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Thin Layer Solar Drying of Cuminum Cyminum Grains by Means of Solar Cabinet Dryer

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Abstract: In this research, thin layer solar drying of Cuminum cyminum grains was conducted by means of a solar cabinet dryer. This system was employed in two drying states (mixed and indirect) and four levels of drying air flow rates (f_1: passive and f_2, f_3, f_4: active). The average initial moisture content of the plant for all drying tests were about 43% on dry basis and the drying was performed continuously, in each test, for a period of 90 min. Drying rate of different drying methods as well as thermal efficiency of solar collector were obtained. The effects of drying air flow rates and drying methods are highly significant on final moisture content of Cuminum cyminum. Natural convection solar drying was selected as the best drying air flow rate because the product has fewer moisture content in each drying time. However, mixed mode has less moisture content comparison with indirect type in the same time. Finally, natural convection solar drying air flow rate in mixed mode was selected as the best drying method for drying of Cuminum cyminum grains. In addition, thermal efficiency of flat plate solar collector was calculated in three levels of active drying air flow rates. It is showed the higher drying air flow rate is the higher thermal efficiency of solar collector.

Key words: Thin layer · Solar drying · Thermal efficiency · Cuminum cyminum

INTRODUCTION

The high-energy consumption of the drying operation and the importance of environmental protection have directed interest towards the application of solar energy to agricultural and industrial processes [1]. Moreover drying process is one of the most important unit operations for food preservation [2,3]. The end product quality as well as quantity will be defected if this unit operation is not performed properly [4]. Open sun drying is the most commonly used method for drying of agricultural products in many rural areas, but it cannot preserve food materials from rain, dust, attack of insects, birds and other animals [5]. The resulting losses of food quality in the dried products may have adverse economic effects on domestic and international markets [6]. Cost-effective and hygienic ways of preserving foods is of great importance given the prevailing insecurity in food supplies throughout the world [7]. Considering the importance of perfected drying process and gradual scarcity of energy sources especially fossil fuels as well as the importance of environmental protection, led to use a solar dryer system for drying of fresh food materials.

Solar drying system may be classified into direct, indirect and mixed modes. In direct solar dryers, the air heater contains the product and solar energy passes through a transparent cover and is absorbed by the product. Essentially, the heat required for drying is provided by radiation to the upper layers and then conducted to the product bed [8]. In indirect drying system, solar energy is collected in a separate equipment, called solar air heater, and the heated air then passes through the product bed. In the mixed mode type of drying system, the heated air from a separate solar air heater is passed through a drying bed, and at the same time, the top surface of the bed absorbs solar energy directly through a transparent cover. The product is dried simultaneously by both radiation with downward conduction of heat and the convection of a heat from the solar air heater [9]. Zaman and Ball [10] reported the thin layer drying of rough rice in open floor, cabinet type and mixed mode dryers. The mixed mode type was found to be superior to either open floor or cabinet type dryers [10]. On the other hand, solar dryers can be further classified into two basic categories namely: natural convection (passive) and forced convection (active) dryers. The natural operation principle is based on the temperature

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difference and consequently the difference in the density of the air inside and outside the drying chamber. This difference provides driving force (buoyant force) for the air to flow through the drying bed. Passive drying system does not require any mechanical or electrical power to run a fan. In general, the construction is simple, easy to maintain and inexpensive but working mechanisms is strongly dependent on the temperature difference and pressure drop across the product bed [11].

Many researches on the solar drying studies have been conducted for different plants such as Sultana grapes, Pistachio, Onion etc. Dadashzadeh reported thin layer solar drying of Sultana grapes by means of a solar cabinet dryer. Natural convection drying air flow rate was selected as the best drying procedure for drying of this plant [12].

Solar collectors have the advantage that they are more effective than sun drying. The efficiency of a solar collector is defined as the quotient of usable thermal energy versus received solar energy. The efficiency is dependent on the temperature of surface of absorber plate. The higher is the surface temperature the lower is the thermal efficiency [13]. Thermal efficiency of an air double pass collector was evaluated. higher thermal efficiency is provided compared to conventional single pass collector [14]. This may be due to; the transmitted heat to the drying air in double pass solar collector is more than the single pass one. In our Study, three levels of drying air flow rates (except natural convection) were employed to determine the thermal efficiency of flat plate solar collector.

Solar drying tests were performed on the Cuminum cyminum grains. The Cuminum cyminum is one of the most important pharmaceutical plants [15]. It is adapted to warm and dry warm climate conditions and may be native of eastern Mediterranean basin. Total surface area devoted to Cuminum cyminum cultivation in Iran was reported to be 50000 hectares in 2005 [16].

MATERIALS AND METHODS

Experimental Set Up: The experimental set up, shown in Fig. 1, mainly consists of a drying cabinet with sample holding meshed tray(300×250mm), a flat plate solar collector (1500×500mm) and a circulation fan. The air was sucked through the solar collector by means of an electrical fan for admitting the air to the drying cabinet. In order to convert the drying system from mixed mode to indirect, a thick cover was spread on transparent front wall of the dryer.

In this work, grains were collected from the Ferdows city farms locating in the eastern part of Iran. Grains were cleaned by hand and stored at fixed temperature 4°C in a cooling device. For each treatment of experiment, a stabilized sample of 70-80 gr was spread evenly (as a thin layer) on a meshed tray. Average initial moisture content of the grains was about 43 % on dry basis (d.b).

Solar collector was constructed from sheet iron with dimension of 1500mm×500mm. A transparent sheet was located over the collector, which allows the air was sucked through the it.

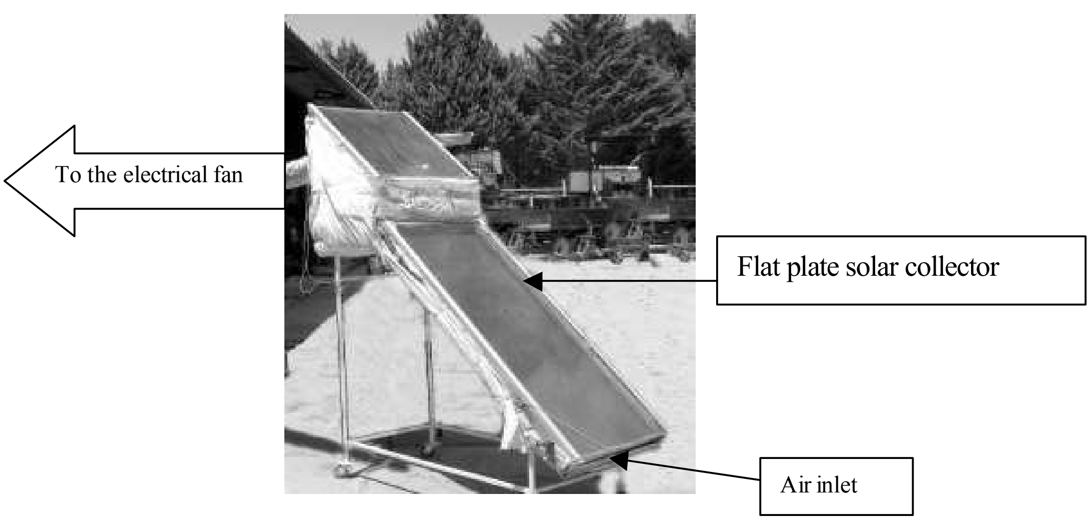

Fig. 1: The cabinet solar dryer used in this research

Procedure: During the drying experiments, air temperature was recorded at different positions of drying system using seven SMT 160 sensors with accuracy of ± 0.5°C. One of them was installed at the solar collector inlet and three at the drying cabinet and three installed at the air exit from the dryer cabinet. Temperature measurements were performed at the regular intervals of 5 min using a data acquisition system. Solar intensity was measured and recorded at the same time interval by a Casella Pyranometer (0-2000W/m^2, 1mv=1W/m^2) placed beside the plane of the collector. Moisture content of Cuminum cyminum was measured using an electrical oven [17].

This Study Was Mainly Devoted To:

- Selecting the best drying procedure for drying of Cuminum cyminum grains.
- Determining thermal efficiency of flat plate solar collector at various drying air flow rates.

In this work, two drying methods, mixed mode and indirect type, and four levels of drying air flow rates, one passive and three active, were adopted.

The efficiency of air solar collector depends on its type and model as well as on the rate of heat losses during operation [1]. Air temperature was recorded continuously at air inlet and outlet of collector. Also at the same time, solar intensity was recorded by means of a solarimeter.

Thermal efficiency of a solar collector is calculated as [18].

$$\eta = Gc_p\left(\frac{T_0 - T_i}{G_T}\right)$$

Where:

η = Thermal efficiency
G = Mass air flow rate(kg/s.m^2)
G_T= Irradiance of solar intensity(w/m^2)
T_0= Air temperature inlet to solar collector(ambient air temperature)(°C)
T_1 = Air temperature outlet from solar collector (°C)
c_p = Air specific heat capacity (J/kg.K)

RESULTS AND DISCUSSIONS

Thin layers (10mm thickness) of Cuminum cyminum grains were dried in the solar cabinet dryer. Four levels of air flow rates [three active air flow rates and one passive] and two methods of drying (mixed and indirect) were envisaged for the experiments. The values of the three active volume air flow rates were: flow1= 0.084, flow2= 0.127 and flow3= 0.155 m^3/s. The average initial moisture content of the grains was about 43% (d.b) and the drying process was performed continuously in three replications for a period of 90min. Therefore, the final moisture content of the grains was depended on the air flow rate and drying method.

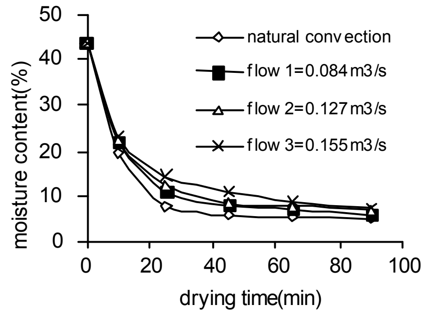

Fig. 2: Drying rate of various air flow rate for Cuminum cyminum grains in mixed mode

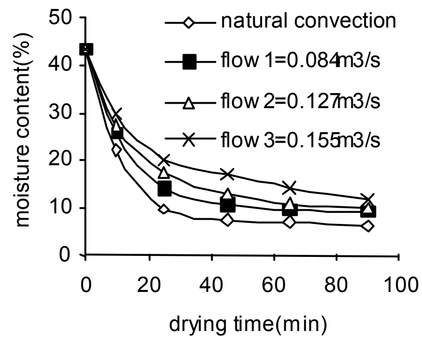

Fig. 3: Drying rate of various air flow rate for Cuminum cyminum grains in indirect mode

Referring to Figures 2 and 3 it can be conducted that the best drying air flow rate is natural convection solar drying as it has fewer moisture content in each drying time for two drying state (mixed and indirect mode). It is because in this state the air temperature of drying chamber is higher due to lower air velocity in compared with forced convection solar drying. Referring to the Fig 4, in mixed mode drying method, the moisture content of grains is fewer than indirect type for each drying time duration. Therefore, mixed mode solar cabinet dryer which using the passive drying air flow rate is the best drying method. Using the dryer in the best selected conditions (natural convection in the mixed mode state), reduced the moisture content of the product from 43.5% to 4.95% after 90 min.

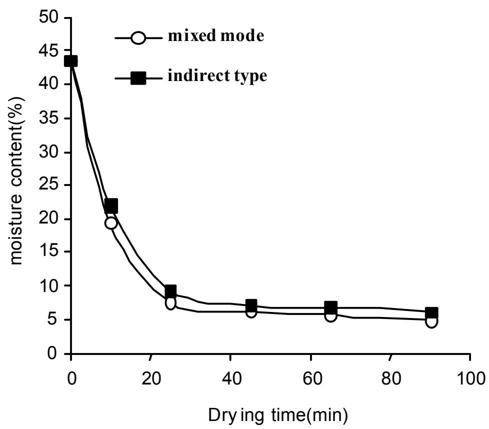

Fig. 4: Drying rate of Cuminum cyminum grains in two drying modes for passive drying air flow rate

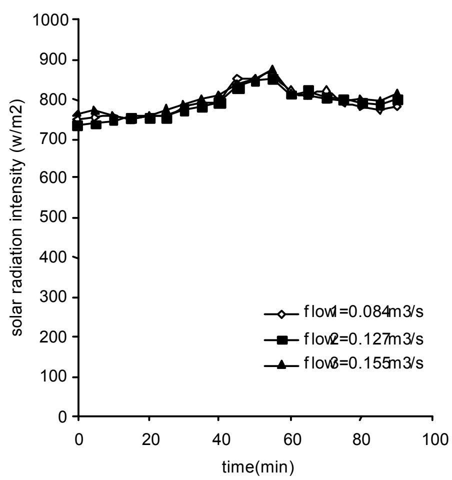

Fig. 5: Solar radiation intensity versus drying time

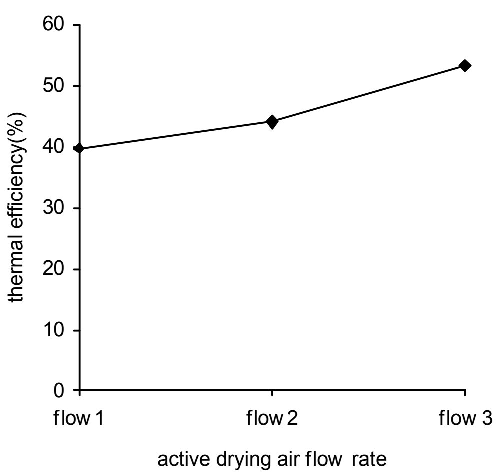

Fig. 6: Thermal efficiency of flat plate solar collector in different active drying air flow rate

Thermal efficiency of solar collector was determined in three levels of active drying air flow rate. Inlet air temperature to the solar collector and outlet air temperature from it as well as solar radiation intensity was used to determine the thermal efficiency of solar collector. Variation of solar radiation intensity versus drying time has been shown in Figure5 for different levels of active drying air flow rate. Thermal efficiency of the flat plate solar collector is calculated as formula (1). Average solar radiation intensity was used in each air flow rate to determine the efficiency of collector. Air mass flow rates equivalent to the volume air flow rates were obtained from standard heat transfer tables. Finally, the thermal efficiency was calculated as shown in Figure6. The higher is the drying air flow rate the higher is the thermal efficiency. It may be due to; in the highest drying air flow rate the transferred heat to the air from absorber plate is the most.

CONCLUSIONS

Thin layer solar drying experiments were performed by means of a solar cabinet dryer to determine the best drying state and thermal efficiency of solar collector. It is resulted the natural convection is the best drying method for drying of Cuminum cyminum grains. Thermal efficiency of flat plate solar collector was calculated in three levels of active drying air flow rates. The highest drying air flow rate resulted the highest efficiency.

REFERENCES

1. Timoumi, S., D. Mihoubi and F. Zagrouba, 2004. Simulation model for a solar drying process. Desalination, 168: 111-I 15.
2. Rajput, R.K., 2005. A Textbook of Power Plant Engineering, New York: Laxmi Publications.
3. Sacilik, K., R. Keskin and A. Elicin, 2006. Mathematical modeling of solar tunnel drying of thin layer organic tomato. Journal of food engineering, 73: 231-238.
4. Brooker, D.B., F.W. Bakker-Arkema and C.W. Hall, 1992. Drying and Storage of Oilseeds. The AVI Publishing Compay , New York. pp: 450.
5. Pangavhane, D.R., R. Sawhney and L. Sarsavadia, 2002. Design, development and performance testing of a new natural convection solar dryer. Energy, 27: 579-590.
6. Mu¨hlbauer, W., 1986. Present status of solar crop drying. Energy in Agriculture 5: 121-37.

7. Yadliz, O., C. Ertekin and H.I. Uzun, 2001. Mathematical modeling of thin layer solar drying of Sultana grapes. Energy, 42: 167-171.
8. Zomorodian, A., D. Zare and H. Ghasemkhani, 2007. Optimization and evaluation of a semi-continuous solar dryer for cereals (Rice, etc). Desalination, 209: 129-135.
9. Simate, I.N., 2001. Simulation of the mixed-mode natural-convection solar drying of maize, Drying Technology, 19(6): 1137-1155.
10. Zaman, M.A. and B.K. Ball, 1989. Thin layer solar drying of rough rice, Sol. Energy, 42: 167-171.
11. Miramare, T., 1997. Design and measured performance of a solar chimney for natural-circulation solar-energy dryers, Renew. Energy, 10(1): 81-90.
12. Dadashzadeh, M., 2007. Design, fabricate and evaluation of a solar cabinet dryer for Sultana grapes. M.sc. Thesis. Shiraz university. Iran
13. Duffie, J.A. and W.A. Beckman, 1991. Solar Engineering of Thermal Processes. 2nd ed., John Wiley and Sons, Inc., New York, USA. pp: 919.
14. Sopian, K., M.A. Alghoul and M. Ebrahim, 2008. Evaluation of thermal efficiency of double-pass solar collector with porous-nonporous media, Renewable Energy, in press, Available online 30 June 2008.
15. Wijesekera, R.O.B., 1991. The Medicinal Plant Industry, aa: CRC Press.
16. Kafi, M., M.H. Rashed, A. Mohassel, Koocheki and M. Nassiri, 2006. Cumin (Cuminum Cyminum): Production and Processing, Tehran: Science Publication.
17. AOAC 1990. Official method of analysis. Association of Official Analytical Chemists, (No. 934.06), Washington, DC.
18. Biondi, P., L. Cicala and G. Farina, 1998. Performance analysis of solar air heater of conventional design. Solar Energy, 41(1): 101-107.