Evaluating a Hybrid Passive Solar-Electrical Dryer For Drying grapes

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ABSTRACT

A passive hybrid solar-electrical dryer was designed and fabricated at Islamic Azad University, Shoushtar branch, Shoushtar, Iran. The heat sources of this dryer was an electrical heater and a flat solar thermal collector with 2 m² area. The dryer was evaluated for drying grapes by a completely randomized design with five treatments and three replications. Treatments in this research were contained: 1. drying in the open air (control), 2. Indirect solar drying, 3. Indirect solar drying with a 600W electrical heater, 4. Indirect solar drying with a 1200W electrical heater, 5. Mixed mode solar drying with 1200W electrical heater. The results showed that there was a significant difference among the moisture ratio of dried samples in each treatment. Dried raisins produced by the third treatment had a better quality, color and appearance. In last treatment, the grapes were dried in less time and with a significant difference compared with the other treatments. The final grape moisture ratio in this research was %16.

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INTRODUCTION

Sun drying of agricultural products is the traditional method employed in most of the developing countries.

Sun drying refers to the exposure of a product to direct solar radiation and the convective power of the wind. Sun drying is a cheap method for drying but often results to poorer quality of products due to its dependence of weather conditions and vulnerably to the attack of dust, dirt, rains, insects, pests, and microorganisms [3]. Solar drying is an alternative which offers several advantages over the traditional method and it has been developed for various agricultural products. Solar energy is environmentally friendly and economically viable in the developing countries [2]. In natural convection solar dryers, the air flow is due to buoyancy induced air pressure, and the drying process needs some days to complete [9]. While in forced convection solar dryers the air flow is provided by using a fan [4]. Some researchers are opting for forced convection solar tunnel drying for drying of various crops [8]. They reported that solar drying for grapes during the night period, it is necessary to develop a system having a back-up of thermal storage. An auxiliary heat and forced convection are recommended for assuring reliability and better control, respectively. However, there exist some problems associated with solar drying i.e. reliability of solar radiation during rainy period or cloudy days and its availability at nighttime. In a hybrid solar dryer, drying is continued during off sunshine hours by backup heat energy or storage heat energy. Therefore, drying is continued and the product is saved from possible deterioration by microbial infestation [1]. Variability and time-dependent characteristic of solar radiation make storage necessary for continuous operations of food drying [7]. The operation of a solar assisted dryer extended through the night hours and found that thermal storage during the day can be used as a heat source during the night for continuing drying of agricultural products and also preventing their re-hydration from the surrounding air [6]. Continuous drying also prevents microbial growth during drying [4]. Also, it was found that storage and auxiliary heat supply can be used to assess compatibility of solar energy to meet the drying process temperature [10]. In the current research a solar-electrical hybrid dryer with natural convection is evaluated for drying grapes.

MATERIALS AND METHODS

The dryer (fig.1) contains four main parts: chassis, drying cabinet, electrical heater and a solar air heater. Chassis maintains the other parts. The drying process was done in the drying cabinet with the length of 1 m,
width of 0.5 m and height of 0.8 m. The cabinet was fabricated with metal sheet. It was dyed black and covered with fiberglass insulation. Two vents were inserted on the top and the bottom of the cabinet. Hot air was entered the cabinet from the bottom vent and humid air was discharged from the top vent. There were three trays in the cabinet that the product was flattened on them. An electrical heater was also used to reduce the drying time and assist drying in hours that solar energy is unavailable. Electrical heater was placed in the cabinet. Electric heater has two modes, 600 and 1200 W. A flat solar air heater with the area of 2×1m was used for supplying the dryer’s primary thermal energy. The solar collector placed an angle of 47 degrees to the south. Using natural convection, air flows through the solar heater and drying cabinet and the humid air passes out through the top vent of drying cabinet. The front face of the cabinet was replaced with glass in the last treatment, hence besides hot air, grapes were exposed to direct sunlight. Therefore the last treatment was mixed mode solar-electrical hybrid drying and the others were indirect solar-electrical hybrid drying. For doing the experiment the dryer was placed in a sunny area. Grapes were pretreated with the solution of vegetable oil and potassium carbonate. Pre-treated samples, about 1.5 kg were distributed uniformly on each sample tray. The initial grape moisture ratio was %78 and the drying process was continued till the final moisture ratio of raisins reached % 16 in all treatments.

![Solar-electrical hybrid dryer](image)

**Fig. 1:** The solar-electrical hybrid dryer.

A completely randomized statistical design with 5 treatments was used for analyzing the experiment. The treatments were included drying in the open air as the control, indirect drying with a 600 W electrical heater, indirect drying with a 1200 W electrical heater and mixed mode drying with a 1200 W electrical heater.

**RESULT AND DISCUSSION**

Table (1) shows the results of variance analysis. There is a significant difference between the treatments with %99 probability. However, for further evaluations, according to table (2) Duncan’s Multiple Range Test was performed at %1 level. This analysis showed that mixed mode drying with 1200W power electrical heater caused the grapes dry in a shorter time because the air temperature of drying chamber was higher and consequently evaporation rate and passive air flow rate increased. Figure (2) shows that the more the electrical power for heating, the less the drying duration. Mixed mode drying also reduced the drying duration. Because, besides hot air, grapes exposed to direct sunlight and received more thermal energy.

![Table 1: The summary of variance analysis](image)

**Table 1:** The summary of variance analysis.

<table>
<thead>
<tr>
<th>source of variation</th>
<th>Squares sum</th>
<th>Freedom degree</th>
<th>variance</th>
<th>Calculated F</th>
<th>F_{0.05}</th>
<th>F_{0.01}</th>
</tr>
</thead>
<tbody>
<tr>
<td>treatment</td>
<td>865/4</td>
<td>4</td>
<td>216/35</td>
<td>5/840**</td>
<td>3/22</td>
<td>5/39</td>
</tr>
<tr>
<td>Test error</td>
<td>5/390</td>
<td>10</td>
<td>05/39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>9/1255</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at %5
** Significant at %1
Table 2: The treatments’ average M.C. reduction.

<table>
<thead>
<tr>
<th>Drying methods</th>
<th>a 69/77</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. (open air) control</td>
<td></td>
</tr>
<tr>
<td>B. indirect drying</td>
<td>b 64/63</td>
</tr>
<tr>
<td>C. indirect drying + 600W electrical heater</td>
<td>b 75/62</td>
</tr>
<tr>
<td>D. indirect drying + 1200W electrical heater</td>
<td>bc 51/65</td>
</tr>
<tr>
<td>E. mixed mode drying + 1200W electrical heater</td>
<td>c 32/73</td>
</tr>
</tbody>
</table>

The means that associated with the same letters, do not have a significant difference at the %1 level.

Fig. 2: The comparison of moisture changes based on time in all drying treatments.

Conclusion and recommendations:

The waste percentage in this dryer was dropped about 40 percents compared with the open air. Also, the raisins dried in this dryer were protected against insects, rain and dust so that dried grapes had better color and higher quality. The comparative evaluation shows that indirect solar drying with 600W electrical heater had a better color, flavor and taste. The reason of a higher quality of the grapes was the optimum temperature inside the dryer cabinet. Also, the direct drying with 1200W electrical heater can dry the grapes in less time which had a significant difference with the open air.

REFERENCES