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RESEARCH ARTICLE | JUNE 26 2018

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AIP Conference Proceedings 1977, 060011 (2018)
https://doi.org/10.1063/1.5043023

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The Forced Convection Biomass and Solar Collector Dryer for Drying Seaweed Using Exhaust Fan

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Abstract. The natural process of drying seaweed takes a long time depending on the sunlight. In addition, the effects of weather, seasons, and the day-night cycle make this process more limited and not fully controllable. The moisture content of post-harvest seaweed is about 92.5%, requiring a relatively long drying time. The design of the dryer developed in this study consists of a solar collector equipped with an exhaust fan—which serves to accelerate the forced heat convection from the collector to the drying chamber and the air heating system using a solar collector with rock bed heat storage material. This paper investigated the drying process by using solar collectors, biomass, and hybrid to dry the seaweed. The method was by testing the activity of the prototype of solar collector unit using rock bed system arranged on solar collector. The results showed at an average solar radiation intensity of 957.48 W/m^2 and an average collector temperature of 79.53^{o}C, the solar collector functions maximally by generating a drying room temperature. At an average of 52.89^{o}C, the spreading of heat from the solar collector reaches every drying tray for the process of drying the seaweed. The average of drying rate obtained by testing on solar collector, biomass and hybrid was 0.0123 gram/sec for two days, 0.0569 grams/sec for 400 minutes, and 0.0893 grams/sec for 300 minutes respectively. The efficiency of drying rate for solar collector, biomass, and hybrid was 4.48%, 10.31%, and 13.36% respectively.

INTRODUCTION

Drying is one of the critical post-harvest handling stages which determine the quality of seaweed. However, natural drying process usually takes a long time because the temperature and energy depend on the sunlight. In addition, the effects of weather, season, and the cycle of day and night make this process more limited and not fully controllable. Under unfavorable weather conditions, the increasing water content will be medium for the growth of certain molds. Moreover, if the process is done in an open area, it will trigger the presence of contaminants, such as dust, dirt and unwanted foreign objects, which potentially reduce the quality of seaweed products [1].

Bala et al., conducted a study on solar dryer by using a transparent collector cover and then heating the absorber. The ambient air is forced through the collector tunnel. Subsequently, the heat is transferred from the air absorber in the collector and the hot air from the collector passes through the product and absorbs the moisture of the product. The solar radiation also passes through a dry transparent cover and heats the product. It increases the drying rate and the temperature in the range from 37.0°C to 66.5°C. Due to its very low resistance, a 20-30 Watt exhaust fan is utilized when the air is forced to pass through the dried product. The findings of the study showed the collector efficiency, drying efficiency and overall efficiency in loading 160 kg of mushroom. The overall efficiency obtained from the experiment was in the range of 30.43% to 38.47%, while the overall efficiency for natural convection of solar dryers was in the range of 12% to 18% [2].

Patil and Sukla developed a type of convection box that can dry a variety of food products. Drying process is tested on redgram, soydal (split soybean) and soyflakes. The results demonstrated from the initial moisture content

Human-Dedicated Sustainable Product and Process Design: Materials, Resources, and Energy
AIP Conf. Proc. 1977, 060011-1–060011-6; https://doi.org/10.1063/1.5043023
Published by AIP Publishing. 978-0-7354-1687-1/$30.00

of 48.83, 62.80 and 30%, respectively, indicating that the drying time was 18, 15 and 6 hours with thermal efficiencies of 17.32, 26.43 and 11.85% [3].

Similarly, Oviantari and Parwata observed the influence and optimization of drying technique and water content of *Eucheuma cottonii* on the quantity (rendemen) and quality (viscosity) of semi-refined carrageenan product. The results of this study concluded that to improve the quantity and quality of the product, direct drying techniques can be employed to produce semi-refined carrageenan (SRC) with high rendemen level and low viscosity. Meanwhile, indirect drying techniques will produce semi-refined carrageenan with high rendemen level and lower viscosity [4].

The research performed by [5] studied modeling that are adapted to predict the prototype dimensions of the required drying time. The model is designed for air parameters (temperature, humidity, and velocity) and moisture content of maize and experiments were carried out to reveal the performance of ISD. The simulation performed based on the thermal equilibrium model showed an uneven distribution of water content when drying process is done without stirring. Factors that influence the artificial drying process are the regulation of flow direction, the speed of hot air and the thickness of the pile of the dried material. Henderson and Perry [6], and Broker et al., [7] stated that the drying process can be divided into two periods, i.e. the constant drying rate period and the falling drying rate period. The drying mechanism of the falling drying rate comprises two processes: the movement of water from within to the surface of the material and the discharge of water from the surface of the water into the surrounding air. The falling drying rate occurs after the constant drying rate in which the moisture content of the material is less than the critical moisture content.

Principally, an alternative to dry seaweed is by using artificial driers or drying machines that have high heat-absorbing qualities as well as biomass energy sources that have the ability to circulate the flow of hot air that spread evenly to maintain the quality of seaweed. Based on this issue, it is necessary to develop an efficient, effective and appropriate technology in drying seaweed. This effort is expected to improve the drying process period and create even temperature distribution, as well as its less dependency on sunlight, weather and micro climate. Therefore, a study to investigate the combination of energy in the drying process of seaweed from the heat from collector system and the heat from biomass that generates uniform heat and eventually produces dried seaweed with high value added.

EXPERIMENTAL METHOD

Materials and Equipment

The materials were *Eucheuma cottonii* as raw material of dried seaweed. The equipments were a dryer unit consisting of a solar collector and a dryer tray, a heating chamber from biomass furnace, production workshop equipment, and other instruments including thermocouple, pyranometer, anemometer, tachometer, digital scales and data recorder.

Method

This study was carried out by following the standard methods, including the design process of identifying problems, formulating and solving problems, functional and structure design, image engineering, fabrication and testing of the performance. Based on the design criteria, the functional design of a solar collector consists of the wall of the collector, glass heat trapping and stone arrangement as a heat storage medium, draft drying tray includes capacity tray dryer, biomass space heating furnace, installation of cyclone turbines ventilators and exhaust fans at the solar collector. The structural design of the dryer was made based on the prior engineering analysis through the selection of particular characteristics of materials. The design and manufacture of this dryer can be seen in Fig. 1 below.

The performance of the dryer was tested to determine the temperature distribution with various ventilator hole diameters on the drying tray, and to determine the effect of the wind speed of exhaust fan. The parameters measured include the temperature of each tray, the exhaust fan spin, and the wind speed. The temperature of the solar collector and the drying tray was identified by using solar collectors and biomass heater. The testing was done by placing the stone structure on the solar collector and the temperature changes on the solar collector and the drying tray were measured in line with the changes in the solar radiation intensity.

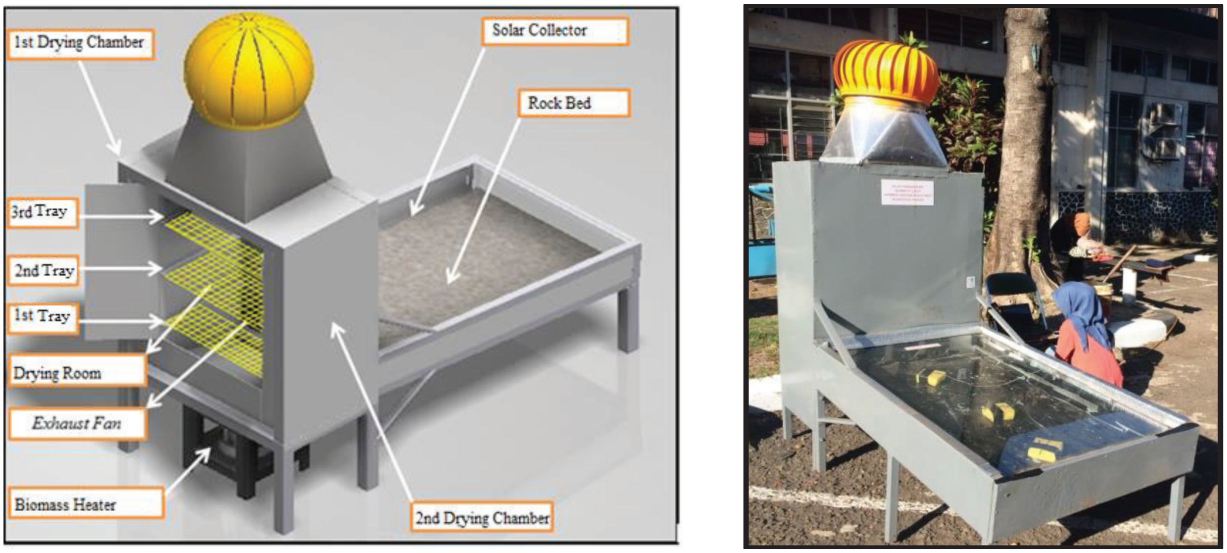

FIGURE 1. Solar collector dryer.

RESULTS AND DISCUSSION

The results of the experiment on the performance of the dryer are described as follows:

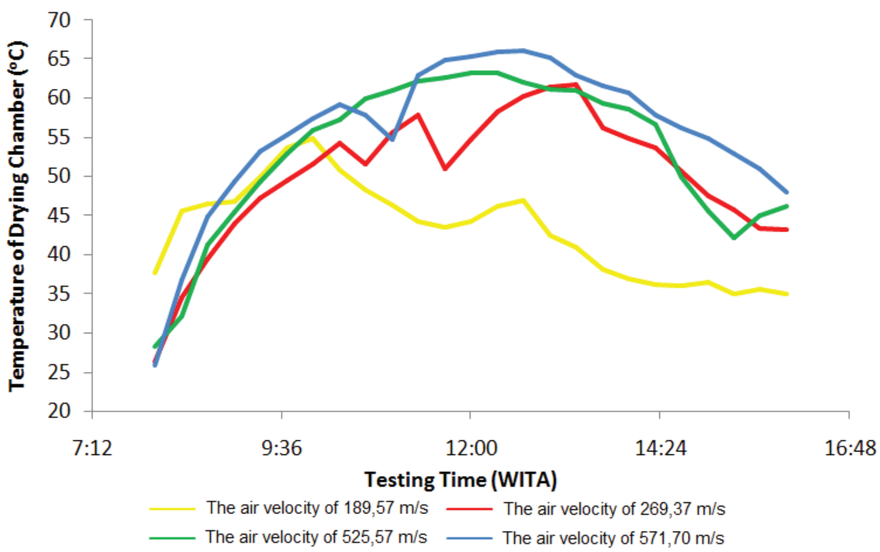

FIGURE 2. The variation of the air velocity versus the average temperature distribution of the drying chamber.

Figure 2 shows the results of the test of air velocity from the solar collector to the drying chamber by using an exhaust fan—which serves to increase the transfer of hot air in the solar collector to the drying chamber. The flow velocity was performed by 189.57 m/s, 269.37 m/s, 525.57 m/s and 571.70 m/s. The maximum airflow velocity of 571.70 m/s provided the highest drying room temperature increase. It indicated that the rotation rate of exhaust fan influences the transfer of hot air flow to the drying chamber so as to increase the maximum drying room temperature with an average value of 55.62°C and the maximum temperature of 66.03°C. The speed of the dryer air flow affects the speed of drying process in evaporating the mass of water transferred into the atmosphere.

Figure 3 shows the relationship of the drying time and the drying rate of diverse materials, as well as the temperature change in the drying chamber. The average temperature of the drying chamber was 33.37°C, with a time span of 540 minutes by utilizing the heat energy from the solar collector. The drying rate on the first tray of 0.0150 gr/s was showed at the beginning of the test, which is higher than the drying rates of the material on the second tray (0.0132 gr/s) and the third tray (0.0117 g/s). The different drying rates are possibly due to the drying position of the first tray is closer to the heat source, in compared to the second and third trays. This following figure shows the higher the temperature in the dryer chamber, the faster the drying process takes place.

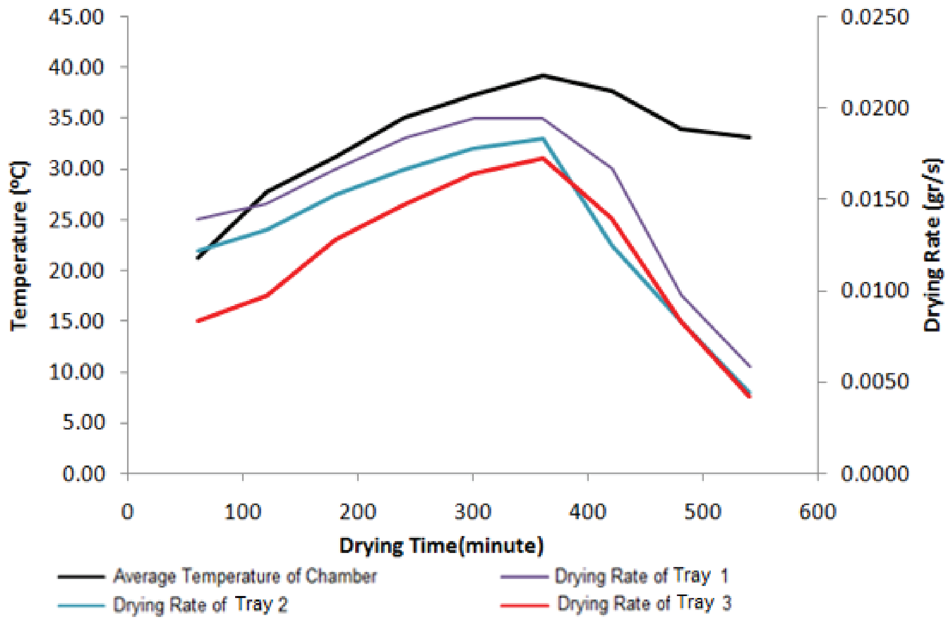

FIGURE 3. Graph of the drying time versus the drying rate and the average temperature of the drying chamber.

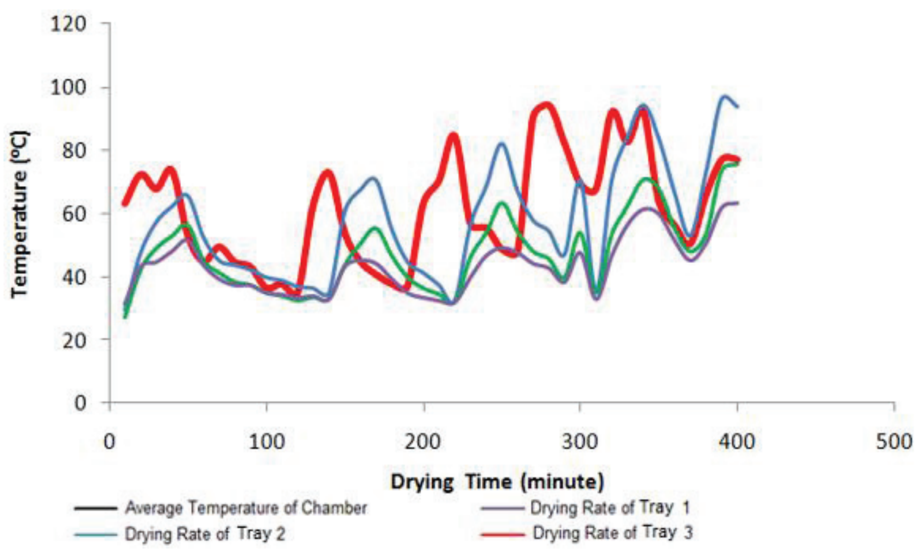

FIGURE 4. Graph of the drying time versus the temperature of heater room and dryer tray.

Figure 4 shows the relationship of the drying time with the biomass heat source and the change of drying temperature in the trays. The heat transfer process of the first heating chamber was 52.44ºC with an average temperature of 61.48ºC, the second heating chamber was 70.07ºC with an average temperature of 61.75ºC while the third heating chamber was 51.12ºC with an average temperature of 46.54ºC. On the condition of these heating room temperatures, it is possible that the drying process occurs appropriately without damaging the structure and the quality of seaweed. The results of this test reasserted a study carried out by [8], reporting stable hot air temperature at 60 ± 3°C for more than 24 hours during the overall drying duration.

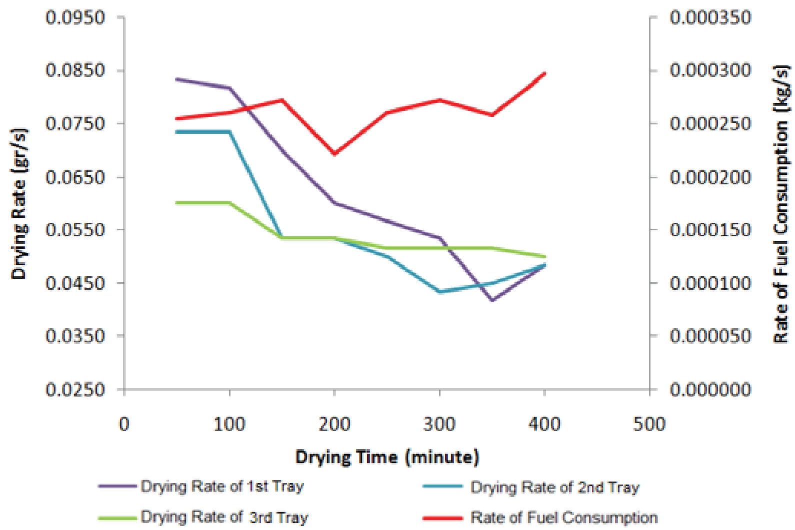

FIGURE 5. Graph of the drying time versus the fuel consumption rate and dryer rate.

Figure 5 shows the average drying rate of materials on the tray first, second and third was 0.057 g/s, using biomass fuel at an average fuel consumption rate of 0.00026 kg/s and 400 minutes of drying time. The longer the required drying time, the higher the biomass fuel consumption. In addition, the high drying rate at the beginning of the process is because the surface of the material is still wet to form a layer of water which will subsequently dry from the surface, therefore evaporation on the top surface of the material is faster. Furthermore, the drying rate will decrease due to the movement of the moisture content from within to the surface of the material by diffusion and the transfer of water content from the surface of the material to the free air.

Research on hybrid solar dryers carried out by Amer et. al. has developed a process of drying ripe banana slices by using direct solar energy and a heat exchanger [9]. Vlachos and Karapantsios developed a low-cost drying design equipped with solar collectors, heat storage cabinets, and solar chimneys. The design is created based on the energy balance and the mean hourly data radiation reduction procedure for sloping surfaces. Total solar radiation measurements in the horizontal plane, ambient temperature, humidity, air velocity, relative humidity and humidity in the dryer as well as solid weight density were used as the data for studying the dryer performance [10]. In the drying process, an investigation has been conducted to obtain minimum energy consumption [11]. The same study conducted by Nur et. al. also investigated the energy consumption in the turning process [12].

CONCLUSION

Based on the results of this study, it can be concluded:

- The test of the variation of air flow velocity from the solar collector to the drying chamber using the exhaust fan showed that the airflow velocity of 571.70 m/s provides the highest drying room temperatureincrease, indicating that the speed of the exhaust fan has an effect on the transfer of hot air flow to the dryer chamber with an average temperature of 55.62^{o}C and maximum of 66.03^{o}C.
- Average drying rate of the tested materials using solar collector heat source was 0.0133 gr/s, while using biomass heat source was 0.0569 g/s. The highest drying rate is obtained by drying process using biomass heat source.
- The use of fuel consumption in the biomass dryer affects the change and the increase of temperature in the heating chamber and further accelerates the process of deterioration. To increase the temperature of the heating chamber with an average rate of 61.26^{o}C, it takes an average fuel mass of 0.76 every 50 minutes of combustion with a fuel consumption rate of 0.000262 kg/s.
- The average efficiency of solar drying system of solar collector and biomass was 4.48% and 10.31%, respectively. It shows that there is higher evaporation rate due to the release of molecular bonds on the material.

ACKNOWLEDGMENT

This paper is supported by DIKTI grant. We would like to thank The Ministry of Research, Technology and Higher Education of the Republic of Indonesia and Politeknik Negeri Ujung Pandang for funding and support.

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