Incorporation of Two Columns of Desiccant Beds into a Solar Drying System: Evaluation of Drying System Performances

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Abstract:- The objective of this study was to evaluate the performance of a solar assisted dehumidification system. This system as incorporation of two columns of desiccant beds into a solar drying system. The main components of the a solar assisted dehumidification system consist of a solar collector, an energy storage tank, an auxiliary heater, two blowers, two columns of desiccant beds (adsorber columns), two water-air heat exchanger, two water circulating pumps, a drying chamber and other ancillary equipment. Silica gel was selected as the desiccant material due to low temperature regeneration. The performance of this system has been investigated under the meteorological condition of Malaysia. A computer program was developed in MATLAB software to calculate the performance of the drying system. The performance indices considered to calculate the performance of the drying system are: Pick up efficiency (η_P), Solar Fraction (SF) and Coefficient of Performance (COP). The results indicated that the maximum values of the pick up efficiency (η_P), solar fraction (SF) and coefficient of performance (COP) was found 70%, 97% and 0.3, respectively with initial and final wet basis moisture content of *Centella Asiatica* L 88% and 15%, respectively at an air velocity is 3.25 m/s.

Key-words: - Performance of the drying system; Dehumidification; Drying of *Centella Asiatica* L.

1 Introduction

The last few decades, considerable importance has been placed on the rational use of energy resources. The increase energy demand in the world and depletion of conventional energy resources, and its adverse on environment has created renewed interest for the use of renewable energy resources. Solar energy provides an alternative to use of conventional energy resources due to its abundance, environmentally friendly, has no moving parts to break down, and does not require much maintenance [1].

Malaysia as tropical country receives abundant solar radiation and having characterized by an average daily solar radiation of about 500-700W/m^2 [2]. This could be used as energy sources for drying foods or other heat sensitive, biologically active products by using solar collector devices.

Centella Asiatica L (CA) belong to the family of umbrelliferae is commonly found in parts of India, Asia and The Middle East. It is known as 'Daun Pegaga' in Malaysia, 'Luei Gong Gen' or 'Tung Chain' in China, 'Vallarai' in Tamil Nadu (India) and 'Daun Kaki Kuda' in Indonesia [3]. *Centella Asiatica* L is a traditional herbal medicine has been used in Asia for hundreds of years [4]. It contains pentacyclic triterpenes, mainly asiatic acid, asiaticoside, madecassic acid and madecassoside [5]. It is has been used for improving memory, treating mental fatigue, anxiety, and eczema [6], curing leukorrhea and toxic fever [7], antitumor [8], antiproliferative [9], antigenotoxic [10], anti-inflammatory, anticancer, antioxidation and anxiolytic [11,12].

After harvesting *Centella Asiatica* L contain high moisture content (85%-89%, wet basis) and it's highly perishable. Therefore, after harvesting its must be dried as soon as possible to reduce the moisture content to such a level where spoilage due to the various reactions is minimized and to prevent the expected contamination by rodents, birds, insects, dust and dirt [13,14].

In the drying process, beside removal of water the drying time, operation cost, the quality of dried product and performance of drying system must be taken into consideration [15].

In Malaysia, conventional hot air drying method is commonly used for drying foods or other heat sensitive (medicinal herbs), biologically active products. Although the method is very cheap and practice, however the conventional hot air dryers which are clearly not suitable to dry them because this method it quality of the products degrades significantly because of heating for long period. To decrease the drying time, air temperature should be increased.

The high drying air temperature may remove important ingredients, cause color reactions and degrade the product resulting in low product quality [16-18]. The low product quality may have adverse economic effects on domestic and international markets value of the product [19]. Therefore, low temperature drying technologies must be applied to minimize quality degradation of the products and short drying time. Solar assisted dehumidification system is an alternative method for drying of foods or other heat sensitive, biologically active products. Because of this system operated with less relative humidity and lower temperature. The solar assisted dehumidification system as incorporation of two columns of desiccant beds into a solar drying system and in this system to decrease the drying time or to increase drying potential, the water vapor in air removed using desiccant materials in column of desiccant bed before used for drying process.

The objective of this study was to evaluate the performance of a solar assisted dehumidification system for drying *Centella Asiatica* L. A computer program developed in MATLAB software to calculate the performance of drying system**.** The performance of this drying system is indicated by Pick up efficiency (η_P), Solar Fraction (SF) and Coefficient of Performance (COP).

2 Description of Solar Assisted Dehumidification System

The system consists of a solar collector, an energy storage tank, an auxiliary heater, two blowers, two columns of desiccant beds (adsorber columns), two water-air heat exchanger, two water circulating pumps, a drying chamber and other ancillary equipment. The schematic diagram of the solar assisted dehumidification system is shown in Fig 1. The solar collectors used were 60-evacuated heat pipes tube arranged in parallel with total area of 6 m^2. The area of absorber in tube each individual was 0.1 m^2, and distance between the tubes was 7.1 cm. The pump electrical capacity was 0.1 kW and was used to circulate water from the water tank to the solar collectors. The water tank with diameter of 45 cm and height of 85 cm was made from stainless steel and insulated using glass wool and foam rubber. Two units of cross flow type heat exchanger have been used. This system has two adsorber columns with dimension of 25 cm (width) x 25 cm (length) x 100 cm (height). The columns were filled up with silica gel to a height of 85 cm. The drying chamber was of the cabinet type with the size of 1.0 m (width) x 1.0 m (length) x 2.5 m (height). The chamber contains the drying trays with adjustable racks to place the medicinal herbs. The dry air from the adsorber column entered the drying chamber at the bottom and exit through an air vent at the top. The dry air was circulated by using blower with electrical capacity of 0.75 kW. Water in the heat storage tank is recirculated in the solar collector by the heat collection pump and this recirculation eventually raises the water temperature in the tank. Since the water in the storage tank is utilized for both the regeneration of the absorbent at a higher temperature and the drying process at a lower temperature, a temperature level of about 70°C-80°C is required. If the solar collector could not raise the water temperature up to this level, then the auxiliary heater is used to supplement the heat energy required to do so. The hot water is first used to produce hot air in the hot water-air heat exchanger for regeneration of adsorbents in one adsober column, and to warm dehumidified air from the other adsorber column in the warm water–air heat exchanger for drying in the drying chamber by manipulation of the two three-way valves. Fresh air for both regeneration and adsoprtion/drying is drawn in by the two blowers.

The adsorbents are packed in two adsorber columns so that air dehumidification could run continuously by simultaneous bed regeneration and adsorption in alternate bed as follows. Regeneration of adsorbents in the adsorber column (B) is carried out by heating the air drawn in by the air blower (B) in the hot water-air heat exchanger (B) and passing the hot air into the adsorber column (B) so that moisture is desorbed and removed from the adsorbents into the atmosphere. At the same time, drying is carried out in the drying chamber by heating the air drawn in by the blower (A) that is dehumidified by adsorber column (A) in the warm water-air heat exchanger (A) and passing the warm dehumidified air into the drying chamber. When the adsorbents in the adsorber column (A) are saturated with moisture and the regenerated adsorbents in the other adsorber column (B) are fully regenerated, then the regeneration process is switched to the saturated adsorber column (A) and the adsorption process is switched to the another adsorber column (B) by manipulation of the two three-way valves.

3 Instrumentation

In order to evaluate the performance of the drying system, measurements of temperatures, humidities, moisture contents, air velocities, static pressures, solar radiation on collector surface and on horizontal, mass and density of *Centella Asiatica* L sample were made during tests conducted. Dry bulb temperatures were measured with type-K thermocouples. Solid-state hygrometers were used to measure humidities at different locations. A hygrometer with type-K thermocouples was also used to measure dry-bulb and wet-bulb temperatures at selected locations in the dryer. These temperatures were used to obtain air humidities from psychometric charts. A turbine flow meter is used to measure the flow rate and velocity of the air. The flow rate of water is measured with the help of a water flow meter. The instantaneous solar radiation has been measured by using the Eppley Pyranometer and mounted near the collector on the plane of the collector. Static pressures were measured periodically by a U-tube micrometer. The moisture measurement in the product has been done with the help of a weighing machine. The power consumption of the system is measured by a wattmeter.

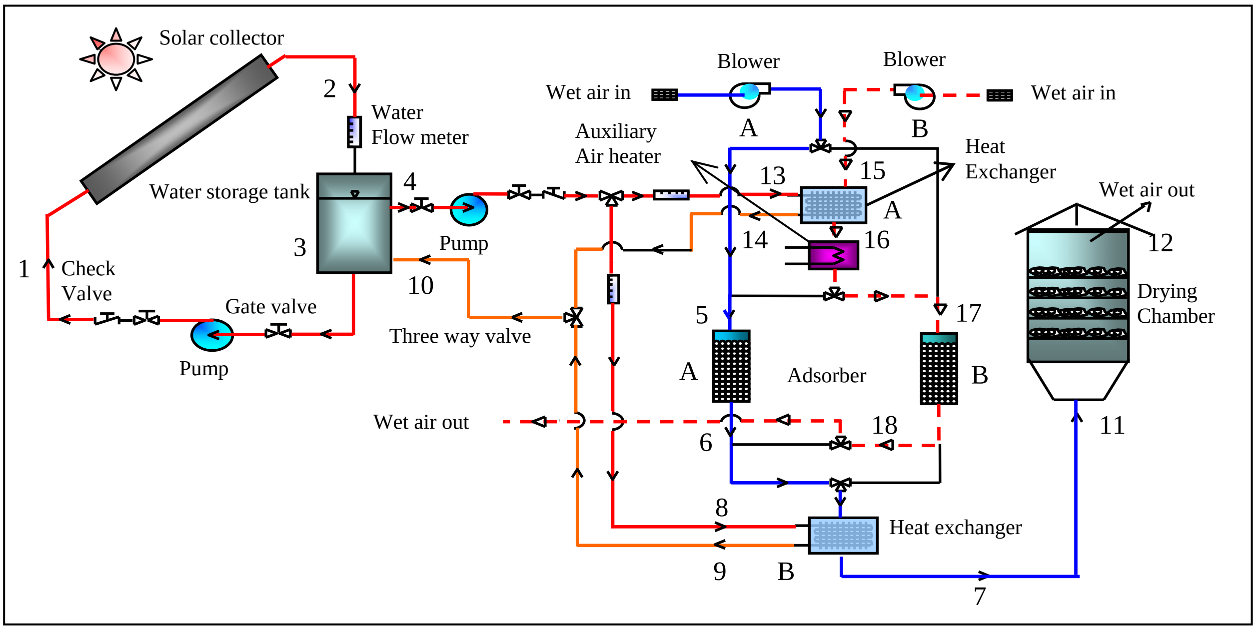

Figure1. Schematic diagram of the solar assisted dehumidification system

4 Procedures

Fresh *Centella Asiatica* L was bought from the local market in Kajang, Selangor, Malaysia and cleaned thoroughly before use. The initial moisture content of the *Centella Asiatica* L sample was 88% wet basis. This sample was placed on a tray in the drying chamber. Weight loss of the sample was recorded every 15 minutes by a weighing machine located inside the drying chamber.

5 Result and Discussion

The drying process of fresh *Centella Asiatica* L with initial weight and initial moisture content of about 3 kg and of 88% wet basis, respectively was conducted in two days and each day was started at 10 am and continued till 4 pm. The *Centella Asiatica* L dried to final weight and final moisture content of about 0.37 kg and 15%, respectively at an air velocity is 3.25 m/s. The performances of solar assisted dehumidification system as shown in Figure (2-10).

The variation of solar radiation and ambient relative humidity during experimentation is shown in Fig.2. At the first day a maximum solar intensity of 972 Wm^{-2} was observed and the ambient relative humidity varied between 52% and 78% with an average of about 63%. For the second day a maximum solar intensity of 941 Wm^{-2} was observed and the ambient relative humidity varied between 53% and 78% with an average of about 65%.

Figs.3 and 4 show variations of drying chamber inlet and outlet air temperature and the corresponding relative humidity at inlet and outlet drying chamber respectively. As seen from figure the drying chamber inlet air temperature was maximum at noon and was about 50^{o}C while the corresponding relative humidity was the minimum and it was about 20%. This stated that the drying air condition is suitable for drying heat sensitive product like *Centella Asiatica* L because of drying process conducted at low air temperature and low relative humidity.

Fig.5. show variation of the moisture content of *Centella Asiatica* L with time. Its moisture content in drying chamber was reduced from an initial value of 88 % wet basis to the final value of 15 % within 2 days or over drying time of about 12 hours.

Fig.6. show variations pick up efficiency of drying system with time. The pick up efficiency depend on the evaporation of moisture from the products being dried inside the drying chamber. It can be seen from this figure that the pick up efficiency always declines during drying process, it because of the evaporation of moisture rate also declines. The pick up efficiency of drying system maximum values were observed at the first day and second day of about 97% and 29%, respectively.

Figs.7 and 8 show variations of energy contribution for drying process and regeneration process respectively. As seen from figure that both these process, the energy contributed by auxiliary heater corresponding with energy contributed by solar collector. The energy contributed by auxiliary heater decreased with increase in the energy contributed by solar collector, this stated that less electrical energy required for drying process and regeneration process, respectively.

Fig.9. show variation of energy contributed by solar collector, auxiliary heater and blower and pump respectively to dehumidification system for drying *Centella Asiatica* L from initial weigh of 3 kg to final weigh of 0.37 kg over drying time of about 12 hours at an air velocity is 3.25 m/s. It can be seen from this figure that total energy required of 47609 kJ, this energy contributed by solar collector, auxiliary heater and pump and blower of about 25315 kJ, 17829 kJ and 4464 kJ, respectively

Fig.10. show variation of solar fraction (SF) with time. The solar fraction depends on the instantaneous solar radiation. With an increase of solar radiation, the collector absorbs more energy, which is transferred to the water flowing though the collector and, hence, increases the solar fraction. At the first day and second day a maximum solar fractions of about 70% and 68% was observed, respectively.

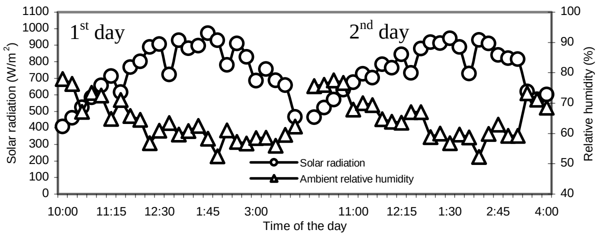

Fig.2. Variations of solar radiation and ambient relative humidity with time.

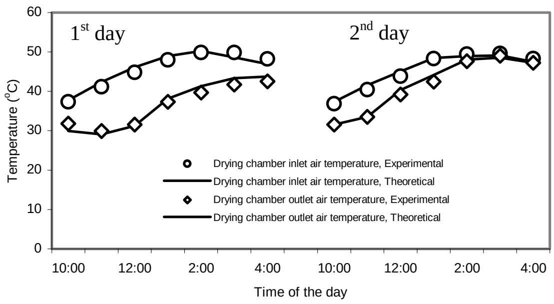

Fig.3. Variations of drying chamber inlet and outlet air temperatures with time.

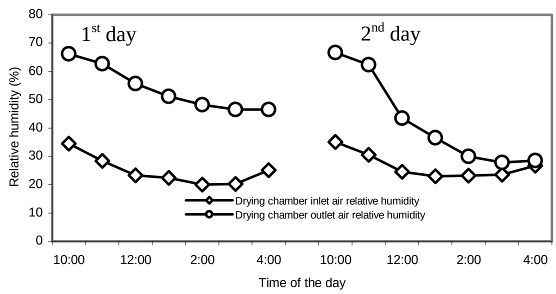

Fig.4. Variations of drying chamber inlet and outlet air relative humidity with time.

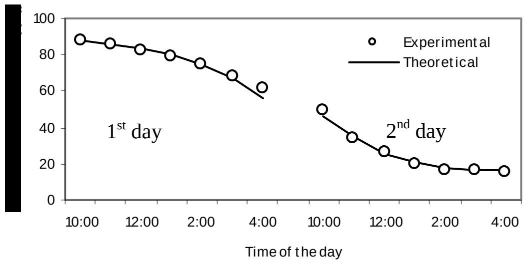

Fig.5. Variations of moisture content of *centella asiatica* L with time.

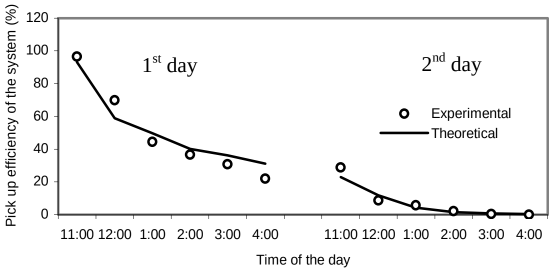

Fig.6. Variations of pick up efficiency of the system with time

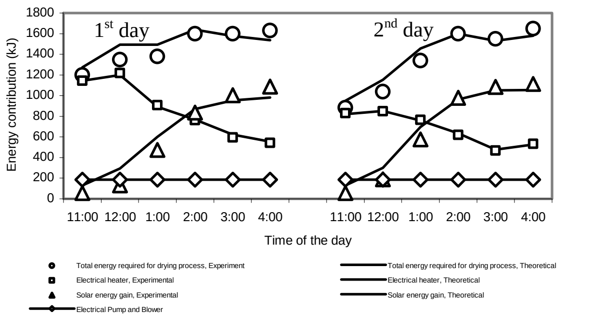

Fig.7. Variations of energy contribution for drying process L with time.

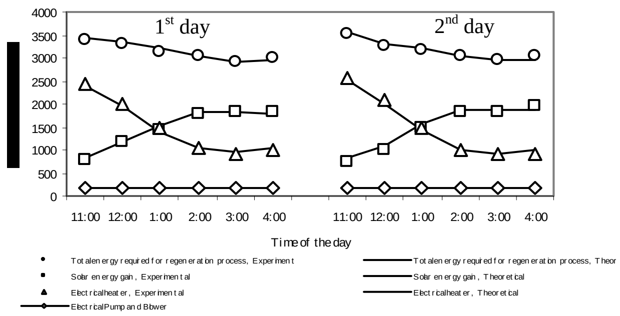

Fig.8. Variations of energy contribution for regeneration process L with time.

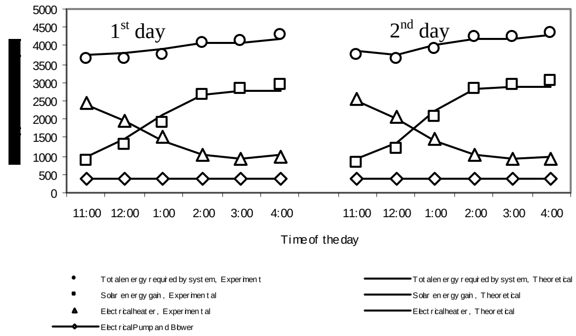

Fig.9. Variations of energy contribution for dehumidification system with time.

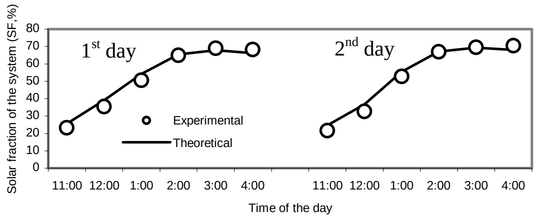

Fig.10. Variations of solar fraction of the drying system (SF) with time.

6 Conclusions

An experimental investigation on the performance of a solar assisted dehumidification system was conducted for drying *Centella Asiatica* L. The *Centella Asiatica* L must be dried for storage before extraction of the active component. The performance of this drying system is indicated by Pick up efficiency (η_P), Solar Fraction (SF) and Coefficient of Performance (COP). The maximum values of the pick up efficiency (η_P), solar fraction (SF) and coefficient of performance (COP) was found 70%, 97% and 0.3, respectively with initial and final wet basis moisture content of *Centella Asiatica* L 88% and 15%, respectively at an air velocity is 3.25 m/s. Based on this results indicated that the solar drying system suitable for drying heat sensitive product like *Centella Asiatica* L because of drying process conducted at low air temperature and low relative humidity. Also the solar drying system may be developed for pilot scale because of contribution of energy from solar is very high.

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