EXPERIMENTAL INVESTIGAT OF DRAYING CHILI BY SOLAR ASSISTED HEAT PUMP DRYER WITH MULTIFUNCTIONAL SOLAR THERMAL COLLECTOR

MOHAMMAD MEHDI SALEHI DEZFOULI, ZAFRI AZRAN, MOHD HAFIDZ RUSLAN, AHMAD FUDHOLI, KAMARUZZAMAN SOPIAN

Solar Energy Research Institute (SERI), Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor,
MALAYSIA.

Email: salehi.solar@yahoo.com

Abstract: This paper has been studied on moisture content changes of dried medical herbs (ginger, lemon grass, onion and turmeric) using solar drying. The experimental of drying has been done in different mass flow rate. In first chamber, drying of medical herbs was carried out at mass flow rate 0.12 kg/s with an average temperature of 44 º C and humidity chamber of 27%. Meanwhile, second chamber drying of medical herbs was carried out at mass flow rate 0.06 kg/s with an average temperature of 54 º C and humidity chamber of 21%. The result shows that for turmeric, ginger and lemon grass, the initial content wet basis were 83 %, 89%, and 65% with took 3.5 h, 4 h and 4.5 h to reach the final content wet basis about 8 %, respectively. For onion, shows that the time period of 4.5 h is required to reduce the moisture content of 78 % to 10 % at 44 °C with air relative humidity 27 %.

Keywords: Solar drying, moisture content,

1. Introduction

Chili have many health benefits for people where are in humid area. On the other hands, chili would be good candidates of health foods to help person adapt high humidity environment. May because of this reason Malaysian people, they using chili in the most of their daily foods. It is interesting that chili is easy to grow in area where are humid and warm, but keeping chili in humid area as fresh is very difficult. Therefore, chili has to as dried for keeping on long time. On of the traditional method for drying chili is open sun drying by using solar energy[1]. With this method, substantial losses of chili due to insects, animals and rain usually occur during drying[2].

Scientific and researchers had many studies on the various methods to improve drying chili by using solar energy draying for solve these problems. Hossain and bala[3] designed a solar tunnel drier can be used to dry up to 80 kg of fresh chilies. They concluded that the use of this drier led to considerable reduction in drying time in comparison to that of conventional sun drying considerable reduction in drying time in comparison to that of conventional sun drying. Desai et al[4], fabricated and evaluated a PAU model farm solar dryer for chili drying. Their result showed that there is saving in drying time of 37.5 per cent for farm solar dryer over open sun drying. Tunde-Akintunde [5] has studied Mathematical modeling of sun and solar drying of chili to select a suitable drying equation. The Page model was found to best describe the drying behavior of chili pepper for sun and solar drying [6]. Kaewkiew et al[2]investigated performance of a large-scale greenhouse type solar dryer for drying chilli. They designed one solar dryer for chilli that nine DC fans powered by three 50 W solar cell modules were used to ventilate the dryer. The performance of an indirect forced convection solar drier integrated with heat storage material was designed, fabricated and investigated for chili drying by Mohanraj[7].The four varieties chilies (pricked and unpicked) were dried at different drying air temperatures of 45, 50, 55,60, and 65C to moisture content of 8% db by arora et al.[8]. Yong et al.[9] have investigated the effect of different mechanical pretreatments on the drying kinetics, color and volumetric shrinkage of chili in a heat pump convective dryer experimentally. Results showed that the drying performance of the products that possess a skin of low moisture diffusivity, such as chili, can be improved significantly by making perforations in the skin. All of studies that mentioned above have investigated on various dryer systems to develop draying chili.

One of the common dryer systems is heat pump dryer. Heat pump includes four main parts such as evaporator, compressor, expansion valve, and condenser [10-12]. The condenser provides heat in dryer chamber and evaporator can be removing the moisture content in dryer chamber, and hence it acts as dehumidifier [13, 14]. One important parameter in the drying process is the temperature of dryer chamber. Zafri et al. [15] have designed a heat pump dryer with assistant multifunctional solar thermal collector to increase temperature of dryer chamber and efficiency. This paper presents a study on experimental investigation draying chili by heat pump dryer with assistant multifunctional solar thermal collector.

2. Material and Methods

2.1 Experimental setup

The heat pump dryer with assistant multifunctional solar thermal collector was installed at Solar Technology Park, UKM Malaysia. The dryer has a length of 0.65 m, width of 0.65 m and height of 0.65 m. Capacity of dryer is about 20 kg of fresh chili. The dryer consists of a cubic structure made form aluminum sheets. The collector consists of aluminum rods and fins that are covered by transparent plastic sheet on the top, and rubber foam on the bottom. It has length of 0.65 m, and width of 0.65 m. The symbolic view of the dryer is shown in Fig. 1. This system includes four operations such as heat pump without solar collector, heat pump with solar collector, solar collector as cooling system, and solar thermal collector as an evaporator. Base on importance of temperature for chili drying, heat pump with solar collector considered to chili draying in this study. In fact, by combining two heat sources (heat pump, and solar energy), draying efficiency will be increase.

The heat pump-solar dryer involve three main systems: heat pump system and solar system, drying chamber. As it is shown in Figure.2 (schematic diagram of the system) is including heat pump system and the multifunctional solar thermal collector that are attached together.

In this system, solar thermal collector has two outputs (a, and b), and one input(c). The dryer chamber has two outputs (g, and f) and two inputs (e, and d).

The hot air from first thermal collector output (a) can be arriving to draying chamber (d) as direct by aluminum cannel. The air can be return back to input collector(c) from output draying chamber (g). Second output of solar thermal collector (b) acted as an evaporator to provide hot air for enters to heat pump evaporator. The compressor compressed working fluid of heat pump (R134a) that is superheated by evaporator of heat pump. The hot air for draying chamber (e) provides by releasing heat of working fluid with high temperature and pressure in condenser. Then, the high pressure R134a becomes liquid in super cool form by expansion valve. Output humid air from drying chamber (f) is passed though heats pump evaporator and becomes non-wet air.

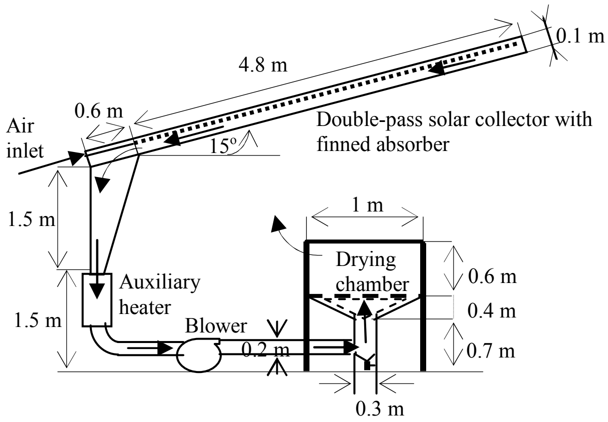

Fig. 1. The Symbolic view of Heat pump-solar dryer

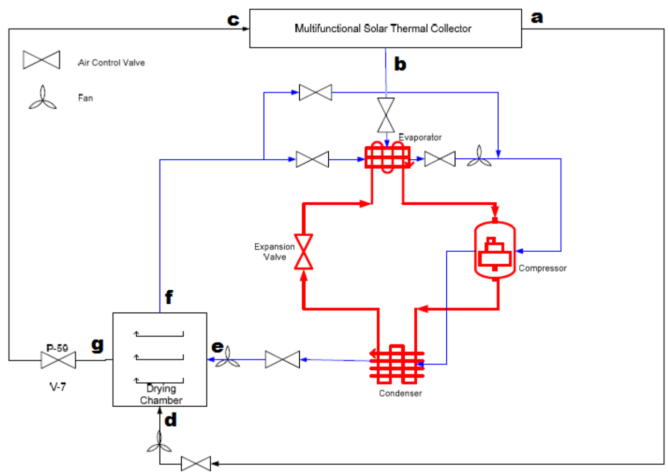

Fig. 2. The schematic diagram of the system

2.2 Experimental procedure

In this study 15 kg of Chili (80% wb) was ready to drying operation in the heat pump-solar dryer to determine its possibility for drying chili. The chili peppers were washed in fresh water. Chilies were placed in three trays (that each tray includes 5 Kg chili) at draying chamber to determine the moisture loss of chilies during experiments. Draying chili experiment was done between 10:00 AM to 6:00 PM. By using digital electronic balances, the moisture loss of chili was determined.
The data were measured solar radiation, air temperature (ambient temperature and chamber temperature), and relative humidity. Solar radiation was measured by a pyranometer, air temperature was measured by T-type thermocouple, and relative humidity was measured by sensors where were installed in middle of drying chamber.
To experimental test of open sun chili draying, one tray include 5 kg fresh chili was placed on the influence the sun. During the drying procedure, moisture content was evaluated by the weight of the chilies in the one tray of dryer chamber and tray of open sun. The temperature and relative humidity in heat pump-solar drier were recorded at 1 minute intervals during experiments by the ADAM Data Acquisition System connected to a computer. The experimental chili drying data was investigated in terms of reduction in moisture content and moisture ratio by increase draying time [16, 17].

2.3 determination of moisture content

The moisture content of chili (M) can be analyzed by two methods such as wet basis (wb) and dray basis (db) that shown respectively in Eq. (1), and Eq. (2).
The moisture content wet basis

$$M_{wb} = \frac{M_t - M_d}{M_t} \times 100\% \quad (1)$$

The moisture content dry basis

$$M_{db} = \frac{M_t - M_d}{M_d} \quad (2)$$

Where,
M_t = mass of wet chilies at instant t
M_d = mass of dry chilies

2.4 determination of moisture ratio

To better explain chili drying behavior, moisture ratio (MR) was calculated by using Eq. (3).

$$MR = \frac{M - M_e}{M_o - M_e} \quad (3)$$

Where,
M = Moisture content of the product, M_o = Initial moisture content, M_e = Equilibrium moisture content.

3. Results and Discussion

Fig. 3 showed experimental result of drying with mass flow rate of 0.12 kg/s, which obtained drying chamber temperature range around 29 °C to 50 °C, and an average temperature chamber about 44 °C. Also, relative humidity of drying chamber around 14 % to 68 % with average about 27 %. Fig. 4 showed experimental result of drying with mass flow rate of 0.06 kg/s, obtained drying chamber temperature range around 31 °C to 66 °C with average about 54 °C. Also, relative humidity of drying chamber around 12 % to 48 % with average about 21 %.

Fig. 5 and Fig. 6 showed decrease in moisture content wet basis and dry basis of drying at 27% RH and mass flow rate of 0.12 kg/s, respectively. For mass flow rate of 0.06 kg/s and average humidity of 21%, decrease in moisture content wet basis and dry basis showed in Fig. 7 and Fig 8. Decrease in moisture content wet basis of drying time at different mass flow rate was shown in Fig. 9 to Fig. 11 respectively.

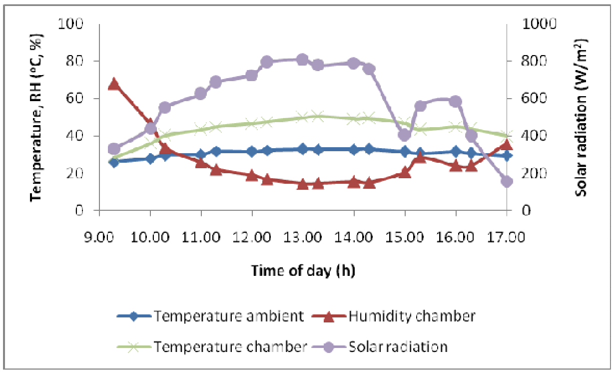

Fig. 3. Air temperature and relative humidity of drying chamber at mass flow rate 0.12 kg/s

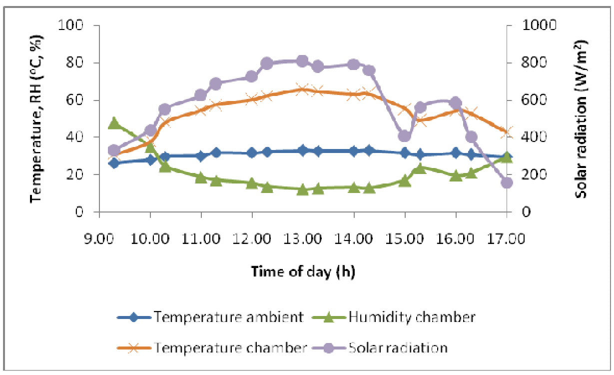

Fig. 4. Air temperature and relative humidity of drying chamber at mass flow rate 0.06 kg/s

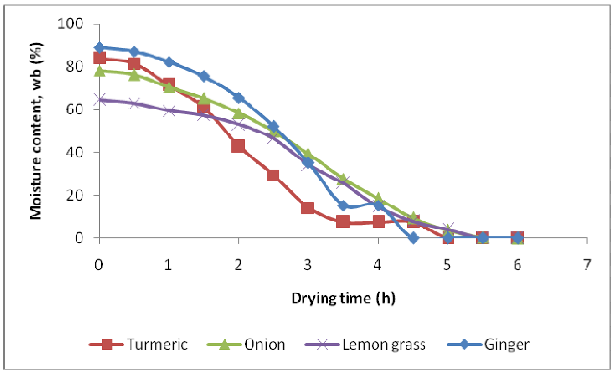

Fig.5. Drying curve: wet basis moisture content versus drying time at 27% RH and mass flow rate of 0.12 kg/s

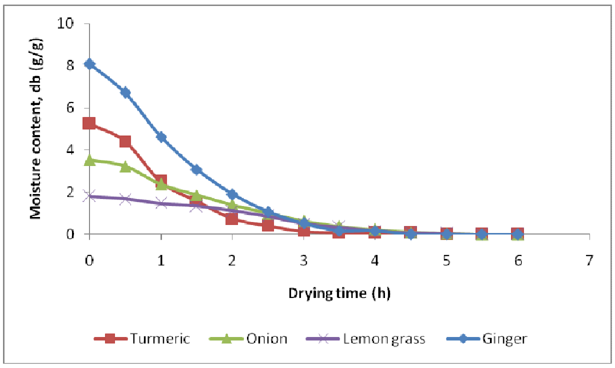

Fig. 6. Drying curve: dry basis moisture content versus drying time at at 27% RH and mass flow rate of 0.12 kg/s

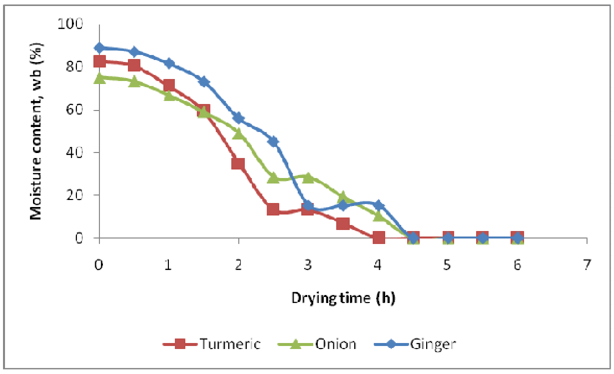

Fig.7. Drying curve: wet basis moisture content versus drying time at 21% RH and mass flow rate of 0.06 kg/s

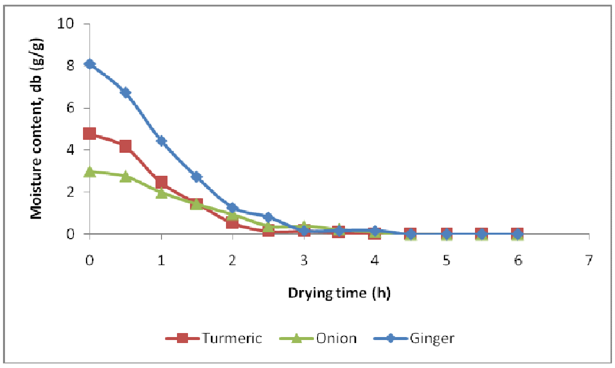

Fig. 8. Drying curve: dry basis moisture content versus drying time at at 21% RH and mass flow rate of 0.06 kg/s

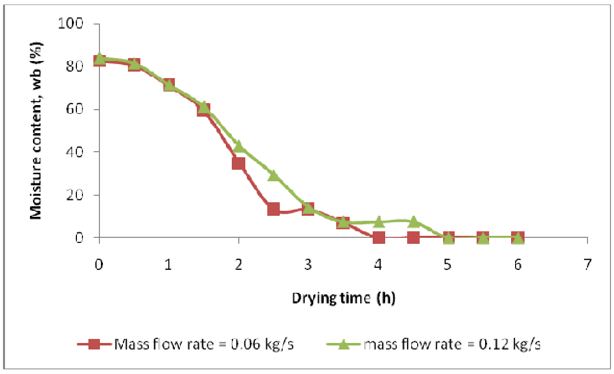

Fig.9. Drying curve: wet basis moisture content versus drying time for turmeric at different mass flow rate

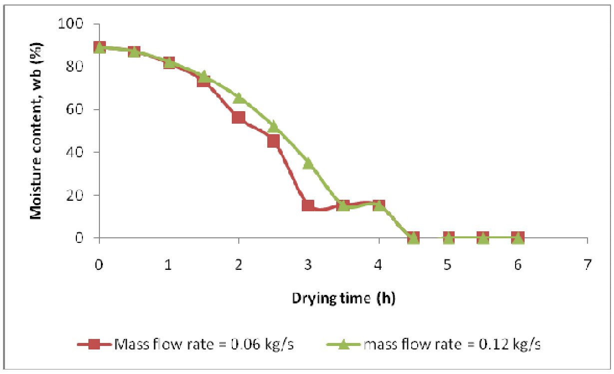

Fig.10. Drying curve: wet basis moisture content versus drying time for ginger at different mass flow rate

ISBN: 978-1-61804-114-2

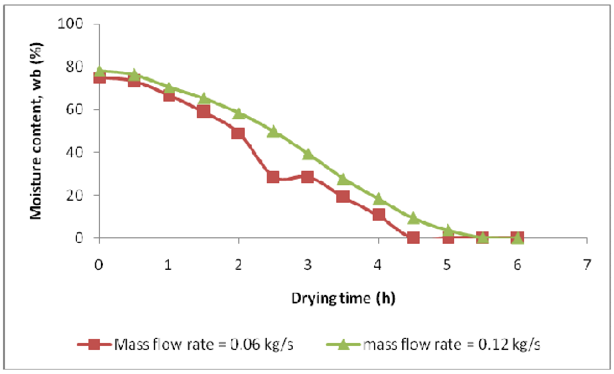

Fig.11. Drying curve: wet basis moisture content versus drying time for onion at different mass flow rate

4. Conclusion

This paper presents the moisture content changes of dried medical herbs (ginger, lemon grass, onion and turmeric) in solar drying. The turmeric, ginger and lemon grass were dried from moisture content of 83 %, 89%, and 65% (wet basis) to final moisture content about 8 % (wet basis) with drying time of 3.5 h, 4 h and 4.5 h, respectively. For drying of onion from moisture content of 78 % to moisture content of about 10 % with a drying time of 4.5 h. From the comparison of the experimental results, it shows that the process of drying at 54 °C with 21% air relative humidity is the faster dry for drying of medical herbs (ginger, lemon grass, onion and turmeric).

Acknowledgements

The authors would like to thank the Solar Energy Research Institute (SERI), University Kebangsaan Malaysia for providing the laboratory facilities and technical support.

References

[1] Ndawula, J., J. Kabasa, and Y. Byaruhanga, Alterations in fruit and vegetable β-carotene and vitamin C content caused by open-sun drying, visqueen-covered and polyethylene-covered solar-dryers. African health sciences, 2004. 4(2): p. 125-130.

[2] Kaewkiew, J., S. Nabnean, and S. Janjai, Experimental investigation of the performance of a large-scale greenhouse type solar dryer for drying chilli in Thailand. Procedia Engineering, 2012. 32(0): p. 433-439.

[3] Hossain, M.A. and B.K. Bala, Drying of hot chilli using solar tunnel drier. Solar Energy, 2007. 81(1): p. 85-92.

[4] Desai, S.R., V. Palled, and M. Anantachar, Performance evaluation of farm solar dryer for chilly drying. Karnataka Journal of Agricultural Sciences, 2009. 22(2).

[5] Tunde-Akintunde, T.Y., Mathematical modeling of sun and solar drying of chilli pepper. Renewable Energy, 2011. 36(8): p. 2139-2145.

[6] Phomkong, W., S. Soponronnarit, and P. Thammarutwasik, Chemical Pretreatments Affecting Drying Characteristics of Chilli (cv. Huarou Yon). Drying technology, 2010. 28(12): p. 1466-1476.

[7] Mohanraj, M. and P. Chandrasekar, Performance of a forced convection solar drier integrated with gravel as heat storage material for chili drying. Journal of Engineering Science and Technology, 2009. 4(3): p. 305-314.

[8] Arora, S., S. Bharti, and V. Sehgal, Convective drying kinetics of red chillies. Drying technology, 2006. 24(2): p. 189-193.

[9] Yong, C., M.R. Islam, and A. Mujumdar, Mechanical means of enhancing drying rates: Effect on drying kinetics and quality. Drying technology, 2006. 24(3): p. 397-404.

[10] Daghigh, R., et al., Review of solar assisted heat pump drying systems for agricultural and marine products. Renewable and Sustainable Energy Reviews, 2010. 14(9): p. 2564-2579.

[11] Fadhel, M., et al., Review on advanced of solar assisted chemical heat pump dryer for agriculture produce. Renewable and Sustainable Energy Reviews, 2011. 15(2): p. 1152-1168.

[12] Goh, L.J., et al., Review of heat pump systems for drying application. Renewable and Sustainable Energy Reviews, 2011. 15(9): p. 4788-4796.

[13] Aktas, M., I. Ceylan, and S. Yilmaz, Determination of drying characteristics of apples in a heat pump and solar dryer. Desalination, 2009. 239(1-3): p. 266-275.

[14] Fatouh, M., et al., Herbs drying using a heat pumps dryer. Energy Conversion and Management, 2006. 47(15): p. 2629-2643.

[15] Majid, Z., et al. Multifunctional solar thermal collector for heat pump application. 2009.

[16] O. Saadatian, L. C. Haw, K. Sopian and M. Y. Sulaiman, Review of windcatcher technologies, Renewable and Sustainable Energy Reviews **16** (2012), no. 3, 1477-1495.

[17] O. Saadatian, L. C. Haw, K. Sopian, N Asim and M. Y. Sulaiman, Trombe wall, A review of Opportunities and Challenges in research and developments, Renewable and Sustainable Energy Reviews in Press, Doi: 10.1016/j.rser.2012.06.032.