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Performance of the Rack Type-Greenhouse Effect Solar Dryer for Wild Ginger (*Curcuma xanthorizza* Roxb.) Drying

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Abstract

Drying is the important process to produce wild ginger powder as herbal medicine. Conventional drying of wild ginger under the sun depends to weather and potencies to contaminate by pollutant. Therefore the objective of study is to obtain the performance of Greenhouse-effect solar dryer – rack type to dried wild ginger. Three conditions of drying experiment were carried out to obtain the performance of the dryer; without-product and using product at two different capacities. The best of drying performance is the drying of 60 kg slice wild ginger at 47.2^{o}C for 30 hours represented by drying efficiency of 8 % and total energy consumption of 29 MJ/kg vapor. The uniform heat air flow is achieved at temperature standard deviation of 2.32^{o}C.

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Keywords: performance; wild ginger; rack; green-house; solar dryer

Nomenclature

CE	energy consumption (J/kg water vapour)
Cp	specific heat of wild ginger (kJ/kg ^{o}C),
Hfg	latent heat for evaporating free water vapour (kJ/kg),

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M_f	final moisture content of product (%db)
M_i	initial moisture content of product (% db)
m_v	vapour evaporated (kg)
m_p	mass of slice wild ginger (kg),
Q_b	energy from biomass combustion (kJ)
Q_s	solar energy (kJ)
Q_e	electricity energy (kJ)
ΔT_p	gradient temperature of wild ginger (^oC)

1. Introduction

Wild ginger ((*Curcuma xanthorizza* Roxb.) or known as temulawak (Indonesian) is one of Indonesia's native plants. Nowadays, dried wild ginger are produced and processed as spices for cooking, healthy and tasty soft drink and herbal medicine with various nutritional values. It could treat liver disorder and malaria [1]. Ethanol 70% extract of rhizome powder of wild ginger inhibited the growth of gram positive bacteria *Staphylococcus aureus* which causes a pimple[3]. Conventional drying of wild ginger usually is carried out under the sun. However, it depends on the weather and the method contaminates to drying product by exposing it to dust, subjects it to destruction by animals and flies and it was not able to dry the product at rainy season. Accordingly, greenhouse effect solar dryer – rack type as artificial dryer is necessary to dry wild ginger in all of weather condition every day. Rack type greenhouse solar dryer was designed for thin layer drying of many kinds of product which could not be dried by deep bed dryer. Technically and economically the dryer have been used successfully for rosella pod.[7]. However it hasn't been tested yet for wild ginger drying. Therefore the objective of research is to obtain the performance of Greenhouse-effect solar dryer – rack type to dried wild ginger. The study is expected to facilitate the drying process efficiently of slice wild ginger which could be applied for farmer and merchant of herbs (traditional medicine).

2. Material and method

The study was conducted on March 2013 in the Field Laboratory of Department of Bio-system and Mechanical Engineering, Faculty of Agricultural Technology, IPB, Bogor, Indonesia.

2.1 Material and equipment

Raw material of fresh wild ginger is obtained from Balitro Bogor. Wood is used as biomass fuel. Moisture content of wild ginger is determined by using drying oven method. Solar irradiation measurement is equipped by pyranometer. Anemometer kanomax-type is used to measure airflow of drying air and ambient air. Another apparatus used are adiabatic bomb calorimeter, digital electronic balanced, thermocouple and thermo-recorder. Relative humidity of drying air and ambient air are determined by measuring of wet bulb and dry bulb thermometer and also calculated by using psychrometric chart. The measurement apparatus is depicted in Fig. 1.

The main equipment of rack type - Greenhouse-effect solar dryer designed by Wulandani dan Nelwan [6] is a transparent building where the product dried is spread on the racks within the structure. The dryer is described in Fig 2. Solar energy is trapped into the transparent building and lead to increasing of air temperature inside the building [4]. To overcome the cloudy and rainy condition, biomass fuel combustion in the biomass stove is provided. The dryer consist 144 trays (dimension of 0.5 m x 0.5 m), four blowers (power of @ 80 W), burner and cross-flow heat exchanger.

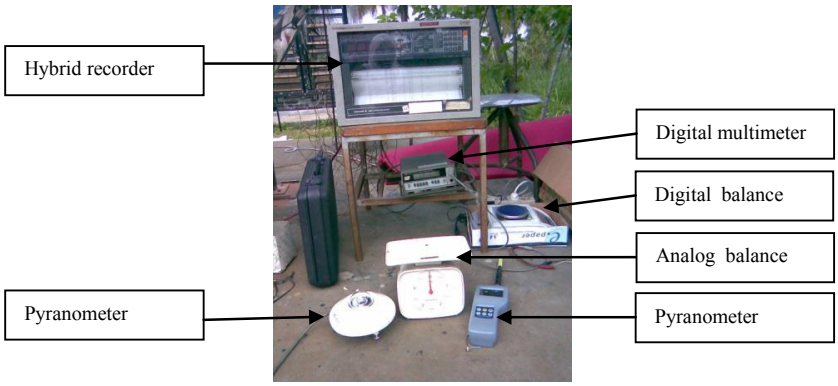

Fig. 1. Measurement apparatus.

Fig. 2. Rack type greenhouse-effect solar dryer.

2.3. Experimental method

After harvesting, fresh wild ginger was treated in several stages, i.e. sorting, washing, slicing, drying and packaging for further processing. Performance test of dryer is carried out by 3 treatments. Each of treatment was performed twice with data acquisition every 30 minutes.

- Experiment-1. Empty condition drying (without product),
- Experiment-2. Drying of 21 kg slice wild ginger, and
- Experiment-3. Drying of 60 kg of slice wild ginger.

2.4. Evaluation of greenhouse effect solar dryer performance

To perform the dryer performance, drying rate (dM/dt), drying efficiency (η) and energy consumption for evaporating vapour from the product (CE) were evaluated from expression given in eq. (1), (2) and (3) respectively.

$$dM/dt = \frac{M_f - M_i}{\Delta t} \quad (1)$$

$$\eta = \frac{m_v Hfg + m_p Cp \Delta T_p}{Q_b + Q_s + Q_e} \quad (2)$$

$$CE = \frac{Q_b + Q_s + Q_e}{m_v}$$

3. Result and discussion

3.1 Performance of dryer without product

The results of condition without drying observed that it was need 2.6 kg/h of biomass fuel combustion at solar irradiation of 515 W/m^2 to reach the drying air of 44.5 ^{o}C, RH of 76 %, and debit of drying air of 0.037 m^3/s. The average of ambient temperature was 35^{o}C and RH of 78 %. This result is useful to estimate the need of energy resources to reach the optimum drying air temperature for wild ginger. All drying processes occurred at the cloudy and sunny-day.Therefore, biomass energy is necessary to maintain the drying air temperature at constant condition of 45^{o}C. The experiment was carried out for 24 hours to perform the daylight and the night. The available of solar energy at daylight contribute to support energy resource for drying. Biomass requirement at night experiment is needed to increase drying air gradient temperature of 10-20^{o}C. This value is twice greater than the gradient temperature of the daylight-experiment therefore the drying operation at night is not suggested to be applied for saving energy, excepted at crucial condition to keep drying continuity at peak season of harvesting.

3.2 Performance of slice wild ginger drying

This research resulted that to dry 21 kg and 60 kg of wild ginger at 80 % wb to 8-11 % wb (final moisture content) required drying time for 27.5 hours and 30 hours respectively. The comparison of wild ginger moisture content between experiment 2 and open sun drying is depicted in Fig. 3. Moisture content decreasing pattern of both of experiments are quite different, due to difference of temperature and RH exposure to the product. Although the experiment-2 achieved higher temperature than sun drying operation, the drying time was reveal to the same condition, due to air quality within the dryer was low.

Moisture content distribution and drying rate of wild ginger during drying process is shown by Fig. 4. It can be seen in Fig. 4 that constant drying period uncounted, while falling rate is estimated be started at the 1st hour of drying time. Critical moisture for both of experiment is occurred at 411 % db or 80.4 % wb. This value must be reached as soon as possible in drying process. The critical moisture indicates the availability of free water on the product surface for micro-organism living. Drying rate decrease continuously along with moisture content decrease or improving of time. This is resulted from the migration to surface of moisture and evaporation moisture from surface is decrease along with moisture content decrease due to bound water existing in the product. Average drying rate of slice wild ginger is 17.2 kg moisture per kg dry matter per hour. The value is nearby the drying rate of white turmeric of 18 kg moisture per kg dry matter per hour [5].

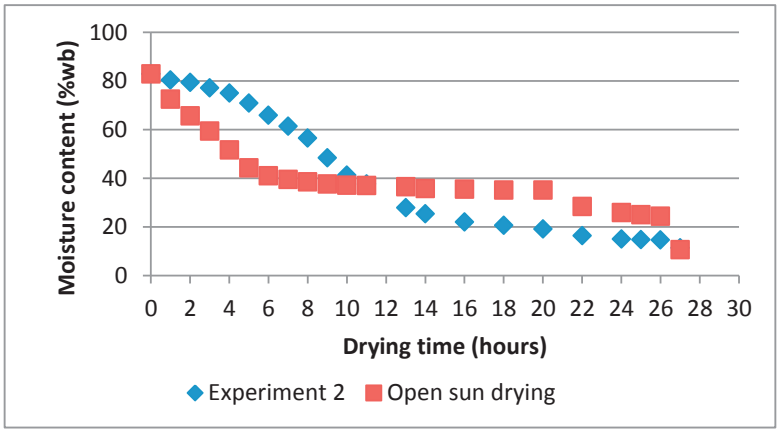

Fig. 3. Moisture content of wild ginger during drying process.

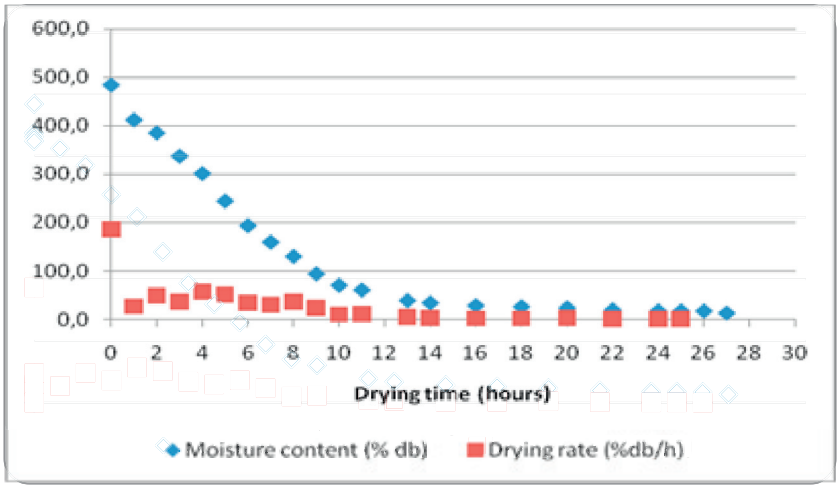

Fig. 4. Decreasing of moisture content and drying rate of wild ginger during drying process (experiment 2).

Experiment-2 dried faster than experiment-3 indicated by drying rates of wild ginger have shown in Table 1, due to the drying capacity of experiment-2 is half of that of experiment 3 and increase of contact surface area between drying air and the product in experiment-2, make the possibility of vapor evaporated rate is faster than those of experiment-3. However, experiment-2 need the drying energy to evaporate water from the product of 57 MJ/kg vapor evaporated greater than those of experiment-3 of 29 MJ/kg. It is caused by removing of drying air into outlet without attached the drying product shown by outlet temperature is still high of 33^{o}C; and it caused by energy losses through transparent wall of 3 % of total input energy. It also caused by amount part of 36 % of total input energy losses through the chimney and absorbed by metal component of dryer . Consequently of energy losses, drying efficiency of experiment-2 is 4 % less than that of experiment-3 of 8 %. Greater of drying efficiency lead to less of energy consumption, as result of dryer's higher energy loss through the transparent wall to ambient air and absorption energy to the construction iron frame, and racks. The experiment results of drying performance of wild ginger are presented in Table 1.

Table 1. Drying performance of wild ginger.

Drying parameters	Experiment		
	1	2	3
Drying air temperature (°C)	-	45.5	47.2
Product temperature (°C)	44.5	46.2	41.8
Initial moisture content (%wb)	-	82.9	81.3
Final moisture content (% wb)	-	11.6	8.4
Mass of wet wild ginger (kg)	-	21.1	60.8
Mass of dried wild ginger (kg)	-	3.1	13.1
Rendemen	-	19.5	20.0
Drying time (h)	24	27.5	30.0
Drying rate (% db/h)	-	17.2	14.2
Solar energy (MJ)	515	361	685
Biomass energy (MJ)	2.3	941.2	1357.0
Electricity energy (MJ)	3.6	1.4	2.6
Drying efficiency (%)	2.9	4.3	8.2
Energy consumption (MJ/kg)	-	57.4	29.2

3.3 Variation of drying air temperature and moisture content of wild ginger

Table 2 represents temperature and moisture content of wild ginger during drying process. Variation of drying temperature has a positive correlation to the variation of moisture content of entire product.

Table 2.Average temperature and moisture content of dried wild ginger and the variation.

Parameters	Experiment 2		
	1	2	3
Drying air temperature (°C)	**44.61**	**46.23**	**41.77**
Top	47.57	53.10	48.29
Middle	44.73	44.81	39.45
Bottom	41.52	40.77	37.56
Variation of drying air temperature (°C)	**3.95**	**2.32**	**3.92**
Top	4.13	1.23	3.07
Middle	4.30	3.07	2.12
Bottom	3.41	4.31	3.90
Final Moisture content (%db)	-	**11.56**	**8.39**
Top	-	11.56	9.13
Middle	-	12.00	9.31
Bottom	-	11.45	6.71
Variation of final moisture content (%db)	-	**0.38**	**0.75**
Top	-	0.27	0.29
Middle	-	0.65	1.77
Bottom	-	0.21	0.20

From the Table 2, the uniformity of wild ginger moisture content is achieved for experiment-2 among the top, middle and bottom trays. It was observed by average of moisture content standard deviation at 0.38 % kg water/kg dry matter, respectively. The experiment result indicated that the product is nearly dry at the same time.

The variation of moisture content may cause by variation of solar radiation and heat airflow reached to the racks. There are positive correlation between variation of temperature and variation of final moisture content. Decreasing of the value of temperature variation decreased final moisture content variation, lead to the uniformity of both parameters. Final moisture content is the important parameter of dried product quality. The highest of moisture content of product on the rack of dryer is the indicator to determine all of drying time.

3.4 Quality of dried wild ginger

Dried wild ginger has pale color than those before drying (little bit orange color). The color of wild ginger is influenced by curcuminoid content [3] which decrease after drying process. Shrinkage was occurred on the dried wild ginger. The loss of moisture due to heating during drying process cause stresses in the cellular structure of the wild ginger leading to change in shape and decrease dimension coupled by increased hardness of product [2].

4. Conclusion

Drying performance of Green-house effect solar dryer for slice wild ginger was obtained. Utilization of dryer at full drying capacity of 60 kg wild ginger (experiment-3) gives the highest performance of dryer which indicated by drying efficiency of 8 %, but with increase in drying time of 30 hours as consequence of insufficient energy resources to raise drying temperature and insufficient airflow to remove vapor from the product and to discharge it to ambient air. Base on the experiment-2 and experiment-3, the increasing of drying capacity will increase the drying efficiency, therefore decreases the energy consumption to evaporate the moisture from the product.

Drying air temperature and moisture content was distributed uniformly throughout the racks within the dryer at variation of 2.32^{o}C and 0.38% respectively. Degradation of dried wild ginger quality was indicated by pale colour, hardness and shrinkage occurred as the consequence of drying.

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