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Drying Characteristic of Apple Slices Undertaken the Effect of Passive Shelf Solar Dryer and Open Sun Drying

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Abstract: Apple Varity (Golden Delicious) is widely cultivated in Syria and is consumed either fresh or in the form processed products such as juice, marmalade, jam and less as dried product. The present study was conducted to investigate the drying characteristics of apple slices and the quality parameter of apple slices (color, Rehydration ratio) undertaken the slice thickness (5, 10 mm) pre-treatment and the drying method by using a Passive Shelf Solar Dryer (PSSD) and in the Open Sun Drying (OSD). Results showed that there is a significant effect of the drying method and slices thickness on the moisture content and the drying time. The drying time decreased by 40% for 5 mm thickness of slices in the (PSSD) drying system comparison to the (OSD) system and the drying time decreased by 22% for 10mm thickness of slices in the (PSSD) drying system comparison to the (OSD) system. The slices thickness has a significant effect on the drying time where, the drying time for 5 mm thickness was less by 80% comparing to 10 mm in the passive solar dryer and less by 57% in the open sun drying. Rehydration ration also affected by the slices thickness and the slices treating by ascorbic acid, where the rehydration ratio values at the drying air temperature of 40°C increased by 41.7% and by 33.3% for treated and untreated slices when the slices thickness increased from 5 mm to 10 mm respectively.

Key words: Natural shelf solar dryer, open sun drying, apple drying, pre-treatment of apple slices, rehydration ration, colour

INTRODUCTION

Most fruits and vegetables contain more than 80% water and therefore are highly perishable. Water loss and decay account for most of their losses which are estimated to be more than 30% in the developing countries due to inadequate handling, transportation and storage (Kaya *et al*., 2007). Preservation of agricultural products is one of the biggest problems facing developing countries. Owing to the lack or inadequacy of preservation methods, large quantities of urgently needed food spoil there, these problems will be aggravated by the growing dietary needs of these countries burgeoning populations. However, drying is one of the primary methods of food preservation on a large scale around the world. Drying is a classical method of food preservation and it is a difficult food processing operation mainly due to undesirable changes in quality of dried product (Maskan, 2000). The basic objective in drying agricultural products is the removal of water in the solids up to certain level, at which microbial spoilage and deterioration chemical reactions are greatly minimized (Krokida and Marinos-Kouris, 2003).

Drying behavior of solids can be described by measuring the function of moisture content loss versus time. Continuous weighing, humidity difference and intermittent weighing are the used methods (Mujumdar, 2006). In Syria this problem exists with many fruit and vegetable varieties which cannot be marketed fast enough owing to their limited keep ability. Large quantities of apricots, grapes and apple spoil owing to inadequate infrastructure, insufficient processing capacities and growing marketing difficulties caused by intensifying competition and protectionism in the world's agricultural markets. Drying these products can help to solve these problems, while also making an important contribution to improving the population's income and supply situation. Food losses in the developing world are thought to be 50% of the fruits and vegetables grown and 25% of harvested food grain (Burden, 1989). Using the sun to dry crops and grain is one of the oldest and most widely used applications of solar energy. The simplest and least expensive technique is to allow crops to dry naturally in the field, or to spread grain and fruit out in the sun after harvesting. The disadvantage of these methods is that the crops and grain are subject to damage by birds, rodents, wind and rain and contamination by windblown dust and dirt. Drying of agricultural products using renewable energy such as solar energy is environmental friendly and has less environmental impact. Sun drying is still widely used in many tropical and subtropical countries. Sun drying is the cheapest method but the quality of the dried products is far below the international standards. Improvement of product quality and reduction of losses can only be achieved by the introduction of suitable drying

technologies (Bala, 2009) Solar drying can be considered as an elaboration of sun drying and is an efficient system of utilizing solar energy (Bala, 1997).
In Syria, where solar energy is plentiful (500-1000 W/m^2) and ambient temperature is relatively high (30-37°C) during the harvesting season for the most fruits and vegetables (May to October) in addition that the fact that solar dryer need low investment as compared with conventional methods, solar drying looks attractive (R.E.O., 2009). Among fruits, apple is the more important one economically and industrially. It is consumed in different forms as fresh fruit, concentrated juice or thin dried slices. Wang *et al.* (2007). Sehedlou *et al.* (2010) studied the effects of drying air temperatures (50, 60 and 70°C) and air drying velocities (0.6, 1.2 and 1.8 ms^{-1}) on the drying kinetics of apple slices using a hot-air tray dryer. The effects of the drying variables on the quality characteristics (such as shrinkage and color) of dried apple were evaluated. In order to select the appropriate drying model, ten mathematical drying models were fitted to the experimental data. According to the statistical criteria (R^2, SSE and RMSE) the Aghbashlo *et al.* (2009) model was found to be the best model to describe the drying behavior of apple slices. They also indicated that the ANOVA results showed that the drying-air conditions had no significant effect on final shrinkage, Hunter color values and total color differences of dried apple.

Nomenclature:

M_{wb}	:	Initial moisture content on wet basis(kg water /kg dry matter)
W_w	:	The initial wet weight of the product (kg)
W_d	:	The final dried weight of the product
+a	:	Redness of the colour
+b	:	Yellowness of the colour
L	:	Lightness of the colour
Δ E	:	Total colour difference
NSSD	:	Natural shelf solar dryer
R	:	Rehydration ratio
OSD	:	Open sun drying

MATERIALS AND METHODS

Materials: The apples (Golden Delicious cultivar) that used in this study were obtained from an orchard in Zabadane (a tourist town and is far about 35 km north-west of Damascus), Syria. It is stored in a refrigerator at 4°C. After stabilization period for 2 h at the ambient temperature, samples of uniform size were selected and washed with tap water and hand peeled, cored with a knife and then cut vertical to their axis into slices of 5 and 10 mm thickness using a hand operated slicer as shown in Fig. 1. The apple samples were dipped in a 1% Ascorbic acid solution for 5 min to prevent non-enzymatic browning and drained for 5 min at room temperature which was called as treated samples.

Fig. 1: Apple slices

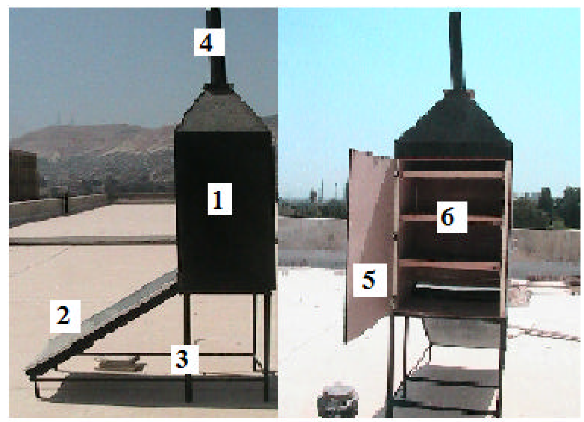

Fig. 2: Experimental setup of the passive shelf solar dryer: (1) drying chamber (2) solar air heater (3) stand up of the dryer, (4) chimney (5)door, sample tray

Experimental apparatus: The experimental apparatus shown in Fig. 2. Which was designed and fabricated to determine the drying behavior of apples slices in the Department of Rural Engineering, Faculty of Agriculture, Damascus University, Damascus, Syria. The solar dryer consists mainly of a flat plate solar air heater coupled to the shelf drying chamber. A single glazed solar air heater is used to supply the required hot air to the chamber. Apple slices were distributed uniformly in a thin layer in the sample three wire mesh trays of 40 x 90 cm in the solar dryer and then exposed immediately to the open sun. The drying chamber was insulated with 50 mm thickness to prevent unnecessary heat losses to the surroundings during test runs. A weighing system consists of an electronic balance is used, The electronic balance, having an accuracy of 0.01 g, was placed outside the drying chamber.

Experimental procedure: Drying experiments were conducted at the ambient air temperatures of almost

30°C, the apple slices as single layer were put on the sample tray and dried there. Moisture loss was recorded at 2 h intervals during the drying process to determination of the drying curves. Drying was continued until no further changes in desired their weight were observed (about 16%, w.b.). The dried slices were cooled for 15 min and then packed in low-density polyethylene bags until the beginning of rehydration and colour experiments within one week after drying. The initial moisture content of apple slices was determined using the vacuum oven method at 70°C for 24 h according to (AOAC, 1990). These experiments were replicated three time to obtain a reasonable average. The initial moisture content of the samples was found to be about 82% w.b. (wet basis) and is computed according to the following equation:

$$Mwb = \frac{W_w - W_d}{W_w}$$

The rehydration ratio (R) was used to express ability of the dried material to absorb water. A sample (10 g) of the dried sample was weighed (initial weight) into a 500 ml beaker containing 150 ml of distilled water and boiled for 5 min. After rehydration, the sample was weighed (final weight). The rehydration ratio was obtained by dividing the rehydrated weight by the initial weight (Prakash *et al*., 2003). Surface colour of both fresh and dried apple slices was measured using a Minolta CR-300 Chroma Meter to obtain the colour values which measures three parameters: lightness (L), redness (+a) and yellowness (+b). The instrument was calibrated against a white standard. Measurements were individually taken for five untreated and treated samples and the average of five readings was calculated. The colour difference was determined using the following equation (Sacilik and Elicin, 2006) and the fresh apple slices were used as the reference and a higher ΔE represents greater colour change from the reference material:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Statistical analysis: Data were subjected to analysis of variance (ANOVA) and means were compared using Duncan's multiple range test. In addition, the experimental data were analyzed at a significance level of 5%.

RESULTS AND DISCUSSION

Effect of the drying method on the moisture content and the drying time: Figure 3 and 4 present the variations in the moisture content as a function of the drying time undertaken the effect of the drying method by using (PSSD) drying system and by using (OSD) drying

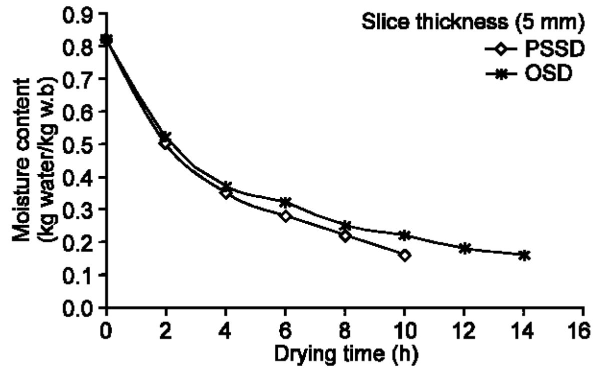

Fig. 3: The effect of the drying method on the drying time and the moisture content of 5 mm slices thickness

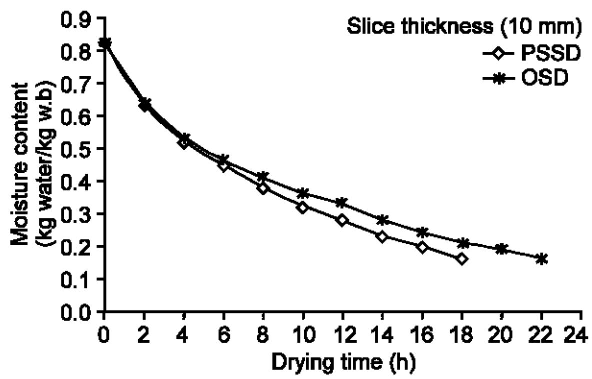

Fig. 4: The effect of the drying system on the drying time and on the moisture content of 10 mm slices thickness

system for the slice thickness of 5 and 10 mm, respectively. From these Fig, it can be seen that the moisture content decreases continually with the drying time. The drying time to reach to the required moisture content (0.16 wb.) for the apple thickness of 5 mm using (PSSD) drying system and by (OSD) system were 10 h, 14 h, respectively and for the apple thickness of 10 mm by (PSSD) system and by (OSD) system were, 18 h, 22 h, respectively. The decrease in the drying time by (PSSD) drying system comparing to the (OSD) drying system is due to the rising of the drying temperature in the solar dryer (40-45°C) compared to the ambient temperature (31-33°C), a higher drying air temperature produced a higher drying rate and consequently. The decreasing in the drying time with increasing in the drying air temperature for apple slices have been observed by Wang and Chao (2002); Sehedlou *et al*. (2010).

Effect slices thickness on the moisture content: The moisture content versus the drying time for apple slices of 5 mm and 10 mm thickness and for two drying

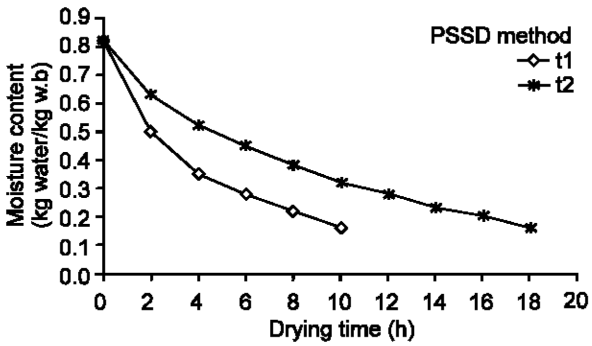

Fig. 5: The effect of slices thickness on the drying behavior in the PSSD drying system

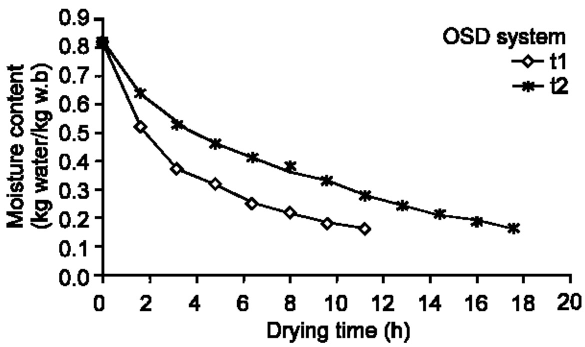

Fig. 6: The effect of slices thickness on the drying behavior in OSD drying system

methods are shown on Fig. 5 and 6, respectively. It is clear that, the drying time for 5 mm thickness is less by 80% comparing to 10 mm in the passive solar dryer and less by 57% in the open sun drying, this increase in the drying time with increasing the slice thickness was due to the reduced distance the moisture travels and increased surface area exposed for a given volume of the samples. Similar results have been reported by Meisami-asl *et al.* (2009).

Determination of quality parameter of dried apple slices: The slice thickness and the treated of apple slices by 1% ascorbic acid solution had significant effects on the rehydration ratio (Table 1). The rehydration ratio obtained for slice thickness of 10 mm were higher than those of 5 mm. When slice thickness changed from 5 to 10 mm, rehydration ratio values at the drying air temperature of 40°C increased by 41.7% and by 33.3% for treated and untreated respectively. Similar results have been reported by Krokida and Marinos-Kouris (2003).

The total color difference: The results also show that the pre-treatments of the apple samples decreased the total colour changes (ΔE) up to 17.3% for 5 mm thickness and by 25% for 5 mm thickness compared to the non-treated samples as shown in Table 2.

Table 1: Rehydration ratio of apple slices in (PSSD)

Slice thickness (mm)	Drying Temperature	Rehydration ratio: Treated	Rehydration ratio: untreated
5	40	2.85±0.032	2.70±0.035
10	40	3.99±0.059	3.60±0.45

Table 2: Means total Hunter colour change of treated and untreated apple slices

Treated (ascorbic acid solution of 1%)		Untreated	
Slices thickness (mm)		Slices thickness	
5	10	5	10
ΔE (%)		ΔE (%)	
9.20	10.02	10.80	13.50

Conclusion: The drying characteristics of the apple slices were studied in a passive shelf air dryer (PSSD) and in the open sun drying (OSD) as a single layer with thicknesses of 5 and 10 mm. The moisture content and the drying rate were affected by slice thickness. decreasing in the slice thickness caused a decrease in the drying time and an increase in the drying rate. The rehydration ratio is also affected significantly with the thickness of slices and treating of slices by ascorbic acid and the same thing had happened to the colour change.

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