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Evaluation of hybrid solar – biomass dryer with no load

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Abstract. Experimental study was carried out to investigate the performance of designed and fabricated hybrid solar- biomass dryer without load. The solar side was a natural convection mixed mode, while the biomass side was a hot air produced from a burner/gas to gas heat exchanger. The experiments have been conducted to test the dryer temperature, inlet and outlet relative humidity, outlet velocity, and biomass feeding rate. In the solar mode the maximum dryer temperature was 63°C. Behaviours of the velocity in the dryer was found to follow solar radiation available to the dryer. The velocity was in the range of 0.6 – 1.35 m/s through the 0.0176 m^2 area of the outlet when the solar radiation was in the range of 150 – 880 W/m^2. Two feeding rates of wood were used to investigate the dryer performance through the night. The results showed that at feeding rate 278 g/hr, the drying air mean temperature was 62 ºC. This temperature was more suitable than the measured drying air temperature at feeding rate 490 g/hr. Also the 62 °C drying environment is more stable and feasible for drying almost all types of products.

1 Introduction

Various drying techniques are employed to dry different food products. Each technique has its own advantages and limitations. Choosing the right drying techniques is thus important in the process of drying of these perishable products. The dryers depend only on solar energy are classified as open sun, direct, indirect, and mixed mode. Appropriate use of solar-Biomass dryer provides reduction of drying time, continuous working in comparison to other types of dryers.

Prasad and Vijay [1] fabricated and studied an integral type natural convection solar dryer coupled with a biomass stove. Experiments have been conducted to test the performance of the dryer by drying of ginger, turmeric and guduchi during the summer climate in Delhi. The temperature recorded at the bottom tray was 59.5ºC. An indirect type natural convection solar dryer with integrated collector-storage solar and biomass-backup heaters has been designed, constructed and evaluated by Madhlopa and Ngwalo [2]. The major components of the dryer are biomass burner, collector- storage thermal mass and drying chamber. The temperature inside the dryer had maintained at 41-56ºC.

Bena and Fuller [3] studied a hybrid direct-type natural convection solar dryer and a simple biomass burner. The dryer consists of a drying cabinet mounted on top of a brick chamber that encloses a simple biomass burner. The biomass burner, designed primarily for fuel wood, was constructed from a 0.2-m drum laid on its side. The average drying chamber temperatures at the husk feeding rates of 3 kg/h, 5 kg/h, 10 kg/h were 43 ºC, 53 ºC, 62 ºC respectively.

Tarigan and Tekasakul [4] studied experimentally a mixed-mode natural convection solar collector

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with biomass burner and heat storage back-up heater. The solar collector system has length of 2.75 m and width of 1.75 m. For back up heating, a biomass burner was constructed from concrete as the wall, and filled up with bricks as heat storage. They had utilized 50 kg wood per night and temperature recorded in the drying chamber was 65ºC.

Al-Kayiem and Yunus [5] studied experimentally a combination of mixed mode hybrid dryer using solar as main heat input and biomass burner as auxiliary source to dry EFB. Series of experimental measurements were carried out at four different drying modes namely, open sun, mixed solar, thermal back up, and hybrid modes to dry 2.5 kg of EFB. The maximum dryer temperature they recorded was around 60 ºC using chip wood as fuel.

The objectives of the recent paper are to present and discuss the measurement results of newly designed, fabricated, and tested hybrid solar dryer. The system comprises solar collector, direct drying compartment, thermal backup unit, and co-gen exhaust system. The measurements were carried out without loading of drying specimen. It is just to compare the results of different operational modes of the hybrid drying system. The main process parameters that are monitored and analyzed are the temperatures, velocities, and the relative humidity.

2 Hybrid solar biomass dryer system configurations

2.1 Solar collector

The solar collector of double pass was fabricated from galvanized plate and aluminum angles. The gap between the cover and the absorber was 0.06 m, and the gap between the absorber and the back was 0.03 m. The external dimension of collector was 1.75 m length X 1.1 m width X 0.14 m depth. The solar collector insulated from back, left and right edges by glass wool thickness 0.05 m. The solar collector tilt angle was 40 degree from horizontal.

2.2 Drying chamber

The drying chamber was fabricated from aluminum angles to avoid heavy weight. The outside dimensions of the dryer are 1.1 m width x 0.42 m depth x 0.9 m height. There are three drying trays, each with a wire mesh base, and in total effective drying area of 0.9 m^2.

2.3 Thermal back up unit

The constructed TBU was comprised of two parts. The lower part is the burner which is cylindrical shape to burn the fuel and produces the flue gases, and the upper part is a gas to gas heat exchanger to exchange the heat between the air and flue gas. The dimensions of the burner were 0.4 m and height 0.35 m. The gas to gas heat exchanger length was 0.45 m. The exhaust flue gas from thermal back-up unit was connected to the chimney of dryer to produce up drafting force to enhance the flow rate inside the dryer. The inlet diameter of flue gas to the chimney was 0.05 m.

3 Experimental setup and instrumentation

A calibrated thermocouples type K (chromal – alumal) measuring temperature in the rang -50 to 1000 ºC with accuracy ± 0.1 ºC were used to measure the temperatures of 26 point in the system. The thermocouple probe fixed in every tray of dryer, the outlet of dryer, outlet of collector inlet to dryer, outlet from thermal buck up unit inlet to dryer, and above the flue gas inlet to the chimney. Thermocouple fixed on the surface of absorber in the three points to obtain the average temperature, on the perspective cover of collector from inside and outside, and in the perspective walls of dryer in the inside and outside. All of the thermocouples were connected to the data logger type GL820-UM-851. A solarimeter type SL200 with accuracy ±5% of measurement was used to measure the

irradiation. The velocity of hot air was measured using vane probe and anemometer type VT200 with accuracy ±3%. The experimental set up is shown in the picture of Fig. 1.

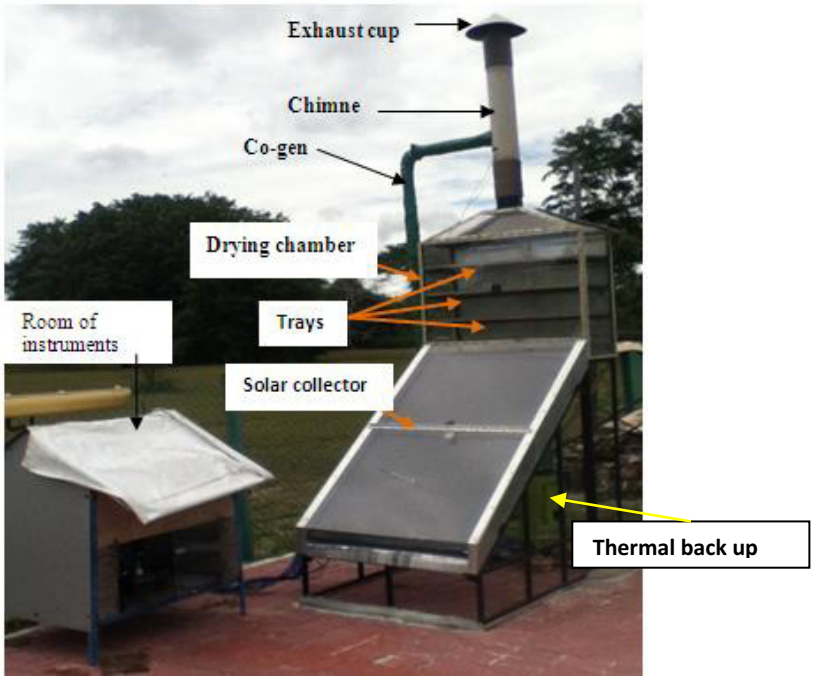

Figure 1: The Experimental hybrid solar biomass dryer.

4 Results and discussion of hybrid dryer without load

The experiment of hybrid solar biomass dryer was taken in the solar research site (SRS) in university technology PETRONAS with five repeatability of each to obtain the average results data with acceptable uncertainty. The fabricated hybrid drying system was shown in the photo in Fig.1.

Fig. 2 shows the results of the performance of dryer and environment parameters with the hours of day. The maximum radiation was between noon and 3 pm. It can be seen that when the solar radiation decay sharply after 3 pm, the trays temperature stay above 45 °C for long time because the walls of drying chamber (front, left and right) are constructed from double perspective and gab of air 5mm in between.

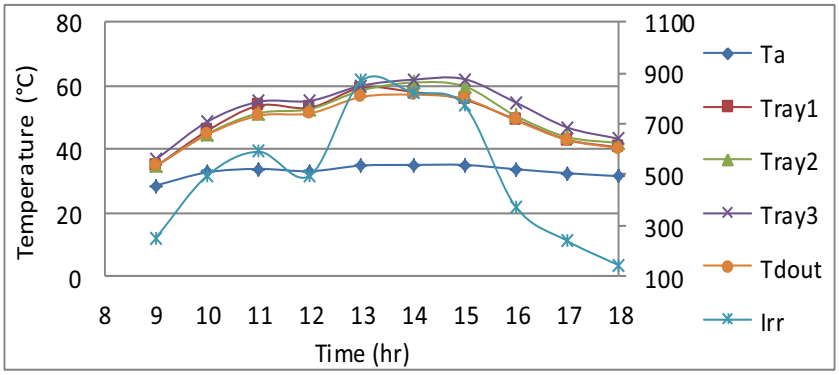

Figure 2: Variation of temperatures and solar radiation with the hours of the day.

This technique was reduced the losses from the walls of dryer and permits the solar radiation to penetrate to inside the dryer. Also it can be seen the temperature of dryer is suitable to dryer almost of product.

The variation of inlet and outlet relative humidity as well as the solar radiation with the hours of the day was illustrated in Fig.3. The outlet relative humidity (RHout) is less than the inlet relative humidity (RHin) in the range (15 – 23) %. The increase in solar radiation leads to decrease the relative humidity.

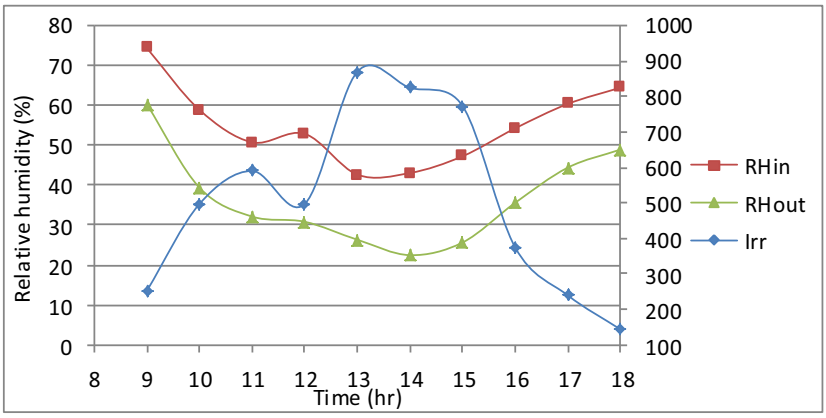

Figure 3: Variation of relative humidity and solar radiation with hours of the day.

The variation of outlet air velocity from dryer and solar radiation is illustrated in Fig.4. The results show the behavior of velocity is the same with the behavior of solar radiation. The velocity was in the range 0.6 – 1.35 m/s through the area of the outlet (0.0176 m^2) when the solar radiation is in the range 150 – 880 W/m^2.

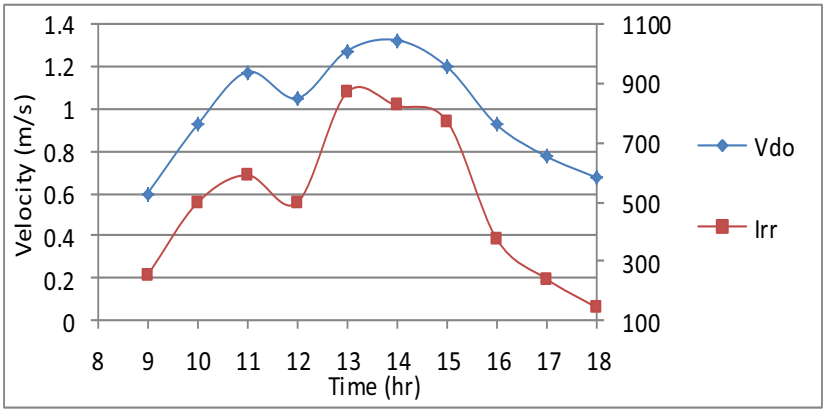

Figure 4: Variation of the velocity of air outlet from dryer and solar radiation with hours of the day.

The variation of trays temperature with change of burning feeding rate of wood was illustrated in Fig.5. Two feeding rates were used to investigate the dryer performance through the night. At feeding rate 490 g/hr the maximum dryer temperature was found to be 80 °C. It is not feasible for drying all of products. At feeding rate 278 g/hr the maximum dryer temperature was found to be 62 °C, which is more suitable for drying many types of products. The result was agreed with the previous researchers. Prasad and Vijay [1] were obtained temperature at the bottom tray was 59.5ºC. Al-Kayiem and Yunus [5] have achieved 60°C dryer temperature, also by using wood chips as biomass fuel in their investigations. In the present work maximum dryer temperature at solar mode was 63°C.

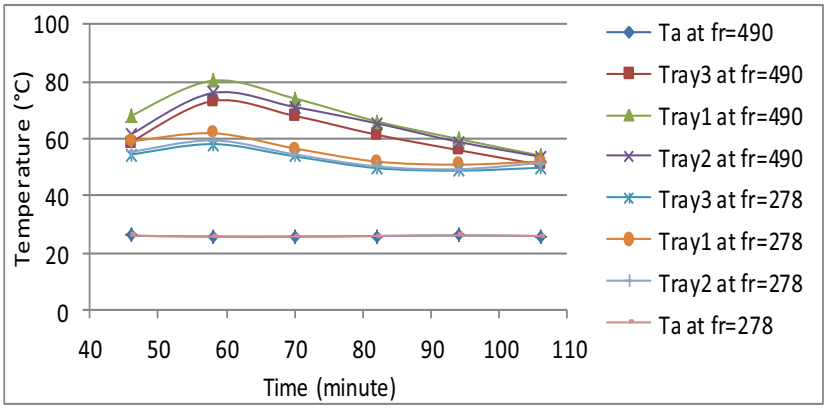

Figure 5: Variation of dryer trays temperatures with different feeding rate of biomass.

The result was agreed with the previous researchers. Prasad and Vijay [1] were obtained temperature at the bottom tray was 59.5ºC. Al-Kayiem and Yunus [5] were obtained 60°C dryer temperature. In the present work maximum dryer temperature at solar mode was 63°C.

5 Conclusions

Experimental evaluation of the drying parameters of hybrid solar dryer was carried out using designed and fabricated prototype. In the solar mode, the maximum dryer temperature is 63°C achieved at the maximum solar irradiation time. The outlet relative humidity is less than the inlet relative humidity in the range of 15% to 23%. The drying temperature is not stable and it follows the irradiation strength. The velocity was in the range 0.6 – 1.35 m/s through the area of the 0.0176 m^2 outlet when the solar radiation in the range of (150 – 880 W/m^2).In the thermal back up mode, the outlet relative humidity is less than inlet relative humidity in the range of 30% to 50%.

It is then recommended that the hybrid solar drying is considerably efficient compared to the mixed solar mode. For extension of the investigation, it is recommended to test the drying performance of various types of agricultural products, as well as the fish.

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