Comparing the Performance of Two Type Collectors on Drying Process of Lemon and Orange Fruits through a Passive and Indirect Solar Dryer

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Abstract
Drying of crops is an important procedure in order to preserve food products. The importance of it from one hand and minimizing fuel consumption from the other hand, emphasize that the designing of a system for solar drying of food is economical and substantial. Although due to increase of population industrial drying has been preferred, considering some issues such as maintaining quality, nutrition properties, marketing, and providing added value in rural societies, which lead to stable development of agriculture in a country, indicate that research and study on applying solar dryers is necessary. Regarding these issues, the process of drying of Lemon and Orange fruits by means of a passive indirect solar dryer under influence of two types of collectors (Iron and Aluminum) was studied and evaluated. The test design selected for this study was a complete random test with 3 repetitions. Data analysis showed that collector's type and duration of sampling was significant on the amount of evaporated moisture from produce ($p < 0.01$). Also analysis showed that the tendency towards buying solar dried lemons and oranges is 5.6 and 4.2 times, respectively, higher than traditionally dried fruits and therefore solar dried fruits have higher marketing value. [Journal of American Science. 2010;6(10):248-251]. (ISSN: 1545-1003).

Keywords: Solar Dryer, Renewal and Modern Energy, Solar Energy, Lemon, Orange

Introduction

Drying is an important post-harvest process for most of agricultural products in order to preserve and lengthen their lives. Problems related to traditional methods, expensive fossil fuels and environmental pollutions derived from them are the reasons that in that past two decades countries are tended to apply solar dryers [Pangavhane et al,2002]. In the past recent years several attempts have been made to construct and develop different types of solar dryers to preserve agricultural and horticultural crops.

In an active solar dryer (equipped with a blower) a tunnel was designed to dry cacao and coconut. Results showed that the in comparison with drying in open air crops dry faster and have better quality [Eddy et al, 1991].
Results related to simulation of the indirect natural convection solar drying of rough rice showed that glass collectors have better performance than the plastic collectors [Bala et al, 1994]. Results of a study on a large solar dryer, which was developed to compare artificial drying by solar energy with traditional drying and also used a co-heating device during low sunlight, indicated that solar drying is faster than traditional drying [Karathanos et al, 1997]. Evaluating the fruit and vegetable qualities dried by both methods of traditional and solar drying showed that the quality of dried produce with complex and indirect solar dryers was higher than traditional method [Gallali et al,2000]. Comparing the process of tomato drying in an indirect solar dryer with traditional drying indicates that using solar dryers can decrease the drying period from 48 days to 15 days [Zhimin,2006]. In an experiment in Shiraz University on a dryer developed to dry grapes, results showed that by using this dryer, the duration of drying with this method can be decreased from 10-12 days in traditional method to 4-5 days and can obtain higher quality than the traditional method [Dadashzadeh, 2006].

Using a tunnel solar dryer equipped with blower for drying spices showed that increasing air flow and sunlight leads to an increase in evaporation rate and consequently increases the drying speed [Hossain et al, 2007]. In another study performance of a ceiling-integrated solar dryer for drying of herbs and spices was evaluated and the results were compared with traditional method. The result of this experiment showed the higher quality of dried spices in comparison with traditional method [Janjai et al, 2006]. There are regions in Iran which because being located in semi-arid and arid areas, favor sufficient sunlight, therefore due to this reason, studies have been carried out on applying solar dryers and optimize designing of these dryers in country [Azad et al, 1990].

In this study the influence of collector type on drying process of both lemon and orange fruits by an indirect passive solar dryer which was designed and built at the faculty of farm machinery faculty of Shahrekurd University was evaluated.

Material and Methods

In this study the drying process of both lemon and orange fruits by means of an indirect passive solar dryer under influence of two different collectors (iron and aluminum) during 28th of June 2009 till 6th of July 2009 in Shahrekurd (longitude: 50 degrees and 49 minutes, latitude: 32 degrees and 20 minutes) was evaluated. The test design selected for this study was a complete random test with 3 repetitions. First, during preliminary tests the uniformity of drying conditions of produce for both dryers was verified. The collector of one was covered with an iron film and the other dryer's collector with an aluminum film. The chamber of each dryer was divided into two rows and each row was consisted of 6 sections.

In order to perform the experiment, samples were first prepared which means that lemon and orange fruits were cut into 2-4 mm slices. Then the samples were held for 24 hours at room temperature so that the moisture content of all samples would become the same. Then, they were held in numbered bowl plates and were weighed. Finally, the numbered plates were transferred to dryer to initiate the drying process. The device was then left in a sunny location and the collectors' angle were adjusted between 10 to 15 degrees higher than the region latitude to gain the highest sunlight depending on the time of year and the collector was set in north-south direction [Moradi, 2008]. Experiments were started at 8 am and at 24 hours intervals the samples were weighed by a digital weight (0.1 g accuracy). The measurement period of samples lasted for 9 days till the weight loss rate become constant. Further, an experiment was arranged to compare solar dryer with industrial dryers. The second dryer (industrial dryer) was designed by adding a blower and a heater to the tested solar dryer and removing its collector. The chamber temperature of the second dryer was 70±5 degrees and the air flow rate was 0.009 kg/s. in order to assess the quality and marketing of dried fruits, dried crops were given to 200 persons and their tendency towards buying them was evaluated. Finally, results from collected data were analyzed by MINITAB(version of 12) software.

Results and Discussion

Data analysis showed that the collector type and sampling timing was significant in amount of water loss from crops ($P < 0.01$). Data showed that the average water loss at each 24 hours for lemon and orange fruits was not significant. This was because the great relative similarity in physical and tissue properties of both plants [Wiley, 1985].

Comparison of average moisture evaporation from both lemon and orange fruits at different periods for both iron and aluminum collectors is shown in figure 1. The average moisture loss from both lemon and orange fruits in dryer with iron collector was 6% higher than the dryer with aluminum collector. This is because of lower special heat capacity of iron than aluminum which means at equal weight amount, iron temperature increases at half the time needed to increase aluminum temperature. Also the iron density is higher than aluminum which makes iron to keep heat for longer after sunset than what aluminum can keep. This is an eminent factor in designing and developing solar dryers with higher outputs. Therefore, it can indicate a better performance in increasing more temperature during a same period and consequently increase convectional air flow with longer stability after a decrease in sunset (Table 1).[Petrucci et al, 1993] Comparison between evaporation averages for two collectors is shown in fig 1. In the first 24 hours in the dryer with iron collector this amount is 64% higher than the dryer with aluminum collector which is because of faster heating up and uniformity of temperature inside the cabin of the dryer with iron collector.

According to insignificant difference in amount of evaporated water for both lemon and orange because of their similar tissues, average amount of evaporated water for both above mentioned products is shown in Fig2. Relation for amount of evaporated water for iron collector is an exponential function and for aluminum collector is a polynomial function. Because in solar dryers more time is spent for drying of products than industrial dryers, one of the important factors that besides the free energy source and environmental issues, justifies the use of solar dryers is the proper marketing of dried products with solar dryers [Lotfalian et al, 2010]. The survey was made in a 200 person population and the following results were obtained by showing them both types of dried products.

Conclusions

- Collector type has impact on duration of crops drying to the extent that in the dryer with iron collector average evaporation is 6% higher than the one with aluminum collector.
- In the first 24 hours in the dryer with iron collector this amount is 64% higher than the dryer 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.

- Duration of drying is another defect for solar dryers.
- 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.

Table 1 – Special heat capacity of both iron and aluminum [Petrucci et al, 1993]

Element Name	**Special heat capacity ($J/g.c^0$)**
Aluminum	0.897
Iron	0.449

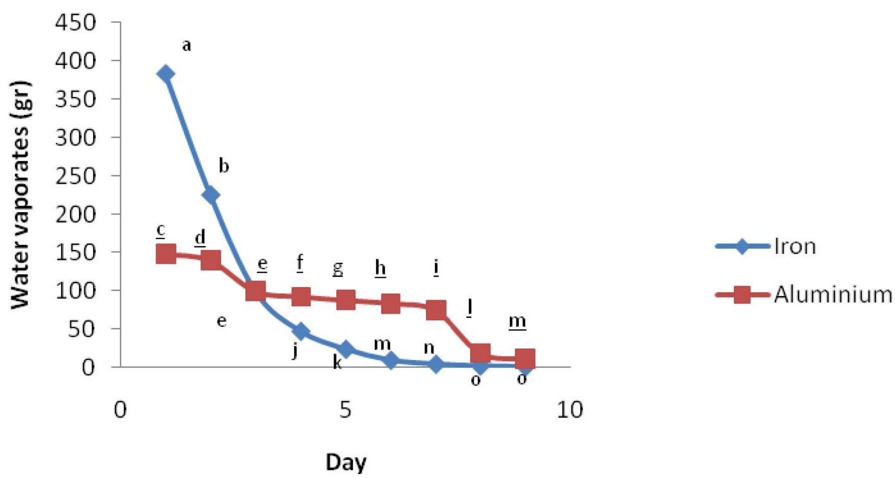

Figure1 – Process of changes in water evaporation for iron and aluminum collectors
(Different letters in each point, shows significant defrence, Duncan5%)

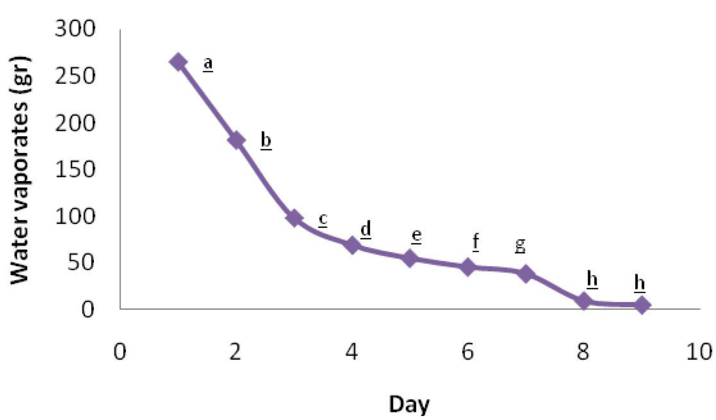

Figure2- Process of changes in water evaporation for avrage of lemon and orange
(Different letters in each point, shows significant defrence, Duncan5%)

Table 2 – Relationship between evaporated water from iron and aluminum collectors on lemon and orange fruits against time (d = day (s) and M = evaporated water amount (gr))

Fruit	Collector	Equation
Lemon	Iron	$M=754.41966e^{-0.652017d}$ $r^2=0.96$
	Aluminum	$M=187.1-41.5347d+6.74546d^2-0.4879d^3$, $r^2=0.98$
Orange	Iron	$M=743.5227e^{-0.647507d}$ $r^2=0.98$
	Aluminum	$M=150.187-9.324523d-0.65238d^2$ $r^2=0.98$

Table 3 – Evaluation od quality and marketing of produce according to the survey

Fruit Type	Color		Smell		Tendency to Purchase
Lemon	Pro-Solar Drying	67%	Pro-Solar Drying	72%	85%
	Neutral	27%	Neutral	21%	
	Against-Solar Drying	6%	Against-Solar Drying	7%	
Orange	Pro-Solar Drying	62%	Pro-Solar Drying	66%	81%
	Neutral	26%	Neutral	13%	
	Against-Solar Drying	12%	Against-Solar Drying	21%	

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