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Drying Characteristics of Loquat Slices Using Different Dehydration Methods by Comparative Evaluation

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Abstract: The objective of this research was to evaluate the impact of four drying methods namely, hot air (HA), solar drying (SD), halogen oven drying (HO) (at 80 and 90°C) and Refractance window drying (RWD) (at 80 and 90°C) on chemical components, physicochemical, physical properties, color parameters, sensory evaluation of loquat (*Eriobotrya japonica*) slices after drying. In order to evaluate color quality of loquat slices the reflected color parameters (L*, a*, b*, chrome and hue value) were measured immediately after drying and during six month storage at 25°C. The results indicated that ascorbic acid content, phenolic compounds, total flavonoid, total sulphur dioxide content decreased after drying by different methods. The highest amounts of total phenolics for loquat slices were obtained at RW drying followed by halogen oven drying. Refractance window dried loquat exhibited a good retention of total carotenoid content similar to that halogen dried samples and color value higher than that of the hot air and solar dried slices. The RW dried loquat slices had the highest value for appearance, color, taste, odor, texture and overall acceptability. After 6 months storage at room temperature all color parameters decreased and the color of dried loquat slices became darker. The results of these trials showed the loquat slices samples that dried by RW drying method have higher quality and their color, an appearance are closer to fresh loquat fruit.

Key words: Loquat · Refractance window drying · Halogen oven drying · Solar drying · Hot air drying · Quality characteristics · Color parameters · Sensory evaluation

INTRODUCTION

Loquat (*Eriobotrya japonica*Lindl.) is a subtropical evergreen fruit tree, native to the southeast of China, belonging to the Maloideae subfamily of the Rosaceae. Loquat is cultivated in Cyprus, Egypt, Greece, Israel, Italy, Spain, Tunisia and Turkey. It is also widely distributed in many European, Asian and American countries [1-3]. Loquat is not widely known in Egypt, trees are propagated either by seeds or by grafting on loquat or quince root tocks [4]. Varieties grown in Egypt are : Early suchary, Large Round, Advance, Premier and Victoria and they appear on market in March and April [5]. In 1993 the acreage cultivated was about 80 feddans (33 ha) and the production was about 450 tons. The fruits of the loquat can be sold at a higher price in spring, since there are few competitive fruits on the mark except for strawberry, green plum and green almond [6].

Loquat fruit is usually eaten fresh without the peel, combined with other fruit in fruit salads, used as a pie filling and made into sauces and gelatin desserts, jam, syrup, jellies, nectar, canned foods, yogurt etc. [6,7]. Along the delicious taste and refreshing flavor, loquat fruits contain a host of active phytochemicals which contribute to health. These compounds have pronounced antioxidant and free radical scavenging agents that could lower the incidence of degenerative diseases such as cancer, arthritis, arteriosclerosis, heart disease, inflammation, brain dysfunction, cardiovascular disease, lung cancer and acceleration of the aging process [8,9]. Loquat is a perishable food whose characteristics are changed with time. Therefore, it becomes necessary to use conservation methods that allow preserving its properties. One of the most commonly used methods for conservation is drying, which is considered the oldest and the most important method of food preservation [10].

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Drying is probably the oldest method of food preservation and it is one of the most common processes used to improve food stability, since it decreases the water activity of the product, reduces microbiological activity and minimizes physical and chemical changes during storage [11].

Drying conditions or drying equipments can be modified to increase overall efficiencies. Hybrid drying techniques can be used, such as combing vacuum or convective drying with electrotechnologies such as microwave, radio frequency and infrared heating [12]. Drying allows for longer periods of storage and minimizes packing requirements, transport, handling, shipping, storage costs and distribution, in addition dehydrated products exhibit high acceptability [13].

In recent years, industrial dryers have been replaced the traditional methods for drying agricultural products. In industrial dryers, drying condition more controlled, the drying time is shorter and final product quality improved. As drying is one of the most energy intensive processes and dryers are expensive pieces of equipment, drying must be carried out as economically as possible. Various drying methods have been developed and use to dry different food produce [14].

Hot-air drying is the most extensively used drying method. The process consists of blowing a stream of hot air on top of the product, which results in moisture evaporation. Although been very common, the method involves high temperatures and long processing times, which are known to damage nutritional and sensory properties of foods [15].The cabinet dryer consists of a closed cabinet fitted with metal trays, which can be perforated or not. The product is placed on the trays as a thin layer, usually 2 - 6 cm deep. Air is first heated and then blown over and/or through each tray at 0.5 - 5 ms-1 [16].

Solar drying is essential for preserving agricultural products. Using a solar dryer, the drying time can be shortened by about 65% compared to sun drying because, inside the dryer, it is warmer than outside; the quality of the dried products can be improved in terms of hygiene, cleanliness, safe moisture content, colour and taste; the product is also completely protected from rain, dust, insects; and its payback period ranges from 2 to 4 years depending on the rate of utilization [17]. The solar dryers could be an alternative to the hot air and open sun drying methods, especially in locations with good sunshine during harvest season [18].

Halogen oven heating is a new technology that combines the time saving advantage of microwave heating with the browning and crisping advantages of halogen lamp heating [19]. Some of the advantages of infrared radiation as compared to conventional heating are reduced heating time, equipment compactness, rapid processing, decreased chance of flavor loss, preservation of vitamins in food products and absence of solute migration from inner to outer regions [19]. Application of infrared radiation heating is gaining popularity in food processing because of its definite advantages over conventional heating. Faster and efficient heat transfer, lower processing cost, uniform product heating and better organoleptic and nutritional value of processed material are some of the important features of infrared radiation drying [20, 21]. A halogen oven consists of a glass bowl with a lid that contains a fan and halogen bulbs. When switched on, beams of infrared radiation are released from the halogen bulbs to produce heat, the fan circulates hot air oven and around the food to cook. Halogen oven can be used to roast, grill, bake, steam, barbecue or dehydrate food, with no need of preheating [22].

Refractance Window drying (RWD) is a new film drying method featured by short processing time, low energy cost and improved product quality [23]. RWD utilizes circulating water at 95-97°C under atmospheric pressure to provide thermal energy via a transparent plastic interface to a wet product. The studies suggested that the water bearing products on the transparent plastic belt create a "window" allowing infrared radiation passing from hot water through the belt to reach the food [24]. As the product loses its moisture through evaporation, the "window" slowly closes, leaving mainly conducted heat to finish the drying process. This slow level of heat transfer in the final stage of the drying helps to prevent quality degradation of the product [25]. Since the RWD is a relatively new technology, there are only a few publications reported its effect on the quality characteristics of dried products [23, 24].

The objective of this work was to evaluate the impact of four drying methods hot air drying (HD), solar drying (SD), halogen oven drying (HO) and refractance window drying (RWD) on the quality characteristics, physicochemical, physical, color parameters and sensory properties of loquat after drying. Additionally, the influence of storage on the color changes of loquat slices was also evaluated.

MATERIALS AND METHODS

Materials: Fresh loquat (*Eriobotrya japonica*) fruits were obtained from local market, Alexandria city, Egypt at the ripe stage in May during the season 2012.

Methods:

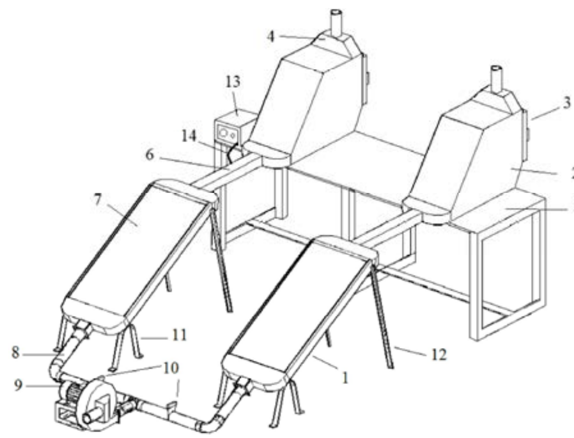
Technological Methods : Loquat fruits were cleaned and washed thoroughly with tap water and the seeds were removed manually, then sliced to 5 mm thickness using adjustable electrical slicer machine (Moneliex). The slices were immersed in 0.5% sodium metabisulplite solution for 5 min prior drying processes. Loquat slices were divided into five parts, one of them was used for analysis of fresh loquat, other parts were used individually for drying process (Hot air drying, Solar drying, Halogen oven drying and Refractance window drying).

Hot Air Drying of Loquat: The second portion was spread on the stainless steel trays in one layer and subjected to 60°C in a cabinet Michell dryer for 6 hours with an air velocity of 1.0 m/s to reach moisture content of about 11 - 13% [26]. The dried samples were packed in polyethylene bags until used.

Solar Drying: The dryer designed and manufactured by Ghanem [72] in the Faculty of Agricultural Engineering, Al-Azhar University, Nasr city, which located at (30° 2\ N and 31°12\ E). Systems are consists of a solar collector, drying chamber, drying box, Chimney and air blower. As shown in Fig. (1). The drying method was carried out at 30 - 60°

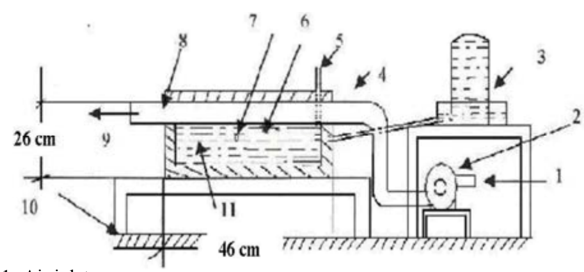
Halogen Oven Drying : Halogen oven drying process was performed using electric Halogen oven (LENTEL, model K Y R - 912A 1300 watt) heated to 80 and 90°C for 60 and 50 minutes respectively. It consist of a pyrex ban, its capacity 20L, halogen lamp as a heat source, its energy 1300 W and fan, it's velocity 1500 rpm. The loquat slices were spread in a single layeron sample tray and dried until constant weight.

Refractance Window Dryer: This study was carried out in the Faculty of Agricultural Engineering, Al-Ahzhar Unviersity, Nasr City.The dryer as reported by Ghanem [27]. (as shown in Fig. 2) consists of a water basin of four sides of galvanized iron sheet of 0.5 mm thick.



1	Solar collector	2	Drying chamber
3	Drying chamber door	4	Chimney
5	Supporting Wood frame	6	Air duct and inlet air heater
7	clear glass cover	8	PVC pipe
9	Air blower	10	Gates
11	Steel Stand	12	Stand
13	thermostat	14	electric wire (AC source)

Fig. 1: Solar dryer



1- Air inlet
2- Electrical air blower
3- Controlling water pressure apparatus
4- Air duct
5- Water vent
6- Water inlet
7- Electrical heater and thermostat
8- Dryer space
9- Air outlet
10- Table
11- Heated water

Fig. 2: Refractance Window dryer (Ghanem)

The basin dimensions are 0.4 × 0.4 m and was insulated from its bottom and sides by 0.03 m polyurethane panels. The space above the basin (dryer bin) is completely tight by a transparent cover tightly from the bottom. The outer surface of the dryer basin is tightly covered with insulated steel cover. A 2 KW heater, thermostat and an indicator circuit was used for controlling the water temperature in the basin. Water basin was continuously compensated by an apparatus maintaining the water at the atmospheric pressure. In present study, some modifications in RW drying system were applied to achieve some advantages as follow:

Transparent plastic belt conveyor as reported by Nindo and Tang [28] is displaced by transparent glass cover to overcome the sticky nature of dried loquat produced and to be easily removed after drying. The basin sides were well insulated and compensated water was siphoned to give energy advantage.

The loquat slices were spread on the conveyor belt of the dryer and the plastic belt was moved over the hot water to dry the slices. The drying process for each run was completed at 80 and 90°C for 45 and 55 min until constant weight.

Analytical Methods:

Proximate Analysis: Moisture content was determined by drying at 70°C according to Tripathi and Nath [29]. Crude protein (N × 6.25), crude ether extract, crude fiber and total ash were carried out according to the AOAC [30] procedures. Total sugars content were determined as described by Dubois *et al.* [31] and expressed as percent.Total reducing sugars was determined according to Lane-Eynon method as described by James [32]. The percentage of non reducing sugars was calculated by the difference between the total and the reducing sugars.

Ascorbic Acid Determination: The 2,6-dichlorophenol indophenols titration method was used to estimate ascorbic acid as described by the AOAC, [30].

Total Carotenoid Content: The carotenoids were exhaustively extracted from the loquat slices (10 to 15 g) using acetone, transferred to petroleum ether (30-70°C) / diethyl ether (2:1) and saponified overnight at room temperature with 10% methanolic KOH. The alkali was fully removed by washing with water and then the solvent was entirely evaporated in a rotary evaporator (Temp.< 40°C) [33]. The major carotenoids were quantified using HPLC.

Analysis by HPLC: The HPLC system model (Water 486), multi wavelengths UV detector set at 254 nm and the data recorder by Millennium Chromatography Manger software 2010 (Waters, Milford MA 01757) was used. Reverse phase C18 Nova pack C18 column 3.9 × 150 m m, 10 μm (Waters U.S.A.) was used. An isocratic mobile phase system of acetonitrile: methanol: 2- propanol (44 : 54 : 2 by vol) was used [34]. β- carotene was obtained from Sigma Chemical Co. (St. Louis, Mo, USA). Peak identification was based on retention time and published absorbance spectral data. β- carotene content was calculated as mg/100g sample.

Total Phenolics Compounds: Total phenolics compounds were measured by using Folin-Ciocalteau reagent according to Konyaloglu *et al.*[35] and Chan *et al.*[36]. Samples (10 g) were extracted by methanol : water (50 : 50, v/v) and left for 30 min with stirring. Test solutions of 0.5 ml were added to 4.0 ml of 1M Na_2CO_3. Five milliliters of Folin-Ciocalteauregeant (1 : 10, v/v) were added and the solutions were allowed to stand at 45°C in water bath for 15 min. Absorbance were measured at 750 nm. The blank consisted of all reagents and solvents without test compounds or standard. The standard was gallic acid prepared in concentrations of 50 - 200 mg/L. This is commonly used as a reference compound. The phenolic concentrations were determined by comparison with the standard calibration curve. Total phenol values were expressed as gallic acid equivalents (mg/100g dry weight).

Determination of Total Flavonoids Content: Total flavonoids content was determined using aluminum chloride method as reported by Kale *et al.*[37]. 0.5 ml of methanolic extract was dispensed into test tube, followed by 1.5 ml of methanol, 0.1 ml of aluminum chloride (10%), 0.1 ml of 1M potassium acetate and 2.8 ml of distilled water. The reaction mixture was shaken and then allowed to stand at room temperature for 30 minutes, before absorbance was read at 514 nm. Total flavonoid content was expressed as quercetin equivalent (QE) in mg/100g material.

Mineral Contents: Ca, Mg, K, Na, Zn, Mn, Cu and Fe contents were determined by using Perkin Elmer Atomic Absorption Spectrophotometer (Mode 119 CL), phosphorus content was also determined by the method of A.O.A.C [30].

Determination of Sulphur Dioxide: Total sulphur dioxide as (ppm) were determined using the iodine titration method as described by Ranganna [38].

Physicochemical Analysis:

Total Soluble Solids (TSS): One gram of the pulp of the loquat fruit was ground in a mortar was transferred to a centrifuge tube and the pulp was centrifuged at

10,000 × g for 15 minutes and the total soluble solids (TSS) content of the supernatant was determined with a manual refractometer (PORTABLE, 0-90%, Poland). The TSS was expressed in °Brix. The extractions were done in triplicate for each sample [39].

Titratable Acidity: Titratable acidity expressed as percentage of mallic acid of loquat samples was determined by titrating 5-9 gm samples with 0.01 N NaOH to pH 8.1 according to Rangsnna [40].

pH Value: The pH values of fresh and dried samples of loquat were measured according to El-Abasy [41]. Approximately 5g sample was homogenized with 30 ml distilled water in homogenized for 10 min and the filtered solution was used for pH estimation by digital pH meter (JENCO 608 U.S.A) at 25°C.

Physical Analysis:

Dehydration Ratio (DR): Dehydration ratio was calculated as mass of sliced loquat before loading to the drier to mass of dehydrated material at the time of removal from drier [42].

Rehydration Ratio (RR): The rehydration test was conducted as recommended by McMinn and Magee [43] and Prabhajan *et al.* [44].

Bulk Density: The bulk density of loquat slices was determined by pouring 5 g of the slices into a 10 ml graduated cylinder. The volume occupied by the sample was recorded and bulk density was calculated [45].

Colour Parameters: Colour of fresh and dried samples of loquat was determined using a Hunter Lab Easy MatchQC (L*, a*, b*) according to Caliskan and Polat [46]. The L* value represents lightness (L* 0 for black, L* 100 for white), whereas the a* scale represents the red/green dimension, with positive values for red and negative ones for green. The b* scale represents the yellow/blue dimension, with positive values for yellow and negative ones for blue. L*, a* and b* values were measured on three different spots in each samples. The results were recorded as the mean of these measurements. The chroma (C*) value, calculated as = $(a^{*2} + b^{*2})^{1/2}$ indicates colour intensity. Hue angle a parameter that has been shown to be effective in predicting visual colour appearance was calculated using the formula hue° = tan -1 (b*/a*) were 0° or 360° = red-purple, 90° = yellow, 180° = green and 270° = blue.

Sensory Evaluation: Panel of trained judges were asked to evaluate the dehydrated loquat samples for appearance, colour, odour, taste, texture and overall acceptability using a score scale from 1-10 where 1 indicates dislike extremely and 10 like extremely [47].

Statistical Analysis: The data obtained were subjected to analysis of variance according to SPSS [48]. Significant differences among individual means were analyzed by Duncan's multiple range test [49].

RESULTS AND DISCUSSION

Chemical Composition of Fresh Loquat Fruits: The chemical composition of fresh loquat fruits at ripening stage was determined (Table 1). Moisture content was 86.71% and agreed well with that reported by Hasegawa *et al.* [2]. The moisture content is considered the most important factor to regulate the deterioration of quality attributes in dried fruits [50]. Moreover, the sugars (total, reducing and non reducing) were 64.03%, 24.71% and 39.32% on dry weight basis, respectively. The balance between sugars and acids is important for the taste of the fruit in general contributing substantially to post harvest quality. The ether extract of loquat fruits was 2.56%, crude protein 4.67%, crude fiber 10.84% and total ash 3.24% on dry weight basis, respectively. This results is in agreement with that reported by Hasegawa *et al.* [2]. The obtained results indicated that total carotenoids (as β- carotene) accounted about 1785.55 mg/100g, on dry weight basis. This results are in accordance with Elif *et al.* [51] who reported that the variation of β- carotene was due to loquat varieties and/or loquat content of vitamin A which is an important nutrient for human health. Pareek *et al.* (2014) showed that loquat fruit was a good source of minerals and carotenoids.

From the same Table, the fresh loquat fruits had a high content (374.57 and 215.65 mg/100g, DW) of phenolic (as gallic acid) and flavonoid compounds, respectively. Ascorbic acid content was36.95 mg/100g on dry weight basis. Patricia *et al.*[52] showed that loquat fruit had lower content of vitamin C (ascorbic acid) in comparison with other fruits rich in vitamin such as oranges and cherries that contain about 40-1005 g/100g, respectively.

Physicochemical Properties and Mineral Contents of Fresh Loquat Fruits: Table (2) shows the total soluble solids (TSS) (°Brix), pH, titratable acidity (%), TSS/acidity and mineral content (Ca, Mg, K, Na, P and Fe) and the values were 11.98 (°Brix), 0.747%, (3.79, 16.04, 32.0, 24.67,

Table 1: Chemical composition of fresh loquat fruits

Component	Value * Fresh weight	Dry weight
Moisture (%)	86.71± 0.4486	-
Total sugars (%)	8.51±0.1473	64.03±0.176
Reducing sugars (%)	3.28±0.4912	24.71±0.206
Non reducing sugars (%)	5.23±0.1795	39.32±0.112
Ether extract (%)	0.34±0.079	2.56±0.105
Crude protein (%)	0.62±0.2629	4.67±0.132
Crude fiber (%)	1.44±0.1707	10.84±0.272
Total ash (%)	0.43±0.0757	3.24±0.114
Total carotenoids (mg/100g) **	237.31±20.033	1785.55±12.08
Total phenolic compounds (mg/g)***	49.78±2.802	374.57±3.43
Total flavonoids (mg/100g)	28.66±3.6505	215.65±4.281
Ascorbic acid (mg/100g)	4.91±1.5448	36.95±2.330

* Mean ±Standard deviation of three determinations

** as β- carotene *** mg gallic acid

Table 2: The physicochemical properties and mineral contents of fresh loquat fruits.

Property	Value *
Total soluble solids (TSS) (°Brix)	11.98±0.23
Titratable acidity (%)**	0.747±0.10
pH	3.79±0.30
T.S.S. / Acidity	16.04±0.22
Calcium (ppm)	32.0±0.08
Magnesium (ppm)	24.67±1.03
Potassium (ppm)	25.68±0.11
Sodium (ppm)	294.0±0.72
Phosphorus (ppm)	2.89±0.05
Iron (ppm)	45.0±.15

* Values are the means of three replicate ± SD

** as mallic acid (the value was 5.62% on dry weight basis)

25.68, 294, 2.89 and 45 ppm), respectively. Acidity of loquat slices (as malic acid) was 5.62% (on dry weight basis) which could be directly related to the concentration of fruit organic acid that is an important parameter in maintaining the quality of fruit. This results is in agreement with that reported by Attiq *et al.* [53] being 90% (malic acid) of the total organic acid in loquat fruit. These results are in full agreement with those reported by Wafaa and Nadir [4] who stated that loquat fruits had higher total soluble solids 11.0 Brix, lower ascorbic acid and can be considered as good source of β- carotene. The value of TSS was nearly close to that reported by Hasegawa *et al.* [2].

The high value for the ratio of sugar/acid found in loquat fruit indicate that the sugar contents is high making the fruit sweet and more suited to in nature consumption. The titratable acidity of fresh loquat fruits was similar to that reported by Hasegawa *et al.*[2]. The balance between sweetness and acidity, expressed as the ratio of the total soluble sugars (TSS) and the total organic acid content of loquat [54].

Physical Properties of Dried Loquat Slices by Different Drying Methods: Physical characteristics of dried loquat slices are considered to be very important properties. The rehydration characteristics of a dried product are widely used as indicators of quality. Rehydration is a complex process that is influenced by both physical and chemical changes associated with drying and the treatments preceding dehydration [55]. Table (3) shows dehydration, rehydration ratios and bulk density (g/cm^3) of loquat slices dried by four different methods (hot air oven, solar, halogen oven and refractive window) and at different times and temperatures. From the obtained data, it could be noticed that the loquat slices produced by hot air oven drying had lower bulk density (g/cm^3) and rehydration ratio than produced by halogen oven and refractance window drying. From the same Table, it could be exhibited that dehydration ratio decreased by all drying methods and the dried samples produced by RW drying exhibited decrease in dehydration ratio at 80 and 90°C compared with hot air drying. This may be due to increase in drying temperature. It is well known that foods that dried under optimum conditions suffer less damage, rapidly rehydrate and have extent shift life than that poorly dried [56].

Chemical Composition of Dried Loquat Slices by Different Drying Methods: The different dehydration systems resulted in differences of some of the evaluated chemical composition parameters of the loquat slices ingredients (Table 4). The refractance window drying (RWD) dried loquat samples presented the highest moisture content 10.88 and 10.92% at 80 and 90°C respectively followed halogen oven drying 11.06 and 10.96% at 80 and 90°C respectively. Drying time and air relative humidity are very important in drying operations since they affect the final moisture content of the product [57]. The total sugars of loquat slices decreased by different drying process (Table,4). The decrease in sugars content may be due to the formation of furfural as reported by Galal *et al.* [58]. The tabulated data indicated that drying process led to increase in reducing sugars and decreased in non reducing sugars. Mattuk *et al.* [59] reported that dehydration process of guava slices had a clear effect on sugars content, while an obvious decrease occurred in the non reducing sugars. A simultaneous increase was observed in the reducing ones, this may be

Table 3: Effect of different drying methods on physical characteristics of loquat slices

	Drying methods					
			Halogen oven		Refractance window	
Properties	Hot air	Solar drying	80°C	90°C	80°C	90°C
Rehydration ratio	2.89±.01^{b}	3.22±.22^{a}	3.19±.04^{a}	3.14±.14^{ab}	3.16±.10^{a}	3.12±12.12^{ab}
Dehydration ratio	3.74±.02^{a}	3.58±.02^{a}	3.28±.08^{b}	3.17±.02^{b}	3.22±.22^{b}	3.15±.03^{b}
Bulk density(g/cm^3)	.596±.017^{b}	.877±.007^{a}	.846±.003^{a}	.861±.001^{a}	.788±.013^{a}	.673±.174^{b}

Mean ± Standard deviation of three determinations

In a raw, means have the same small superscript letter are not significantly different by Danken's Test at 5% level

Table 4: Chemical characteristics of dried loquat slices by different drying methods

	Drying methods					
			Halogen oven		Refractance window	
Component	Hot air	Solar drying	90°C	80°C	90°C	80°C
Moisutre (%)	11.25±.251^{a}	11.13±.13^{a}	10.96±.001^{b}	11.06±.103^{a}	10.92.002^{b}	10.88±.008^{b}
Total solids (%)	88.75±.005^{b}	88.87±.007^{b}	89.04±.004^{a}	88.94±.004^{b}	89.12±.12^{a}	89.08±.138^{a}
Total sugar (%)	56.17±.170^{d}	60.52±.002^{b}	59.89±.009^{c}	59.87±.87^{c}	62.86±.006^{a}	62.37±.002^{a}
Reducing sugar (%)	32.76±2.0^{c}	33.65±.05^{c}	35.89±.001^{a}	34.76±.001^{b}	35.92±1.0^{a}	34.86±1.0^{b}
Non reducing sugar (%)	23.41±2.09^{d}	26.87±.004^{c}	23.997±.08^{d}	25.11±.88^{b}	26.94±.94^{b}	27.51±.99^{a}
Total acidity (%) *	4.86±.001^{c}	5.16±.16^{b}	5.33±.03^{a}	5.29±.04^{a}	5.32±.001^{a}	5.28±.001^{a}
pH - value	3.11±.11^{b}	3.01±.17^{b}	3.45±.005^{a}	3.42±.002^{a}	3.48±.004^{a}	3.47±.002a
Ascorbic acid (mg/100g)	22.42±.20^{e}	25.31±.31^{d}	33.62±.2^{c}	35.09±.16^{b}	35.51±.002^{a}	35.72±.003^{a}
Toal carotenoids (mg/100g)	1447.52±.09^{f}	1529.42±.11^{e}	1638.06±.15^{c}	1640.32±.09^{d}	1677.46±.16^{a}	1670.11±.105^{b}
Total phenolic (mg/100g)	302.74±.577^{d}	326.12±.24^{a}	320.31±.31^{b}	312.66±.006^{c}	328.24±.69^{a}	323.67±.67^{b}
Total flavonoids (mg/100g)	120.68±1.0^{e}	133.92±.002^{d}	162.16±2.0^{b}	150.91±.1^{c}	164.32±.32a^{b}	154.18±1.10^{c}
Sulphur dioxide (ppm)	1268.21±.11^{c}	1370.09±.31^{b}	1389.16±.156^{a}	1387.21±.20^{a}	1389.0±1.0^{a}	1388.0±3.0^{a}

Mean ± Standard deviation of three determinations

In a raw, means have the same small superscript letter are not significantly different by Danken's Test at 5% level

* as malic acid

due to the fact that under acidic conditions and drying temperature the non reducing sugars are inverted to reducing ones.

A significantly ($p < 0.05$) decrease in total acidity after drying process of loquat slices was noticed. This may be attributed to the loss of organic acids that coud be consumed in the hydrolysis of polycarbohydrates[60].

The titratable acidity of loquat slices decreased significantly ($p < 0.05$) on dry matter basis after drying. The reduction on acidity may be due to leaching out acids from fruit during sulphiting before drying.

From the obtained data shown in Table (4), it is clear that the drying process caused remarkable significant ($p < 0.05$) reduction on ascorbic acid content. The decrease in ascorbic acid could be caused by the oxidization of ascorbic acid during drying as reported by Galal *et al.* [58]. It obvious that ascorbic acid content of loquat slices samples dried by hot air were significantly higher than those dried by RWD or halogen oven..

Total phenolic content of fresh loquat slices was 374.57 mg/100g (on dry weight basis) which was dramatically decreased by drying process. Since, total phenolic content of loquat slices dried by RWD (dehydrated at 90, 80°C), halogen oven (dehydrated at 90, 80°C), solar drying and hot air were 328.24, 323.67, 312.66, 320.31, 326.12 and 302.74 mg/100g, respectively. The drying methods caused significant ($p < 0.05$) reduction on phenolic compounds. In this respect, Arts and Hollman [61] found that phenolics were highly unstable to thermal processes because they rapidly transformed into various products, mainly due to plant cell damage that causes biochemical and chemical changes. The loss of phenolics could also be a result of thermal instability or enzymatic oxidation, especially during the pre-processing operations [62]. Contradictory to the results of Kim *et al.* [63] who showed that total phenol content of grape seed extract was significantly increased by heat treatment. They suggested that heat could be liberated phenolic compounds from the fruit tissue. Our results indicate that the greatest loss of phenolic compounds was associated with oven drying, most likely due to the length of the drying period, which allows aerial oxidation and enzymatic degradation.

Total carotenoids of loquat slices was significantly ($p < 0.05$) decreased by drying process. The significantly ($p < 0.05$) highest decrease (1447.52 mg/100g) in total carotenoids was occurred in loquat slices dried by hot air drying which may be due to the length of drying period. This decrement may be due to some oxidation reactions that developed during drying as reported by Morton and Waston[56]. From the obtained data, loquat slices dried by RWD had the highest levels of total carotenoids followed by halogen oven comparing with hot air drying.

With regard the changes of total flavonoids in dried loquat slices as affected by different drying methods (Table,4), the RW drying process caused, in general, a highly retention of total flavonoids followed by halogen oven drying and solar drying in dried loquat slices which depending upon the drying time comparing with hot air drying (4 h), whereas, the RW drying process caused a highly considerable retention of total flavonoids at ratio of 76.20%, 71.495% (at 90 and 80°C) and 69.98%, 75.196% (at 90 and 80°C), respectively, while the loquat slices dried by hot air drying process not more retention than 55.96% of total flavonoids. These results are in agreement with those reported by Abul-Fadl and Ghanem [64]. The RW drying technology has become attractive for applications in food industry because the dried products are of high quality and the equipment is relatively inexpensive [65].

Sulphur dioxide is considered to be one of the most important factors that affect quality attributes and prevent colour and quality deterioration of dried fruits [66]. Drying processes had a great effect on sulfur dioxide content, whereas, large quality of SO_2 was lost during hot air drying (Table,4). Mattuk *et al.* [59] recorded 40-60% loss in SO_2 in the dried guava powder.

Color Measurements: Food color is a major determinant of product quality and affects consumer preferences [67] and may be used as an indicator topredict the chemical and quality changes due to thermal processing.

From a consumer acceptance viewpoint, color is an important attribute of the dried product. Color parameters are represented by Hunter a and b values, while any change in a and b values is accompanied by a simultaneous change in L values [68]. Hence color measurement (Hunter L, a and b) should be used to evaluate the effect of drying methods on the colour quality of loquat powder. Results in Table (5) show that the drying process decreased lightness in all samples dried by different methods. Lighness (L*) reached (42.86, 42.32), (40.36, 41.41), 40.67 and 33.87 for loquat slices dried by refractance window (at 90, 80°C), halogen oven (90, 80°C), solar drying and hot air, respectively. This may be due to formation of brown pigments. From the obtained data, it could be noticed that the samples dried by hot air had lower value of Lightness and seemed darker in color compared to samples dried by refractance window or halogen oven. This could be related to the drying time to which each sample was subjected. These results are in agreement with those reported by Khazaei *et al.* [69] who reported that lower temperature with longer drying periods may cause more damage than higher temperatures for shorter drying time. There were significant ($p < 0.05$) differences in these parameters between fresh and dried loquat samples. Referring to Table (5), it could be noticed that samples dried by refractance window had higher color parameters followed by halogen oven as compared to the other dried ones.

Chroma (degree of saturation of color) and hue angle values were calculated and the results are shown in Table (5). The results indicated that chroma values decreased after drying. The lower values of chroma indicate a reduced purity of color (darkening) [70]. The best colour intensity (saturation) was found in loquat samples dried by refractance window and it decreased from 21.25 to 18.43 and 18.25 for 90 and 80°C, respectively. The less color alterations in RWD samples may be linked to less carotenoids decomposition and/or less formation of undesirable pigments as a result of mild drying conditions.Valdenegro *et al.* [70] reported that an increase in drying duration reduced the chroma values for the fruits, regardless of the drying method. Changes in browning may be well represented by the decrease in L* and b* [67]. These results clearly demonstrate that each drying method affects the browning reactions that occur during the process in a different way, especially in hot air drying method. These are in agreement with reported by Obied *et al.* [71].

Sensory Evaluation of Dried Loquat Slices by Different Drying Methods: All the RW, halogen oven, solar and hot air dried loquat slices were judged by panelists immediately after drying process for appearance, color, odor, taste, texture and overall acceptability and results are shown in Table (6). It is obvious that organoleptic properties (appearance, color, odor, taste, texture and overall acceptability) were significantly ($p < 0.05$)

Table 5: Color parameters of fresh and dried loquat slices by different drying methods

		Drying methods					
				Halogen oven		Refractance window	
Color Parameters	Fresh	Hot air	Solar drying	80°C	90°C	80°C	90°C
L*	46.33±1.00[a]	33.87±3.0[c]	40.67±0.67[b]	41.41±1.0[b]	40.36±5.0[b]	42.31±1.0[ab]	42.86±2.0[ab]
a*	18.46±.46[a]	13.31±1.0[d]	16.28±.28[b]	15.21±.36[c]	15.36±.36[c]	16.09±.09[bc]	16.31±.31[b]
b*	20.17±.17[a]	13.48±.48[d]	17.52±.00[c]	17.56±.03[c]	18.46±.46[b]	18.52±.52[b]	18.48±.48[b]
a/b	0.915±.02[a]	0.987±.00[b]	0.929±.03[b]	0.866±.01[c]	0.832±.03[d]	0.869±.01[c]	0.883±.01[c]
Chroma	21.25±.144[a]	14.39±.23[d]	16.87±.05[c]	17.96±.57[b]	18.12±.07[b]	18.25±.144[b]	18.43±.25[b]
Hue	63.47±.58[a]	46.46±.27[g]	54.33±.19[d]	52.15±.09[f]	53.26±.15[e]	56.14±.58[c]	58.32±.18[b]

Mean ± Standard deviation of three determinations

In a row, means have the same small superscript letter are not significantly different by Danken's Test at 5% level

Table 6: Sensory evaluation dried loquat slices by different drying methods

	Drying methods					
			Halogen oven		Refractance window	
Attributes	Hot air	Solar drying	80°C	90°C	80°C	90°C
Appearance	6.1±.10[d]	7.6±.10[c]	7.86±.02[c]	7.80±.02[c]	8.20±.346[b]	8.60±.01[a]
Colour	6.0±.00[e]	7.30±.30[d]	7.80±.05[c]	8.10±.173[bc]	8.60±.01[a]	8.20±.20[b]
Odour	6.25±.161[c]	7.20±.346[b]	7.60±.20[ab]	7.40±.40[ab]	7.66±.01[ab]	7.70±.05[a]
Taste	6.98±.02[f]	7.11±.11[d]	6.88±.01[e]	7.32±.02[c]	7.85±.05[a]	7.65±.05[b]
Texture	7.0±.00[c]	7.00±.50[c]	7.20±.20[c]	7.30±.05[bc]	7.75±.05[b]	8.40±.40[a]
Overall acceptability	6.466±.00[f]	7.24±.02[e]	7.47±.02[d]	7.58±.02[c]	8.01±.017[b]	8.11±.11[a]

Mean ± Standard deviation of three determinations

In a row, means have the same small superscript letter are not significantly different by Danken's Test at 5% level

influenced by the drying methods. The significantly ($p < 0.05$) lowest scores of all characteristics were given for hot air drying loquat slices. The tabulated data indicated that loquat slices dried by RWD (at 90, 80°C) was highly acceptable followed by halogen oven (at 90, 80°C) and solar compared with dried by hot air. According to the values, no significant differences were found between loquat slices dried by halogen oven (at 90 or 80°C) and solar with respect to appearance, odour and texture. Therefore, the best sensory quality of the dried loquat slices was found by drying the fresh fruits with RW drying at 90 and 80°C. Further, samples which dried by RW drying at 80°C had the highest color score followed by RW drying at 90°C, whereas the samples dried by hot air had the lowest color score. Aydogdu *et al.*[72] reported that hot air drying method was widely used in industry and the food was exposed to heat for longer time, so it causes some problems related to quality characteristics such as unacceptable color, flavor, texture, sensory properties, loss of nutrients, shrinkage, reduction in bulk density and rehydration capacity. In conventional air drying, high temperatures are employed that adversely affect the texture, color, flavor and nutritional value of the loquat slices.

Changes in Color Parameters of Loquat Slices During Storage: The hunter color scale parameters, lightness (L*), redness (a*) and yellowness (b*) were used to estimate color changes after storage of dried loquat slices. The effect of storage on color of the dried loquat slices was shown in Table (7). L*, a*, b*, chroma and hue value decreased by increasing the storage period and the color became darker. This may be due to the reduction in total sulphur dioxide used during the pretreatments and thus the browning reactions happened.

Table 7: Changes in color parameters of loquat slices during storage

Treatment	Storage time	L*	a*	b*	Chrome	Hue
Fresh	-	46.33±.12	8.46±.06	20.17±.21	21.25±.08	63.46±1.2
Hot air	Zero	33.87±.09	13.31±.23	13.48±1.09	14.39±.11	46.46±.50
Drying	3	29.25±.11	9.05±.19	8.82±.21	8.42±.03	44.32±.12
	6	26.81±.14	6.26±.22	4.21±.03	5.16±.23	43.09±.11
Solar drying	Zero	40.67±.31	16.28±.21	17.52±.04	16.87±.01	54.30±.1.09
	3	35.97±.11	12.23±.09	11.97±.14	10.43±.15	53.04±.24
	6	35.51±.05	8.15±1.12	9.14±.34	7.96±.28	50.13±.00
Halogen oven drying (80°C)	Zero	41.42±.12	15.21±.00	17.56±.32	17.96±.03	52.15±.17
	3	36.82±.32	11.62±.12	11.36±.00	11.51±.79	51.86±.00
	6	35.27±.22	9.06±.11	8.09±.12	8.48±.04	50.29±.11
Halogen oven drying (90°C)	Zero	40.36±1.0	15.36±.34	18.46±.00	18.12±.21	53.26±.05
	3	35.74±.45	11.55±.07	10.56±.22	11.88±.13	52.47±.11
	6	34.36±.22	9.18±.09	7.17±.10	7.76±.66	52.06±.23
RWD (80°C)	Zero	42.31±.05	16.09±.00	18.52±.08	18.25±.20	56.14±.33
	3	37.42±.13	12.37±.32	11.18±.22	11.80±.07	56.22±.12
	6	35.18±.65	10.32±.11	9.52±.03	8.72±.21	55.12±.08
RWD (90°C)	Zero	42.86±.09	16.31±.04	18.48±.22	18.43±.11	58.32±.18
	3	38.25±.16	12.52±1.0	11.36±.08	12.28±.03	57.96±.31
	6	36.19±.13	9.16±1.12	9.66±.17	8.09±.00	56.35±.22

Mean ± Standard deviation

CONCLUSIONS

In conclusion, we demonstrated that loquat fruit is highly nutritious value which can play a great role in human health. RWD could be the preferred drying method for loquat slices for a higher retention of its quality characteristics.

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