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Experimental study of the prototype of acid gelugur solar dryer (*Garcinia atroviridis*) with air velocity of 1.5 m/s

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Abstract. A prototype of a constant flow type of Solar Gelugur Acid (*Garcinia atroviridis*) dryer using 2 racks was investigated experimentally. The aim is to explore the performance and characteristics of the prototype. A box of solar acid Gelugur (*Garcinia atroviridis*) is designed and made. In experiments the thickness of Acid Gelugur consists of 3 mm and 5 mm. The speed of heat flow sourced from the solar collector is 1.5 m/s. Prototype exposed to sunlight located in the city of Medan. The average solar collector temperature is 92.20°C, the drying box temperature averages 33.54°C, Gelugur Acid Moisture average 94.42%, and Ambient Temperature data measured System efficiency is analyzed. The results showed that with a flow velocity of 1.5m/s constant, the percentage of acid content in Acid Gelugur (*Garcinia Atroviridis*) with a slice thickness of 3mm was greater than that of 5mm with drying for 8 hours.

1. Introduction

Asam Gelugur or *Garcinia* is a medium to large evergreen trees, the scientific names of which are *Garcinia atroviridis* for strains found in Southeast India and *G. atroviridis* in Southern Thailand and North Malaysia. *Garcinia* fruit has been used as food for centuries in many tropical regions of Asia. The fruit may resemble a small yellow or reddish pumpkin, or it may have a unique purple color [1]. *G. cambogia* and *G. atroviridis* are traditionally used in the preparation of food and cooking spices, having a very typical sweet and sour taste [2]. The fruit contains fruit acids such as hydroxycitric acid or HCA that promotes fat burning and utilization of carbohydrates at rest and during exercise [3]. Hydroxycitric acid (HCA) is claimed to be an effective ingredient extracted from the skin or *Garcinia* fruit pericarp. *Garcinia* fruit inhibits adenosine triphosphate citrate lyase, an enzyme that is specifically responsible for the conversion of carbohydrates to fat. HCA, the main organic acid in fruit, was found to have a concentration of 16-18% b / b. [4]. In North Sumatra, Asam Gelugur is generally consumed by mixing boiled fish or Arsik Medan cuisine. Generally in North Sumatra Gelugur acid is widely used as a seasoning, which is called cut acid. During this time the acid has been known as a cooking spice to improve flavor [5][6].



To get the content of citric acid contained in Garcinia depends on a good drying process and as far as possible the content of temperature and air velocity must be controlled. The material is dried first in slices of different thickness with a size of 3mm and 5mm. Furthermore, the drying process in the drying box is carried out from the morning at 8:30 a.m. until 17:00 with a temperature and constant air pressure. The process of forced flow rate is higher when compared to the natural flow process, but the operational costs are very high because it uses electricity as a driver for the blower to drain hot air.

There are many types of Gelugur acid dryers found in the literature, such as dryers that for material thicknesses 2, 4 and 6 mm, temperatures of 55 ° C and airspeed of 1.2 m / s suitable for drying. The most suitable time is where the final moisture content that meets commercial standards is found 199.256 and 427 min. The higher is the temperature, the shorter is the drying time. It was also observed that the suitable drying time for materials was 2mm thick and the air velocity of 1.2 m/s was 199.159 and 99 min for drying temperatures of 55.65 and 750°C, respectively. Drying characteristics were also reported. Most drying rate curves appear in decreases in the rate period except at low temperatures and low speed operating parameters, namely 55°C and 0.5 m/s for 4 mm thick material, where the drying rate is constant around 0.09 kg water/min. The results showed that the air flow rate and temperature affected the drying rate at the temperature of 55°C and a flow rate of 2.25 m/s could reduce water content by 90% within 540 minutes.

2. Result and Discussion

Heat transfer and mass transfer that occur during the drying process are very complex processes because of the many factors that can influence the process [7]. During the drying process, not only heat transfer occurs but also the addition of water vapor to the air. The addition of water vapor from the material to the air is caused by differences in vapor pressure where the drying process occurs by means of evaporation of water. This method is done by reducing the relative humidity of the air through the flow of hot air or pressurized air so that the water vapor pressure of the material is greater than the pressure of the air vapor[8]. Relative humidity compares between the content / pressure of actual water vapor with a saturated state or at the capacity of air to hold water vapor. The capacity of air to hold water vapor (under saturated conditions) depends on the air temperature. The level of saturation is strongly influenced by temperature. The three relationships are illustrated in Figure 1.

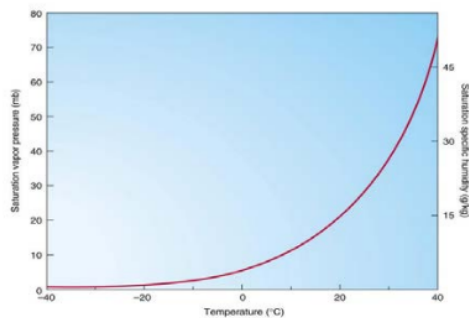


Fig 1. Relationship of Saturated Steam Pressure to Saturated Temperature and Humidity

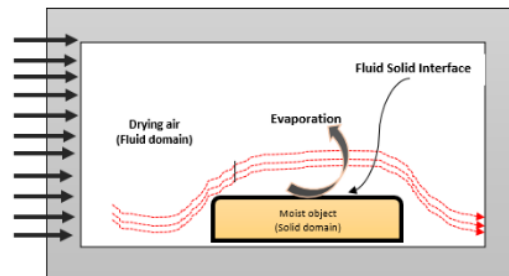


Fig 2. Heat and mass transfer mechanism in drying

Drying is a process to reduce the moisture content of a dried object [9]. This process is known and has been used by mankind since ancient times. The process of drying dry grapes using solar energy can be traced to Greece in 1490 BC. Drying is a heat and simultaneous problem of mass transfer between the drying medium and the object as shown in Figure 1. Briefly, the moisture inside the object diffuses to the surface due to differences in concentration. In solid interfaces, water evaporates into steam and will flow out by drying the air. In addition, evaporation requires several energy sources to supply latent heat from changes in the water phase to steam. The energy requirements for evaporation will be the driving force for heat transfer between objects and drying air. This fact shows that there are three different mechanisms occurring at the same time, they are heat transfer, mass transfer and phase change. This process is also known as a significant energy consumption process [10]. The racking system shows that at the bottom shelf the higher temperature content of the upper shelf at the beginning of the heat flow moves [11]. The drying mechanism through the drying box does not require physical treatment to change the position of all Gelugur acid slices when dried [12].

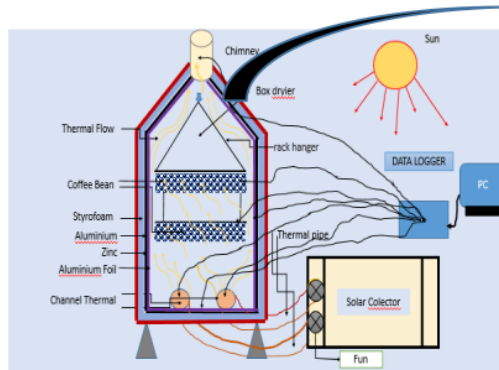


Fig.3. Experimental set up

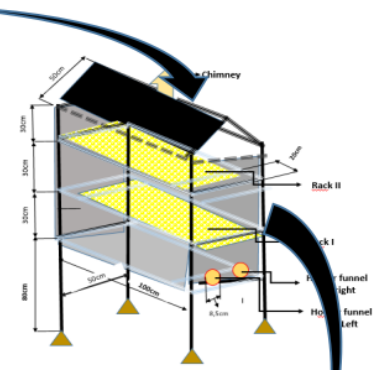


Fig 4. Geometrical Arrangement

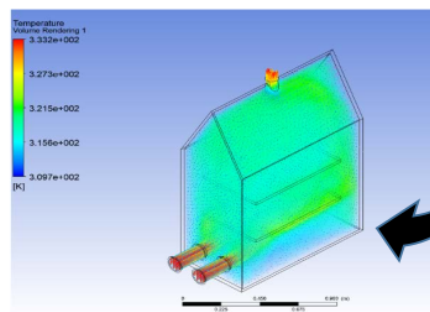


Fig 5. Hot air distribution and meshing of the computational domain 3D View

Governing equations

The air flow modeling is governed by the continuity equation, the momentum equations and the energy equation [13][14][15]. Substituting expressions into instantaneous equations and taking time average yields, we can write in the Cartesian system:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i} (\rho \cdot u_i) = 0 \dots\dots\dots 1$$

$$\frac{\partial}{\partial t} (\rho u_i) + \frac{\partial}{\partial x_j} (\rho \cdot u_i \cdot u_j) = \frac{\partial \rho}{\partial x_i} + \frac{\partial}{\partial x_j} \left[\mu \left(\frac{\partial u_j}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3} \delta_{ij} \frac{\partial u_i}{\partial x_i} \right) \right] + \frac{\partial}{\partial x_j} (-\rho \overline{u_i' \cdot u_j'}) F_i \dots\dots\dots 2$$

$$\text{where: } \overline{u_i \cdot u_j} = \overline{(\overline{u_i} + u_i')(\overline{u_j} + u_j')} \\ = \overline{u_i \cdot u_j} + \overline{u_i' \cdot u_j'} + \overline{u_i' \cdot \overline{u_j}} + \overline{\overline{u_i} \cdot u_j'} = \overline{u_i \cdot u_j} + \overline{u_i' \cdot u_j'}$$

These equations are the RANS (Reynolds-averaged Navier-Stokes) equations, which present the same form as the instantaneous equations. The new terms introduce the Reynolds stresses $\overline{u_i' \cdot u_j'}$ should be modeled to close the RANS equation. The used method applies the Boussinesq hypothesis relating the Reynolds stresses with the mean velocity gradients:

$$-\overline{\rho u_i' u_j'} = \mu_t \left(\frac{\partial \overline{u_i}}{\partial x_j} + \frac{\partial \overline{u_j}}{\partial x_i} \right) - \frac{2}{3} \left(\rho k + \mu_t \frac{\partial \overline{u_k}}{\partial x_k} \right) \delta_{ij} \dots\dots\dots 3$$

This hypothesis is undertaken in different turbulence models. This approach presents low computational cost compared to other numerical methods. By using the standard k- ω turbulence model, the turbulent viscosity μ_t is defined by:

For the correction of the low-Reynolds number, α^* is calculated as follows:

$$R_{et} + \frac{\rho k}{\mu_\omega} \dots\dots\dots 4$$

However, for the high-Reynolds number:

$$\alpha^* = \alpha_\infty^* = 1 \dots\dots\dots 5$$

For the standard k- ω turbulence model, the equations of the turbulent kinetic energy k and the specific dissipation rate ω are written as follows:

$$\frac{\partial}{\partial t} (\rho k) + \frac{\partial}{\partial x_i} (\rho k \cdot u_i) = \frac{\partial}{\partial x_i} \left(\Gamma_\omega \frac{\partial k}{\partial x_j} \right) + G_k - Y_k + S_k \dots\dots\dots 6$$

$$\frac{\partial}{\partial t} (\rho \omega) + \frac{\partial}{\partial x_i} (\rho \omega \cdot u_i) = \frac{\partial}{\partial x_j} \left(\Gamma_\omega \frac{\partial \omega}{\partial x_j} \right) + G_\omega - Y_\omega + S_\omega \dots\dots\dots 7$$

By using the concept of the Reynolds analogy, the energy equation is written as follows:

$$\frac{\partial}{\partial t}(\rho E) + \frac{\partial}{\partial x_i} [u_i(\rho E + P)] + \frac{\partial}{\partial x_j} \left[\left(k + \frac{C_p \mu_t}{\rho_{ri}} \right) \frac{\partial t}{\partial x_j} + u_i (\tau_{ij})_{eff} \right] + S_h \dots \dots \dots 8$$

Where E is the total energy, K is the thermal conductivity and $(\tau_{ij})_{eff}$ is the deviatoric stress tensor, defined as:

$$(\tau_{ij})_{eff} = \mu_{eff} \left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j} \right) - \frac{2}{3} \mu_{eff} \frac{\partial u_k}{\partial x_k} \delta_{ij} \dots \dots \dots 9$$

2. Materials and Methods

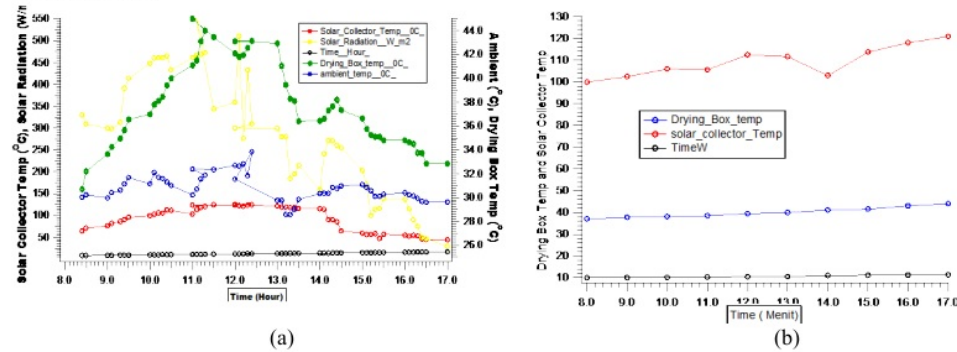
Sample Preparation

Fresh Gelugur acid is yellow, originating from the Parsoburan area of Toba Samosir Regency. The average weight of each is chosen to be 300-350 g. Un peeled fruit is cut into flat sheets with 3mm and 5mm thickness and the slab diameter is in the range 7-10 cm. To prevent diffusion of moisture and evaporation in the radial dimension, the skin of the skin is not removed.



Figure 6. (a). Acid Gelugur Fresh (b). Sliced Asam Gelugur. (c) Acid Gelugur Slices on the Rack

3. Discussion



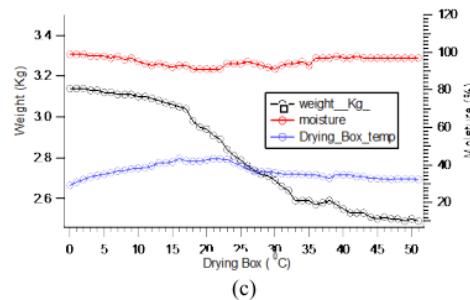


Fig 7 . Drying Box Temp, Solar Collector Temp, Solar Radiations Temp, Ambient Temp, Moisture, Weight Vs Time

From Figure 7.a it is shown that an 8-hour test which is started at 8:10 a.m. the percentage decrease in Acid Gelugur weight is 79%. The minimum weight occurs at 16.50 where the temperature in the drying box is 32.85 °C. The maximum temperature in the dryer box occurs at 11:30 but the humidity is still high at around 91% and the decrease in weight is also relatively high at around 97% with the understanding that the decrease in weight is directly proportional to the lower value of humidity 78% and a weight of around 2.79 kg or 88.72% means that with the speed of constant hot air flow and the average temperature in the drying box of 33.54 °C heat transfer occurs by decreasing the weight and moisture of the acid Gelugur slowly.

The average temperature of the solar collector is 92.20 °C and the amount of solar radiation averages 288.94 w/m² and the ambient temperature is 30.74°C. The large percentage of heat that is moved experimentally from the solar collector to the 41% drying box is relatively good, this is due to the speed of hot air flow from the solar collector with forced convection of 1.5m/s constant.

4. Conclusion

Drying box coated with 10mm thick Styrofoam cork, 1.3 mm Aluminum Plate and inner lining Aluminum foil have volume of 0.7m³ consisting of 2 shelves with a shelf distance of 30 cm and a diameter of 8.5 cm hot air ducts 2 pieces with a length of 50 cm, have a flat temperature average 33.54 °C with hot air sources from solar collectors averaging 92.20 °C with solar radiation averaging 288.94 w/m². The total acid content of Asam Gelugur with a thickness of 3mm is 0.6393% and a thickness of 5mm is 0.6991% for 8 hours of drying.

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