is assumed 0.9 and *I, A, τ, α,* solar intensity [W/m^2], solar collector area [m^2], transmittance, and absorption coefficient, respectively. The total heat loses from the collector is calculated by the following equation

$$\dot{Q}_1 = \dot{Q}_w + \dot{Q}_b + \dot{Q}_t \quad (3)$$

Where $\dot{Q}_w$[W], $\dot{Q}_b$ [W], $\dot{Q}_t$[W] are the heat loses from the wall, bottom, and the top of the solar collector, respectively. The heatloss from the wall and the bottom of the collector are calculated using the following equations, respectively:

$$\dot{Q}_w = U_w A_w \, (T_p - T_\infty) \quad (4)$$

$$\dot{Q}_b = U_b A_b \, (T_p - T_\infty) \quad (5)$$

Here U_w[W/M^2 K] and U_b[W/M^2 K] are overall heat transfer coefficient of wall and bottom of the solar collector, respectively. They are calculated using the thermal resistant and anology as depicted in while, the heat loses from the top of the collector is determined using the following equation:

$$\dot{Q}_t = U_t A_t \, (T_p - T_\infty) \quad (6)$$

Where Ut [W/m2 K] is overall heat transfer coefficient from the top of the double glasses cover.

2.4. Drying effectiveness

Drying characteristics of the cocoa beans will be discussed in the form of moist content versus time curve. Non-dimensional moisture content (MR) was used and defined as:

$$MR = \frac{(M - M_e)}{M_i - M_e} \quad (7)$$

Where M, Me, and Mi are moisture content at t time, moisture content at equilibrium, and moisture content at initial condition, respectively. In this study, the cocoa bean is assumed as asphere with radius of r [m]. The local moisture content *(M)* can be written as the following governing equation:

$$\frac{\partial \mathrm{M}}{\partial \mathrm{t}} = D_{eff} \frac{\partial^2 M}{\partial \mathrm{r}^2} + \frac{2}{\mathrm{r}} \frac{\partial \mathrm{M}}{\partial \mathrm{r}} \quad (8)$$

Where D_{eff} [m^2/s] is an effective diffusivity. This parameter is a coefficient form ass transfer of the water with in the object. The phase of water includes liquid and vapor.

3. Results and Discussion

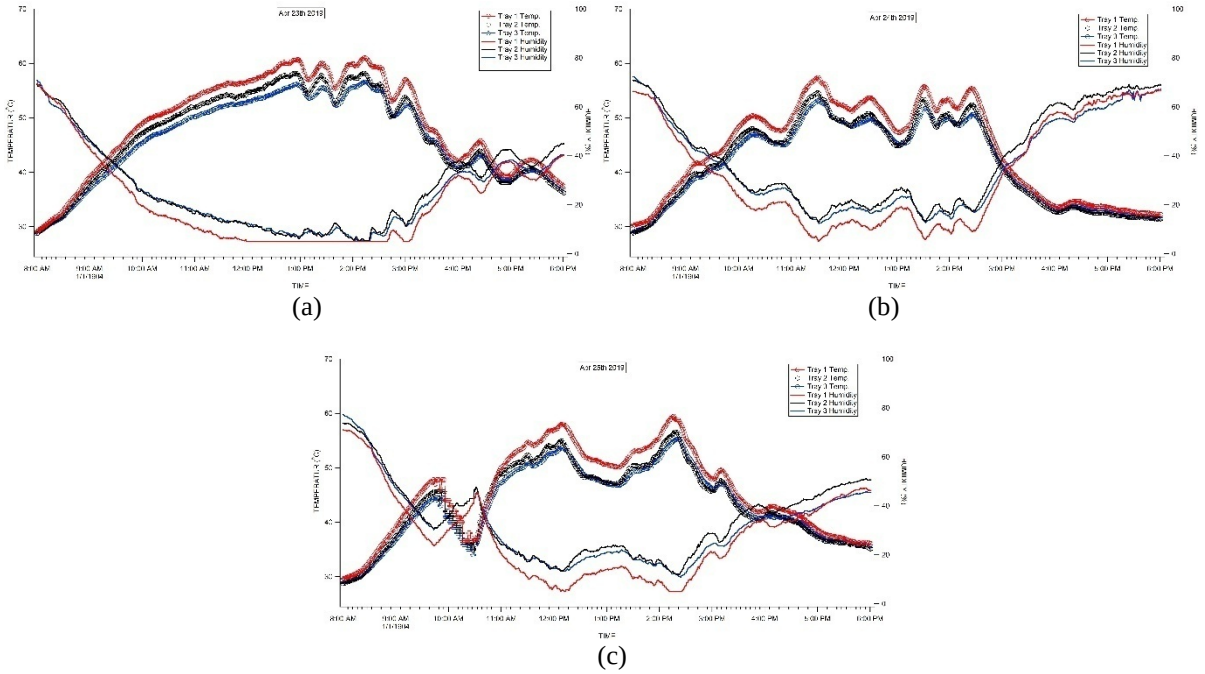
These drying had been carried out during 23 April–25 April 2019 in Medan city, Thi drying uses coffee as commodities with duration is carried out for three days with drying time at 7.00 am-18.00 pm. And the drying process is terminated if equilibrium is reached. The results for each group are presented in the section below.

3.1 Conditions dryer

The Condition of these dryer only sunrise. The drying parameters such as Temperature and humidity in the drying chamber and ambient air, solar radiation, and moisture ratio history of the coffee beans will be discussed:

3.2Temperature and Humidity

In these part will be show temperature and humadity (RH) with duration three days



(a) (b)

(c)

Figure 2. Chamber of temperature and humidity at 23 April(a), 24 April(b), 25 April 2019(c)

This Fig. 2 Showed of the temperature and humadity from day 1 to day 3 and. These results were taken from the best day of experiement, so the best results of these Experiement at the first day, the consideration because of the weather.These Drying divided by 3 trays, tray 1 the minimum temperature start 29.1^{o}C at the time 8.00 am and maximum temperature 60.9 ^{o}C at the time 14.15 pm, with humadity (RH) 69.5 % at the time 8.00 am and maximum 5% at the time 12.00 pm to 14.39 pm (a). Tray 2 the temperature start 28.7^{o}C at the time 8.00 am and maximum temperature 58.2 ^{o}C at the time 14.16 pm, with humadity (RH) 69 % at the time 8.00 am and maximum 5.2% at the time 12.54 pm (b). Tray 3 the temperature start28.8^{o}C at the time 8.00 am and maximum temperature 56.6^{o}C at the time 14.16 pm, with humadity (RH) 70.8 % at the time 8.00 am and maximum 5% at the time 14.15 pm (c).

3.3 Mass and Intensity

In these part will be show Mass and Intensity, and these is the comparison number of solar radiation between mass of coffee beans, if solar radiation is increse it will be reduce the weight of coffee beans, as shown below:

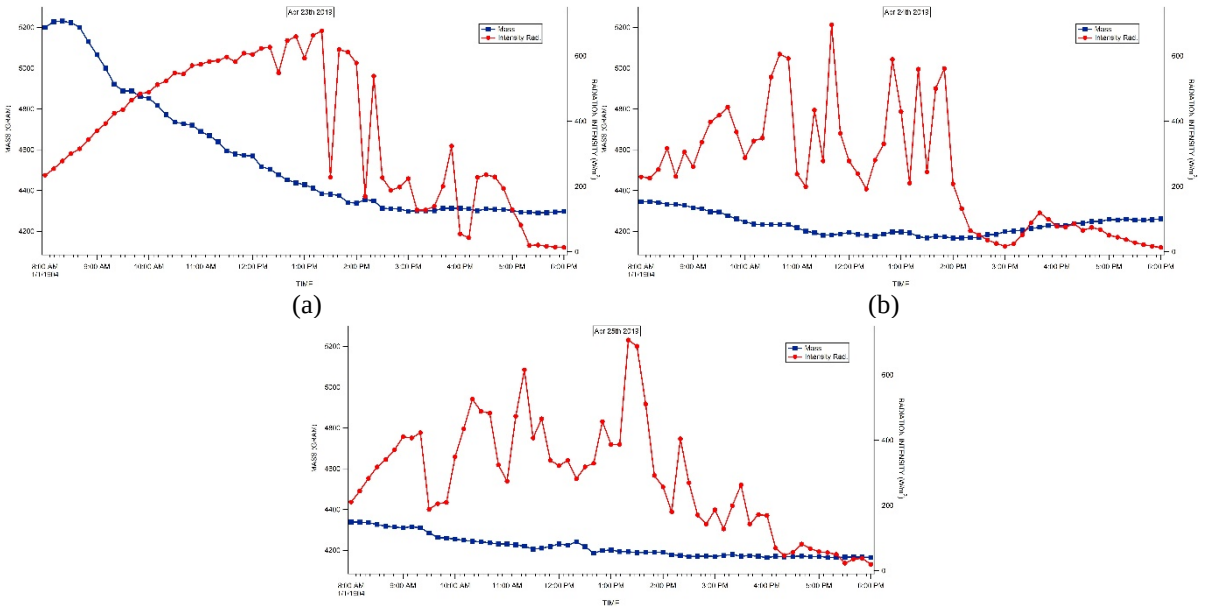


Figure 3. Comparisson between Mass and Intensity of radiation at 23 April (a), 24 April (b), 25 April 2019 (c)

This Fig. 3 showed of the Intensity of radiation and Mass of coffee Beans, the minimum Intensity of radiation occur 234.4 W/m^2 at the time 8.00 am and maximum Intensity of radiation 688.1 W/m^2 at the time 13.18 pm, with Massa from 5.112 kg at the time 8.00 am and can be reduce maximum 4.291 kg at the time 17.21 pm (a)

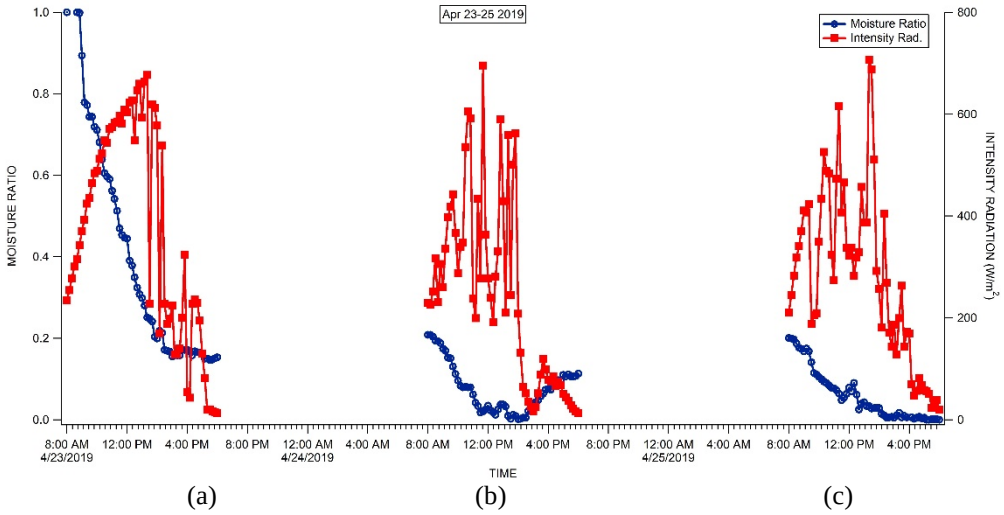


Figure 4. Comparisson between Moisture Ratio (MR) and Intensity of radiation at 23 April (a), 24 April (b), 25 April 2019 (c)

From figure showed Comparisson between Moisture Ratio (MR) and Intensity of radiation, from first day 0.14991 at the time 17.00 pm, second day 0.001207 at the time 14.00

pm, third day 0 at the time 17.10 pm. The results of drying in these section show that, the higher the intensity of solar radiation will reduce the drying Moisture ratio.

4. Conclusions

The conclusions obtained from the coffee dryer are as follows:
These coffee drying can be increase the temperature withinthedryingchambervariedfrom45-60^{o}C, time of drying more efficient, thesetemperaturesarevery suitablefordrying coffee beans, the higher the intensity of solar radiation will reduce the drying Moisture ratio and can be reduce of mass coffee.

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