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Drying Characteristics of Lemongrass in Solar Assisted Chemical Heat Pump Dryer

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Abstract. An experimental study was performed to investigate the drying characteristics of lemongrass in solar assisted chemical heat pump dryer under the meteorological Malaysian conditions. A solar assisted chemical heat pump dryer has been designed, and built. The system located on the roof top of a three-storey building at the National University of Malaysia (Universiti Kebangsaan Malaysia). It consists of four main components: solar collector (evacuated tubes type), storage tank, solid-gas chemical heat pump and dryer chamber. Three representative days for sunny, cloudy and semi-cloudy were presented, and two air drying speeds (1m/s, and 3 m/s) have been investigated. The weight was recorded on personal computer at 5 minutes intervals, and about 65 g of fresh lemongrass was dried from average initial moisture content of 9.1 db to an average final moisture content of 0.36 db. The solar assisted chemical heat pump dryer system for agriculture products is superior to the conventional solar dryers, as it can be operated at low temperature and relative humidity.

Keywords: moisture ratio, lemongrass, solar chemical heat pump, drying

1. Introduction

Drying is one of the oldest and most widely used primary methods of food preservation [1]. Drying process provides longer shelf life [2], smaller space for storage [3], and lighter weight for transportation [4]. The aim of drying food products is to enhance the storage stability with minimized pac kaging requirements and reduced transport weights [5]. Sun drying is the common method used to preserve agricultural products in tropical and sub-tropical countries [6]. However, this process has many disadvantages: spoilt products due to rain, wind, moisture and dust; loss of produce due to birds and animals; deterioration in the harvested crops due to decomposition, insect attacks and fungi, etc. Further, the process is labor intensive, time consuming and requires a large area for spreading the produce out to dry. Solar-drying technology offers an alternative which can process the vegetables and fruits in clean, hygienic and sanitary conditions to national and international standards with zero energy costs. It saves energy, time, occupies less area, improves product quality, makes the process more efficient and protects the environment [7]. The low temperature thermal requirement of the heat pump makes the system an excellent match for thermal applications for both domestic and industrial use; such as water heating, solar drying, space cooling, and space heating and cooling. Heat pump dryers have been known to be energy efficient when used in drying operations. A chemical heat pump (CHP) is proposed as one of the potentially significant technologies for effective energy utilization in drying. Ogura and Mujumdar [8] studied the CHP and proposed a chemical heat pump dryer (CHPD) system for ecologically friendly effective utilization of thermal energy in drying. The aim of this paper to investigate the drying characteristics of lemongrass in solar assisted chemical heat pump dryer under the meteorological Malaysian conditions.

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Lemongrass is widely used as an herb in Asian (particularly Khmer, Thai, Lao, Sri Lankan, Vietnamese) and Caribbean cooking. It is commonly used in teas, soups and curries. It is also suitable for poultry, fish and seafood. It is often used as a tea in African countries (Togo).

2. Experiments

2.1. System description

A solar-assisted chemical heat-pump dryer has been designed and built, as shown in Fig. 1. The system is located on the roof top of a three-storey building at the National University of Malaysia (Universiti Kebangsaan Malaysia). Fig. 2 show the photograph of the experimental set-up. The system consists of four mean components solar collector (evacuated tubes type), storage tank, chemical heat pump unit and dryer chamber. In this study, a cylindrical tank is selected as a storage tank. The chemical heat pump unit consists of reactor, evaporator and condenser. In the chemical heat pump a solid gas reactor is coupled with a condenser or an evaporator. The reaction used in this study is:

$$CaCl_2.2NH_3+6NH_3 \rightarrow CaCl_2.8NH_3+ 6\Delta Hr \tag{1}$$

The drying chamber contains multiple trays to hold the drying material and expose it to the air flow. The chemical heat pump operates in heat pump mode. The overall operation of chemical heat pump occurs in two stages: adsorption and desorption. The adsorption stage is the cold production stage, and this is followed by the regeneration stage, where decomposition takes place. During the production phase, the liquid-gas transformation of ammonia produces cold at low temperature in the evaporator. At the same time, chemical reaction between the gaseous ammonia and solid would release heat of reaction at higher temperature. The incoming air is heated by condensing refrigerant (ammonia) and enters the dryer inlet at the drying condition and performs drying. After the drying process, part of the moist air stream leaving the drying chamber is diverted through the evaporator, where it is cooled, and dehumidification takes place as heat is given up to the refrigerant (ammonia). The air is then passing through the condenser where it is reheated by the condensing refrigerant and then to the drying chamber.

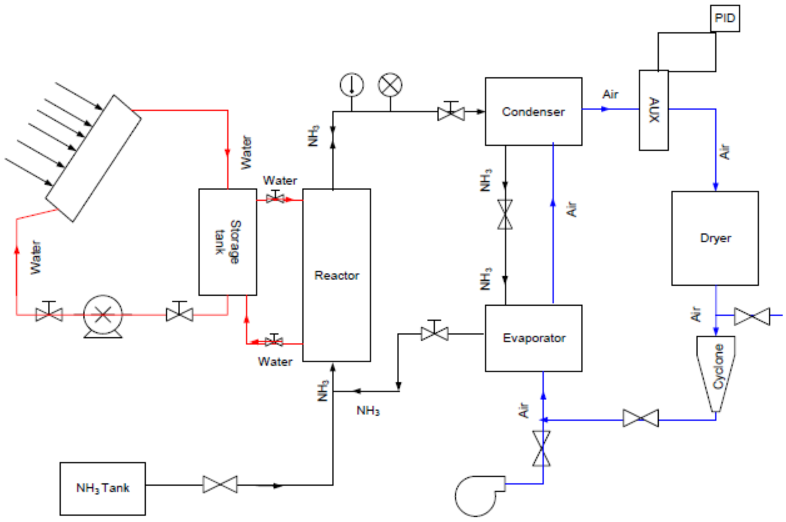

Fig. 1: Schematic diagram of solar assisted chemical heat pump dryer

2.2. Instrumentation

A well-equipped instrumentation system is deployed to measure various properties of the drying process, such as temperature, pressure, humidity and velocity. For the measurement of temperature at different locations of air, water and refrigerant path, K-type thermocouples are used, and for measurement of pressure at different locations of the system pressure gauges are used. Vane type anemometer is used to measure the flow rate and velocity of the air, and the flow rate of refrigerant is measured with the help of a Hydorex flow meter. A pyranometer is mounted near the collector to measure the instantaneous solar radiation. The relative's humidities of the air entering and leaving the drying chamber are measured with the help of two humidity transmitters. The weight data of the drying material was recorded on personal computer at 30 second intervals using the data acquisition software. The power consumption of the system is measured by a

Wattmeter. Shimadzu digital balance (model UX2200H, Capacity of 2200g, Readability of 0.01g, Shimadzu Corporation, Japan) is used to weigh the mass of Lemon grass. Moreover, the data was recorded at 5 minutes on a personal computer. The initial and final moisture were determined using gravimetric method at 105 °C using convective oven. The various readings of instruments are monitored continuously and recorded with the use data loggers. The acquired data from the data loggers are transferred to personal computer for further analyses.

Fig. 2: Photograph of the experimental set-up

2.3. Moisture ratio

The moisture ratio (MR) is the ratio of the moisture content at any given time to the initial moisture content (both relative to the equilibrium moisture content). It can be calculated for each time interval using the following formula:

$$MR = \frac{M - M_e}{M_o - M_e} \tag{2}$$

where

M is the instantaneous moisture content, (gw/gdm^{-1})

Mo is the initial moisture content, (gw/gdm^{-1})

Me is the equilibrium moisture content, (gw/gdm^{-1})

The amount of moisture in a product is designated on the basis of weight of water is:

$$\%MC_{db} = \frac{W_w}{W_d}(100\%) \tag{3}$$

3. Results and Observations

Drying characteristics of lemongrass in solar assisted chemical heat pump dryer has been investigated for various environmental climate conditions. Three representative days for sunny, cloudy and semi-cloudy are presented. The drying curves are formed by the measurement of the material moisture content as a function of time under constant drying air conditions. The temperature 55 ^oC and two air drying speed (1m/s, and 3m/s) has been investigated under different meteorological Malaysia conditions. The weight was recorded on personal computer at 5 minutes intervals, and about 65g of fresh lemongrass was used in each run. The lemongrass was dried from average initial moisture content of 9.1 to an average final moisture content of 0.36 (g water per g dry matter). The hourly average values of meteorological data (hourly radiation and ambient temperature) for a typical sunny day, the hourly average values of meteorological data for a typical cloudy day, and the hourly average values for a typical semi- cloudy day in Malaysia, are shown in Fig. (3a, 3b, and 3c, respectively). Fig. (4a, 4b, and 4c) present the plotting of the experimental and predicted moisture contents, expressed as dimensionless moisture ratio (MR) against the drying time at constant temperature 55^oC and constant air speed 1 m/s, for sunny, cloudy and semi-cloudy days, respectively. It was obvious, that the lines of experiments and predicted moisture contents data were identical for the most of the drying time.

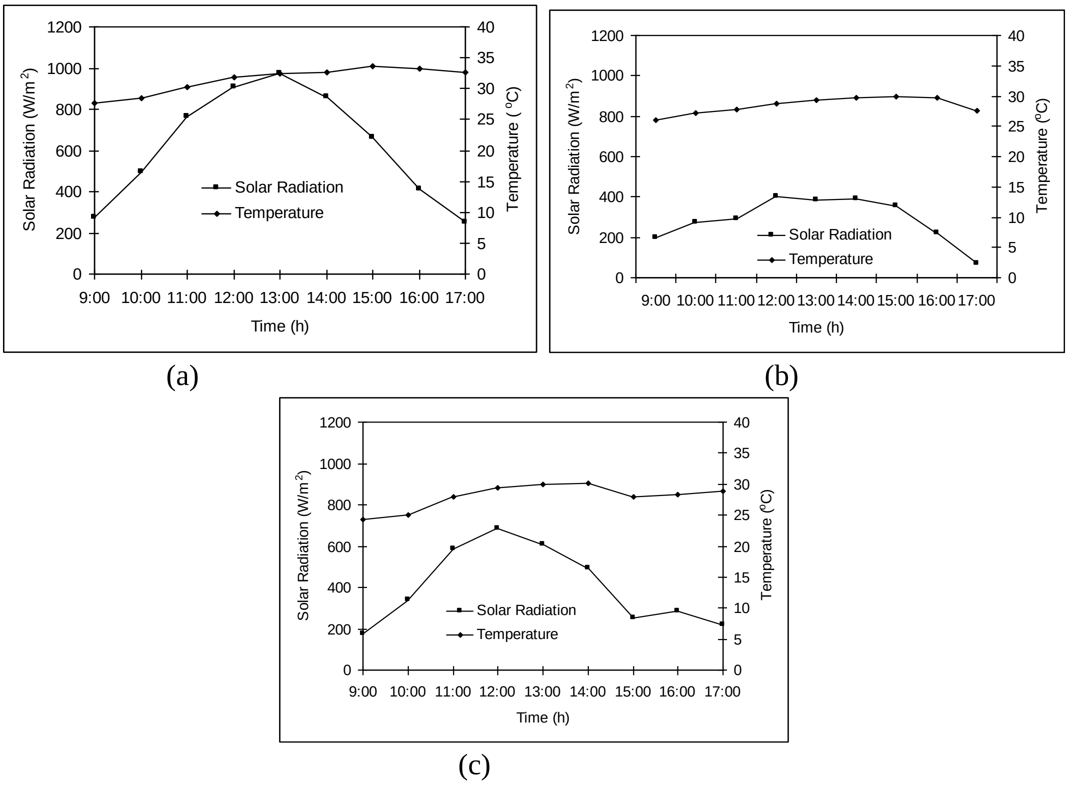

Fig. 3: Average hourly radiation and ambient temperature in Malaysia for: (a) typical sunny day, (b) typical cloudy day, and (c) typical semi-cloudy day

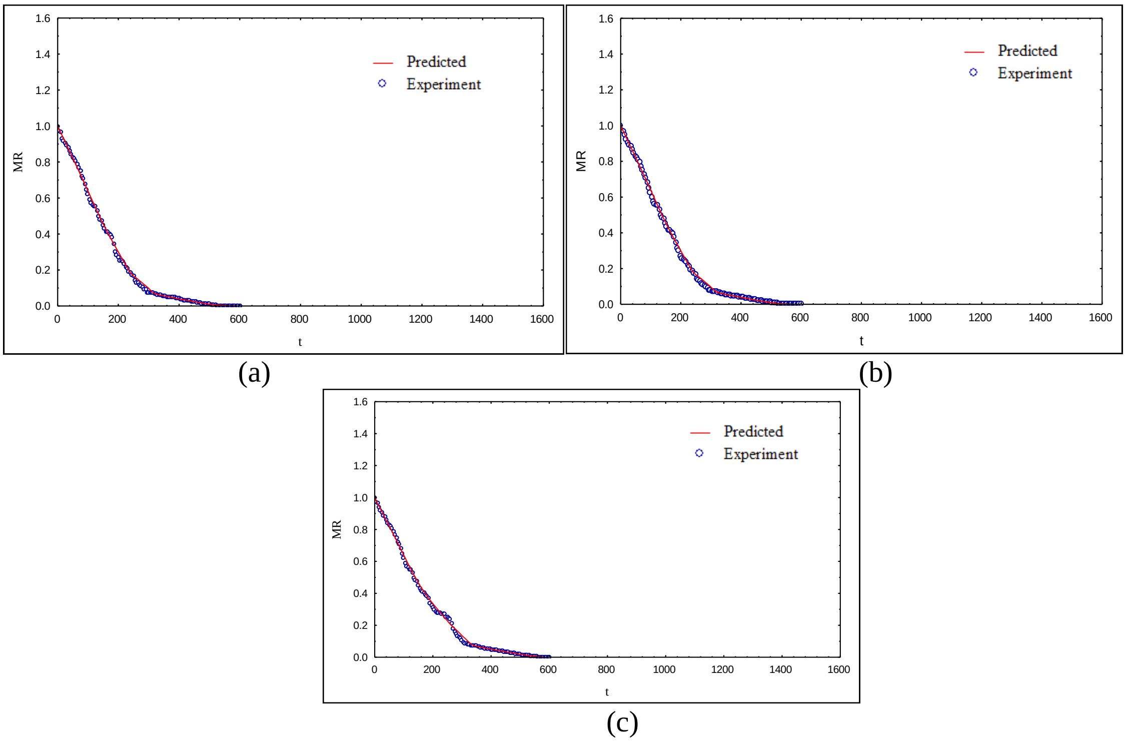

Fig. 4: Comparison between predicted and experimental moisture ratio of lemon grass for: (a) sunny day, (b) cloudy day, and (c) semi-cloudy day

The effects of changing air velocity on the drying curves of lemongrass have been studied. Two velocities was applied (1m/s and 3 m/s) at fixed drying temperature 55 ^{o}C. Fig. 5 illustrates the effects of changing air velocity on the drying curves of lemongrass at fixed drying temperature. It was noticeable that the effect of air velocity on the drying time was very low. Compared to the drying air temperature, changing in air velocity was not considerably accelerating the drying process, as it was observed in pervious works of several authors [9].

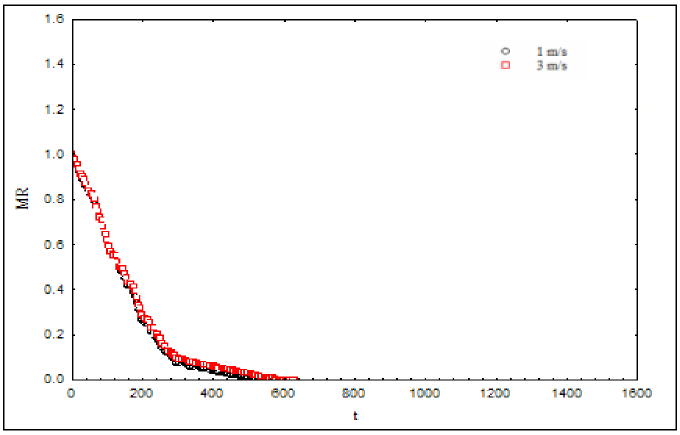

Fig. 5:MR against time at 1 and 3 m/s (55 ^{o}C)

4. Conclusion

The drying characteristics of lemongrass dried in solar assisted chemical heat pump dryer have been Investigate under different meteorological Malaysia conditions. The lemongrass was dried from average initial moisture content of 9.1 db to an average final moisture content of 0.36 db. It was obvious that the lines of the observed moisture contents and predicted moisture contents data were identical for the most of the drying time. The total energy required to maintain a drying temperature of 55 ^{o}C is about 60 kWh over nine hours drying time. The total system energy output from the experiment at clear day is 51 kWh against 25 kWh of cloudy day and 31.8 kWh of semi-cloudy day. Any reduction of energy at condenser as a result of a decrease in solar radiation will decrease the coefficient of performance as well as decrease the efficiency of drying.

5. Acknowledgements

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