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Reviewing Drying of Dill and Spearmint by a Solar Dryer and Comparing with Traditional Dryers

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Abstract: In this study the process of dehydrating both dill and spearmint crops was examined at one hour intervals by means of an inactive and indirect solar dryer, which was designed and assembled at Shahre Kurd university department of mechanics of farm machinery, under influence of two different collectors (iron and aluminum). The test design selected for this experiment was a complete random design which was performed with 3 repetitions. Data analysis showed that the dried crop type factor, collector's type and duration of sampling in crop's water loss were significant at 1% statistical level. Data showed that average water loss of spearmint crop was 6% more than dill at each hour. This is because different physical and textural properties of plants. Also comparison of amount of water evaporation in different durations for both iron and aluminum collectors showed that average amount of water evaporation in dryer with iron collector is 10% more than the one with aluminum collector. Also statistics indicated that crops dehydrated with solar dryers are more favorable and benefit higher qualities from the viewpoint of marketplace. As the tendency to buy dehydrated dill and spearmint crops with solar dryers is 2 and 2.4 times, respectively, higher than the crops dehydrated by traditional dryers.

Key words: Solar energy % Modern and renewable energy % Solar dryer % Spearmint % Dill

INTRODUCTION

Application of solar energy is as old as existence of humans on earth. Today, daily life of people is dependent on the production and use of energy; therefore, the demand and supplying of it is increasing in human societies. Currently 77% of the world's total energy is provided with fossil fuels which emit polluting and greenhouse gases, by degrading ozone layer excessively threaten environment and leads to more global warming. Therefore, in order to maintain environment, considering substitute energies (new energies) has become an essential task [1].

Drying agricultural crops is an important procedure to maintain food products [2]. The importance of it together with minimizing fuel consumption indicates that the designing of a food drying system by means of solar energy is cost-effective and influential. Although traditional drying of food in open air by exposing to sunlight is an old and relatively beneficial method for rural areas, this method cannot preserve food from onset of birds and insects, rainfall risk and molding. Furthermore, this method needs large time and space in order to dry food, therefore, food loss may be much higher. Thus this drying method is not cost-effective [3]. Drying with solar dryers is a proper way to decrease food moisture, preventing them from degradation [4]. In this study, first a review on some of manufactured devices is addressed, then the procedure of dehydrating both dill and spearmint crops by an inactive and indirect solar dryer, which was assembled at Shahre Kurd university department of mechanics of farm machinery, under influence of two types collector (iron and aluminum) is reviewed.

Ferreira *et al*. [5] studied the design of a solar chimney for dehydrating crops in Brazil (Figure 1-1). In this method drying of agricultural crops by generating a convection current by means of s solar chimney was studied. Therefore, a chimney with a given height was established on the floor and then it was covered with a plastic film which beneath that layer the crops were placed. As the sun shines on this surface, the temperature difference between beneath the plastic film and the surroundings increases, results in a convection current towards the chimney. This research suggests that the height of chimney has a direct association with improvement of dryer's performance [5].

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Hossain and Bala [6] used a tunnel solar dryer for drying of spices. This dryer received air from one side of the tunnel from a blower and blew it throughout the tunnel. In this dryer air flow and sunlight caused an increase in evaporation rate and consequently increased drying speed [6].

Madhlopa and Ngwalo [7] designed and built a solar dryer with a biogas supplying system. In this dryer a heating system with biogas fuel was used to increase drying rate of crops or for operation in rainy days. This dryer is stationary and is operated either in combination of biogas and solar energy or normally only with solar energy [7].

Bentayeb *et al*. [8] introduced modeling and simulation of a wood solar dryer in Morocco. In this model a structure was presented which had two northern and southern doors, the northern one was used for inserting wood and a moisture outlet was embedded at ceiling [8]. Janjai *et al.* [9] evaluated the performance of a roof-integrated solar dryer for herbs and spices and compared its results with traditional drying method. Results showed the higher quality of dried spices with this method in comparison with traditional method. Also obtaining higher added-value and rapid capital return has been proved in solar drying method [9].

Koyuncu [10] studied the operation of a solar dryer for drying greenhouse commodities (Figure 1-14). This dryer because of direct radiation of sunlight on produce is referred as direct type dryer, which there are shelves inside of it for placing different commodities and has facilitated the reception of light and heat from different directions [10].

Palsingh *et al*. [11] designed and built a multi-shelf domestic solar dryer which was used to dry domestic herbs and crops at a small and limited scale. Its performance was unfocused convectional current type since it had multiple separated parts and was capable of drying various crops simultaneously [11].

Sarsavadia [12] designed and introduced an active solar-assisted dryer for dehydrating onions. This dryer uses a fan and a covered air current for decreasing heat loss, which sucks air from the collector and after passing through the drying chamber, returns to the collector for reheating. This system generates a closed loop cycle in order to prevent heat losses [12].

Bahnasawy and Shenana [13] built a dryer for dehydrating fermented dairy products. This dryer was consisted of a tower-like chamber mounted on a chassis and two collectors. This system uses intelligent computer control terminals which can record and maintain data referring to the status of temperature and moisture [13].

Bennamoun and Belhamri [14] designed an active type dryer. This dryer was composed of an energy absorbing plate, drying chamber and crops trays. In this dryer a fan was placed at the ceiling of the chamber to transmit the inner air to outside [14].

MATERIALS AND METHODS

In this study the process of drying two crops, dill and spearmint, by an inactive, indirect solar drying under influence of two collectors (iron and aluminum) was reviewed on June 22nd 2009 at Shahre Kurd (longitude 50°49´ and latitude 32° 20´). The test design selected for this experiment was a random block design with 3 repetitions. At first two prototypes of the expected dryer was built and by preliminary tests the uniformity of the drying conditions for both was studied. One of the dryers' collectors was covered with an iron layer and the other one had an aluminum coated collector. The inner space of each dryer was divided into two rows and each row had 6 compartments.

Before starting the test, the samples were conditioned by removing the plants leaves from the stem and then placing them at lab temperature for 24h, unifying samples moisture contents. Afterwards, they were placed inside numbered plates and were weighed. Eventually, these plates were placed inside the dryers to initiate drying procedure. The device was placed in a sunshiny site and the experiments started at 8 AM and at one hour intervals the samples were weighed by an existing digital balance (accuracy = 0.1g). The samples were measured for 8 hours until the rate of moisture loss neared to a constant number. Then an experiment was arranged to compare the solar dryer with industrial types. The latter dryer was designed by addition of a blower and a heater to the examined solar dryer and removing its collector. For the second dryer the chamber temperature of 60±4°C and airflow of 0.006 $kg.s^{-1}$ were selected. To examine the quality and marketing of the dried products by two methods, solar and industrial, the samples were shown to 160 people and their tendency to purchase the product was evaluated. Finally, the results of collected data were analyzed by MINITAB and MSTAT softwares.

RESULTS AND DISCUSSION

Data analysis showed that the type of dried crop, collector type and duration of sampling in amount of water loss are significant at 1% statistical level. Results indicate that the average water loss per hour for spearmint is 6% more than dill. This is because of the

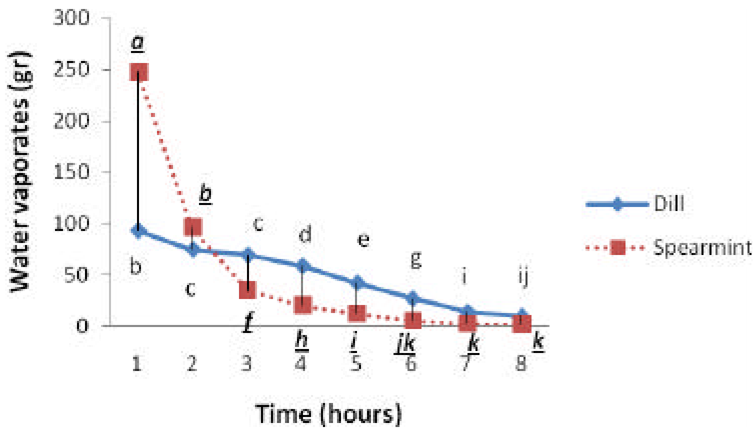

Fig. 1: Process of water evaporation variations for spearmint and dill crops (Different letters in each point, shows significant deffrence, Duncan5%)

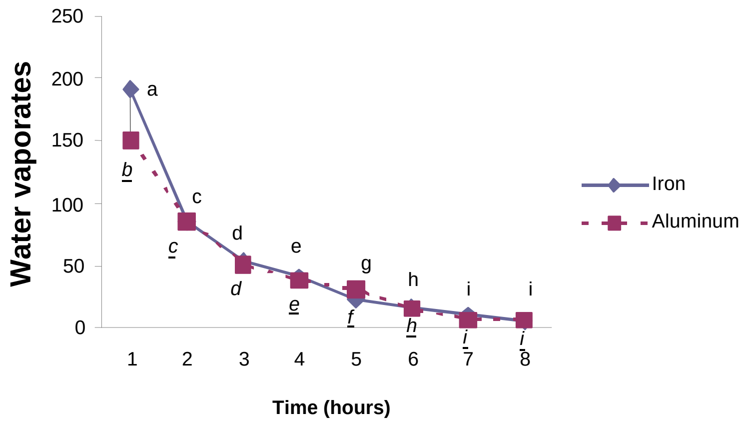

Fig. 2: Procedure of water evaporation variation for iron and aluminum collectors (Different letters in each point, shows significant deffrence, Duncan5%)

differences in their physical and textural properties. For example physical structure of spearmint leaves is broader and due to higher level of evaporation and flatness of plant texture cells, as well as larger respiratory porosity and the spongy texture of the leaves, evaporation rates are faster than dill; since dill leaves are round and rod-like, which therefore their cells are smaller and thinner, respiratory porosities are tinier than spearmint leaves, resulting in smaller contact area with airflow and consequently decreases the evaporation amount lower than the spearmint produce [15].

The average comparison of evaporated water amounts is shown at Figure 1. At the first hour, spearmint, due to the above-mentioned textural and physical reasons and also existence of more non-osmotic water through spearmint leaf cells, lost more water than dill. As time goes on, the amount of water loss decreases in both crops, which eventually the amount of moisture loss decreases to the extent that is no more significant in Duncan test (P<0.1).

Comparison of amount of water loss in different time for two collectors, iron and aluminum, is shown in Figure 2. Amount of water loss was 10% higher in dryer with iron collector than the dryer with aluminum collector, which is because of the higher specific heat capacity of iron rather than aluminum that means at same weights, iron heats in half the time needed for heating of aluminum. Also iron density is higher than aluminum which helps it to remain warm for a longer period after sunset than aluminum and this is an important issue in the designing. Therefore it can show a better performance in terms of a higher temperature increase during same period and consequently increase in convection flow of the air with more persistency after a decrease in sunshine (Table 1) [16].

Comparison of water evaporation data averages are presented in the following figure. At the first hour, evaporation in the dryer with iron collector was 22% higher than the dryer with aluminum collector, which is due to higher speed of warming and temperature uniformity throughout iron collector dryer compartment.

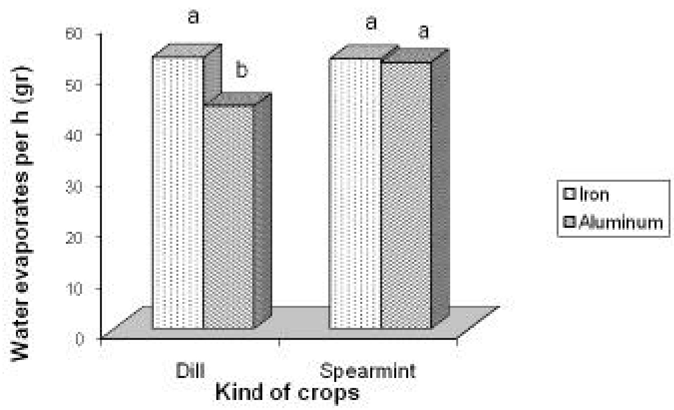

Fig. 3: The diagram of the interactive effect of collector type on amount of evaporated water for dill and spearmint(Different letters in each column, shows significant deffrence, Duncan5%)

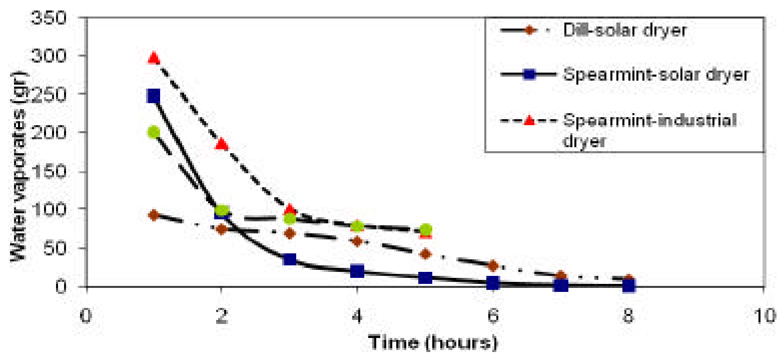

Fig. 4: Procedure of water loss variations in both types of dryers

Table 1: Specific heat capacity for iron and aluminum [16]

Element	Specific heat capacity (J/g.c^0)
Aluminum	0.897
Iron	0.449

Table 2: Relationship between water evaporation amount (g) in iron and aluminum collectors on dill and spearmint crops against time (h)

Crop	Collector	Equation	
Dill	Iron	$M=119.8-17.3h+0.45h^2$	$r^2=0.96$
	Aluminum	$M=90.14-8.58h-0.3h^2$	$r^2=0.98$
Spearmint	Iron	$M=760.88e^{-1.03h}$	$r^2=0.98$
	Aluminum	$M=499.27e^{-0.8h}$	$r^2=0.98$

Table 3: Evaluation of the quality and marketing of crops regarding the surveys

Crop	Color		Scent		Tendency to buy
Dill	Solar Pros	58%	Solar Pros	65%	67%
	Neutral	27%	Neutral	22%	
	Solar Cons	15%	Solar Cons	13%	
Spearmint	Solar Pros	63%	Solar Pros	59%	71%
	Neutral	26%	Neutral	18%	
	Solar Cons	11%	Solar Cons	23%	

The interactive effect of dried crop and collector type was significant. In the case of dill, because of the above-mentioned textural conditions, the collector type effect on it was significant, but this effect was weaker for spearmint.

Figure 4 shows the drying procedure of both dill and spearmint crops by two inactive solar dryer and active non-solar dryer (industrial). Considering the higher speed of crop drying with latter dryer and also absence of sunlight and drying space limitations, there are more tendencies towards this type, however, the marketing and appearance quality of the product (color and scent) shown in Table 3 indicate that from the viewpoint of people, the crop dried with the first dryer was better from the standpoint of color and scent and also was more likely to be purchased.

CONCLUSION

- Collector type has impact on duration of crops drying to the extent that in the dryer with iron collector average evaporation is 10% higher than the one with aluminum collector.

- Maintaining color and scent of dried crops is an advantage in these dryers.
- Other advantage of these dryers is that they use free energy for drying and preserve environmental issues.
- Process of drying in solar dryer is function of environment conditions; i.e. radiation intensity and surrounding temperature affects its performance, which is a defect.
- Duration of drying is another defect for solar dryers.

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