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EFFECT OF DRYING TECHNIQUES ON PHYSICOCHEMICAL AND TEXTURAL PROPERTIES OF LOQUAT (*ERIOBOTRYA JAPONICA*)

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Abstract

The present study was undertaken to study the effect of different drying methods on physicochemical and textural properties of loquat slices. Uniform size of loquat slices were pre-treated with 1% potassium metabisulphite. These slices were dried by using different drying techniques *i.e.* tray drying (55 °C), vacuum drying (55 °C, at 500 mm Hg) and freeze drying (-40°C,0.006 bar). Physical properties of dried slice were assessed by bulk density (BD), tap density (TD), Carr index (CI), Hausner ratio (HR), porosity, rehydration ratio (RR), coefficient of rehydration (COR), dehydration ratio (RR) and hygroscopicity. Color value was analysed in terms of L*, a*, b*, total color difference (TCD), Hue, Croma and browning index (BI). Hardness was analysed by using texture analyser. It was observed that freeze-dried slices shows decreasing trend of all aspects of physical properties except rehydration ratio and coefficient of rehydration. Freeze-dried samples showed less change in BI and TCD among all the samples. It was found that freeze-dried rehydrated sample reflect lowest hardness than other rehydrated samples.

Key words : Indian loquat, Drying techniques, Freeze-drying (FD), Tray drying (TD), vacuum drying (VD).

Introduction

Fresh fruits in their natural form are good sources of phytochemicals and micronutrients, but, most of the fruits are seasonal, perishable and unavailable throughout the year. With the advancement in the technology, many processing methods have developed to ensure the availability of the seasonal fruits throughout year in the form of processed products, which are generally ready to use.

Loquat *(Eriobotrya japonica)* is an Asian fruit belonging to the family of Rosaceae. China is largest producer of loquat and it also has been commercially cultivated worldwide in countries such as Japan, India, Brazil, United States, Australia, Spain and South Africa (Lin *et al.,* 1999; Morton *et al.,* 1987*).*During the seasonal glut, the yield per unit land area of loquat is very high but due to its highly perishable nature, producers does not show interest for the cultivation of this fruit. Loquat is considered as an evergreen tree in China and Japan with short branches that flowers in late autumn or early winter (Hong Y. *et al.,* 2008).

In India, loquat is cultivated mainly in different region of Uttar Pradesh(C.P. Khare; 2009). Varieties grown in India make their presence in the market in the month of March and April. As few competitive fruits are available in the market during spring season, loquat fetches a higher price during this season (Lin *et al.,* 1999).

Loquat is consumed both way, *i.e.*, with peel or without peel. Loquat is a very high medicinal value plant and all of its parts are used for the treatment of many ailments like inflammation, cough, sneezing, chronic bronchitis, diabetes, and cancer (Magalhaes A.S. *et al.,* 2009). The fruits also contain antioxidant properties due to the presence of flavonoids, phenolic and tocopherol compounds, vitamins, acids and sugars. Loquat is used for making some processed products like jelly, jam, preserves, candy, various drinks like wine, vinegar and fermented products etc. (Rajlakshmi P. *et al.,* 2017)

Tray drying is a simple drying method and is used for high volume drying of fruits & vegetable in general. It is usually chosen because of its low cost and easy operational methods. Although being a very common drying method, it uses high temperature and high processing times leading to the alteration of the properties of foods (Mohite and Sharma, 2018).

Vacuum drying is a better dehydration technique and is generally used for heat sensitive products in order to avoid product degradation due to high temperatures. Vacuum drying works at lower pressure and temperature, water molecules diffuse on the surface of fruit slices and evaporates at lower temperature because of low pressure. Colour, flavour, texture and antioxidant properties are preserved due to the absence of air in vacuum drying (Drouzas A. E. *et al.,* 1996).

A well-known modern drying method used for food materials is freeze drying. Freeze dryer works on the principle of sublimation, where a frozen food product is converted to its dried form. Because of the ability of this dehydration method to preserve the biological activity of thermo-sensitive components and the original nutritional properties of the food materials, it has a broad spectrum of application. It is reported that freeze-drying technique maintains the quality of dehydrated materials such as texture, colour, nutrition, flavour and overall appearance. The freeze-dried products also have high rehydration capacity (N. Harnkarnsujarit *et al.,* 2016).

This research was aimed to evaluate the physical characteristics of slices of loquat fruit grown in India, as well as to evaluate the impact of different drying methods (tray drying, vacuum drying and freeze-drying) on overall quality of developed loquat slices. The Kandala variety of loquat was procured from the orchids of Baghpat district (U.P.) to conduct the study. The literature survey disclosed that few research studies have been reported and published on the comparative different drying study of Indian cultivar loquat creating a possibility to investigate the proper suitable drying method.

Materials and Methods

Sample collection and preparation

Loquat fruits (*Eriobotrya japonica*) of the "kandala" variety were collected from Baghpat district of Western Uttar Pradesh, India. Fresh fruits were manually peeled, cored and cut with slice thickness of 0.5 cm. Total soluble solids (TSS) of fresh fruit was determined and was found in the range of 9-10° Brix. The slices were immersed in 1% sodium metabisulphite solution for 10 minutes to prevent enzymatic browning and allowed to drain. The Loquat slices were then kept for drying using the three different drying methods(tray drying, vacuum drying and freeze-drying). Accordingly, the samples were coded as TD (tray drying at 55 °C), VD (vacuum drying at 55 °C) and FD (freeze drying at -40 °C).

Drying Process

Tray drying

The pre-treated samples of loquat slices were placed on trays of tray drier (IK-112, New Delhi).Tray drier mainly consists of a thermostat, fan and temperature controller. Drying was carried out at 55°C for 10 h with an air velocity of 0.8 m/s so that moisture content in the final sample reaches to 8 -9 %. After drying, the dried slices were cooled, packed and stored in polyethylene bags for different studies.

Vacuum drying

The pre-treated samples of loquat slices were dried on stainless steel trays in lab model vacuum dryer at 55°C and 500 mm Hg pressure. Slices were dried until the constant mass was obtained. The vacuum (500 mm Hg) was maintained throughout the experiment (Mohite and Sharma, 2018).Finally, the sample was allowed to cool in desiccators and packed in zipped polyethylene bags and stored for further study.

Freeze-drying

Freeze-drying of loquat slices were carried out by using freeze dryer (Lyophilizer) (Model H-T40m-P). The pre-treated loquat slices were uniformly spread on stainless steel plates and placed in the freeze dryer. The freeze-drying of the slices was carried out at -40°C and 0.006 bar for 38 h. The freeze-drying of loquat slices was continued until it attained a moisture level of 7 to 9 % (wb). As the slices reached the desired moisture content, the drying was stopped and slices were subsequently cooled and stored for further study.

Physical Properties of Loquat Slices

Density

Both bulk density and Tap density were studied as described by Patil and Chauhan (Patil *et al.,* 2014). The bulk density of slices was determined by taking 15 g of loquat slice sample and placing in a 50 ml cylinder. Tap density was calculated from the weight of dried loquat slices contained in the cylinder after hand tapping for 100 times. The bulk and tap density of slice sample was calculated by following formulas, equation(1), (2).

$$\text{Bulk density } (\rho b) = \frac{\text{Weight of slice}}{\text{Volume occupied in the cylinder}} \tag{1}$$

$$\text{Tap density } (\rho t) = \frac{\text{Weight of slice}}{\text{Volume occupied in the cylinder after tapping}} \tag{2}$$

Flowability and Cohesiveness

Flowability and cohesiveness of the slice sample was estimated in terms of Carr index (CI) (Carr R.L., 1965), and Hausner ratio (HR) (Hausner H.H., 1967)and (Mohite *et al.,* 2019) respectively equation (3), (4).

$$\text{Carr Index (CI)} = \rho t - \rho b / \rho t \quad (3)$$

$$\text{Hausner ratio (HR)} = \rho t / \rho b \quad (4)$$

where, ρt and ρb are tap density and bulk density of sample

According to Carr, if the value of Carr Index is within the range of 5 -15% it will lead to excellent flow ability and if CI range is above 25%, it is the indication of poor flowability (Carr R.L., 1965),.

Ranges for HR in defining the flowability are as following:

(i) For free flowing powder: $1.0<HR<1.1$, (ii) for medium flowing powder: $1.1<HR< 1.25$, (iii) for difficult flowing powder: it should be$1.25<HR<1.4$, and (iv) for $HR>1.4$, it shows very low flowing property.

Porosity

Porosity (ε) is obtained by following equation (5)

$$\text{Porosity} (\varepsilon) = 1 - \frac{\rho b}{\rho t} \quad (5)$$

Where,

ρt and ρb are tap density and bulk density of sample

Dehydration Ratio (DR)

Dehydration ratio is defined as the ratio of mass of slices before drying to the mass of dried samples. Dehydration ratio was expressed as the mass of sliced loquat before keeping in the drier to the mass of dried slice after removal from drier (Tunde *et al.,* 2008)as shown in equation (6).

Rehydration Ratio

$$D_{\text{ratio}} = \frac{M_{\text{before}}}{M_{\text{after}}} \quad (6)$$

The rehydration ratio was conducted to explain the reconstitution property of the dried loquat slices (Rangana S. 2008). Take 5 g of the dried samples and allow it to soak in sufficient amount of water for 10 minutes at room temperature, rehydration ratio and coefficient of rehydration were calculated through equation (7), (8).

$$\text{Rehydration Ratio (RR)} = C/D \quad (7)$$

Coefficient of Rehydration (COR) =

$$\frac{\text{C/Dx100} - \text{A}}{100 - \text{B}} \quad (8)$$

Where,

A=moisture present in sample before drying (%wb)

B=moisture present in dried samples (% wb)

C=mass of sample after water soaking (g)

D=mass of sample before soaking (g)

Hygroscopicity

Hygroscopicity was studied by the method described by Cai and Corke with slight modifications (Cai Y.Z. *et al.,* 2000). 1g of samples was placed in a glass plate at 25ºC with a saturated NaCl solution (75.29% relative humidity) in a desiccator and allow for equilibrium. Equilibrated samples were weighed after an interval of one week, and hygroscopicity was expressed as grams of intake moisture per 100 g of dry matter (Goula A.M. *et al.,*2005).

Determination of pH

The pH of the solution was measured describe by using a pH meter (Deluxe pH meter- 101) with little modification,10g of sample was homogenized with distilled water (100ml) and three measurements were taken on every sample. The results were represented as unit of pH (Moumita Chowdhury, 2018; Rangana S. 1986)

Proximate composition

Moisture, fat, protein, as hand crude fibre content in dried slices were calculated as per standard methods (AOAC, 2000). Total carbohydrate was calculated by subtracting the value of moisture, protein, fat, crude fibre and ash content from 100.

Colour

Colour measurement of dried loquat slices were carried out by manual chroma meter (Chroma Meter CR-400, Minolta, Japan). Before each measurement instrument was calibrated. The coordinates of color 5Ø?Ü* (lightness), 5ØNÜ* (redness), and 5ØOÜ* (yellowness) was taken for colour estimation of dehydrated slices. Three replicates of each sample were measured to get the average L^*, a^* and b^* values (Barnwal, *et al.,* 2015). In addition, the hue angle, chroma and Browning Index (BI) were calculated from the L^*, a^* and b^* values (Anuradha M. *et al.,* 2014; Gat YS *et al.,* 2015) by using equation (9), (10) and (11).

$$\text{Chroma(C)} = \sqrt{(a^2 + b^2)} \quad (9)$$

$$\text{Hue Angle } (H^0) = \tan^{-1} (b^*/a^*) \quad (10)$$

[100(x – 0.31)]

$$BI = \frac{[100(x - 0.31)]}{0.17} \quad (11)$$

Where

$$x = \frac{(a^* + 1.75L^*)}{(5.645L^* + a^* - 3.012b^*)}$$

Texture measurement

The textural property of dried loquat slices was perform in terms of hardness by using a texture analyzer ((TA-Hdi), Stable Micro systems (U.K.) with a load cell of 2.5 kg. The dried slices were compressed twice 75% of their original height by two consecutive compressions using a P/25p ; 25mm diameter Cylinder Lap Perspex cylindrical probe at the compression rate of 1 mm/s (Rahman M.S. *et al.,* 2005). The time interval between the two com-pression cycles was 10 s. The instruments automatically controlled all steps. The result was automatically recorded in the form of force-time curve. All textural measurements were per-formed with four replicates of each sample (Mohite *et al.,* 2019).

Statistical Analysis

All data were subjected to statistically for analysis of variance (ANOVA) followed by Duncan's test. All data were taken in triplicates. In addition, the experimental data for physical, and colour quality were analysed at a significance level of 5%.

Results and Discussion

Effect on proximate composition of dried loquat slices

The effects of drying techniques on the proximate composition of loquat are discussed in (Table 1). Moisture, carbohydrate, fibre, ash, fat, protein and energy of fresh loquat was 85.61%, 12.72 g, 1.5 g, 0.53 g, 0.13, 0.52 g and 53.86 Kcal respectively. Proximate composition of dehydrated slices were significantly (p d"0.05) affected by different drying techniques. Samples dried by using freeze-drying technique are prone to freezing injury, which might cause mechanical damage to the plant cell membrane due to the formation of ice during freezing (Akubor P.I *et al.,* 2012). Freeze-dried slice had highest moisture content (8.8%), followed by tray drying (8.7%) and vacuum drying (8.2%). There was a non-significant ($p \leq 0.05$) reduction in fat, fibre, protein and ash content during different drying methods. Tray dried sample was most affected followed by vacuum dried sample which might be due to secretion of fat with moisture removal. The findings in this study were comparable to reported kinnow properties (Shafiya Rafiq *et al.,* 2019). Decrease in protein content probably occurs because of Millard reaction which results in complex changes in food due to the reaction between amino acids and reducing content (Lee-Hoon H *et al.,* 2019). Decrease in protein content and other proximate component due to formation of complexes between anti-nutritional substances and proteins in the presence of heat, which cause reduction of protein availability (Enomfon-Akpan J. *et al.,* 2004).

Physical characteristics of loquat slices

The bulk density and tap density play a significant indication of the packing and flow behaviour of the slices, as well as the designing of storage equipments. Physical properties of dehydrated slices were shown in Table 2. The bulk densities and tap densities of the dried slice varied from 0.37 to 0.19 g/mL and 0.41 to 0.20 g/ml respectively depending on the drying methods and temperature. Freeze drying exhibited lower bulk and tap density followed by tray drying. Vacuum drying showed highest bulk density and tap density. Drying ratio was significantly varied from 10.21 to 4.93. Freeze-dried slices reported highest dehydration and rehydration ratio and lowest value was observed in tray drying. This is due to the reason that in freeze-drying product dehydrates by sublimation and produce porous texture, which absorb water easily, and tray and vacuum dried slice samples show non-significant difference. CI and HR varied from 8.69 to 5.67 and 1.06 to 1.1 respectively with freeze dried slices showing lowest CI and HR followed by vacuum dried slices. The Hausner ratio and Carr index showed the flowability as per the scale described. The hygroscopicity values of loquat slice obtained by different drying methods are shown in Table 2. The Freeze-dried slices have shown higher values of hygroscopicity compared to vacuum and tray dried slices. This may be developed due to porous structure of freeze-dried sample during ice sublimation. Therefore, at the same equilibrium condition, freeze-dried loquat slices adsorbed higher moisture. A similar observation was also reported for carrot slices study for vacuum drying, air-drying and freeze-drying (Lin T.M. *et al.,* 1998).

Effect of drying techniques on color properties of loquat slices

Different drying techniques employed a significant (p d"0.05) changes on the colour values of loquat slice. Fresh loquat samples were found L*, a* and b* values is 47.74, 5.65 and 27.30 respectively in (Table 3). Similar results were also reported (F. Samia El-Safy, 2014).Due to temperature increase during drying L* a* and b* value decrease significantly ($p \leq 0.05$). Tray dried sample was shows minimum L*(52.12) value and found to be darker in colour due to maillard reaction. Whereas freeze-dried sample reflect higher having L* value higher (59.48). Based on over all colour quality (lightness, yellowness, darkness); the better-considered sample was freeze-dried

Table 1: Proximate composition of fresh fruits and dried loquat fruits.

S.No.	Parameters	Loquat fresh Fruits	Dried fruit slices(TD)	dried fruit slices(VD)	Freeze dried Slices(FD)
1	Moisture (%)	85.61±0.49[a]	8.7±0.43[b]	8.2±0.29[b]	8.8±0.51[c]
2	Carbohydrate (%)	12.72±0.04[c]	88.65±0.25[b]	89.21±0.65[a]	88.41±0.35[b]
3	Protein (%)	0.52±0.39[c]	0.51±0.24[b]	0.50±0.56[a]	0.50±0.37[a]
4	Ash (%)	0.53±0.07[c]	0.62±0.02[b]	0.63±0.31[b]	0.66±0.05[a]
5	Fat (%)	0.13±0.03[a]	0.07±0.0[a]	0.12±0.03[a]	0.12±0.01[a]
6	Fiber (%)	1.5±0.15[a]	1.4±0.21[a]	1.3±0.23[a]	1.5±0.34[a]
7	Energy, Kcal	53.86±0.54[b]	357.62±0.24[a]	359.98±0.04[a]	356.76±0.64[a]

Mean values with different letter a,b,c on the same row differ significantly (Duncan's test, $p \leq 0.05$).

Table 2: Physical properties and Flow properties of loquat slices.

S.No.	Parameters	TD	VD	FD
1	Bulk Density (g/ml)	0.35±.05[a]	0.37±.07[a]	0.19±.04[b]
2	Tap Density (g/ml)	0.39±.05[a]	0.41±.07[a]	0.20±.05[b]
3	Carr- Index (*CI*)	8.69±1.80[b]	8.40±.85[b]	5.67±1.77[b]
4	Hausner Ratio (*HR*)	1.10±.02[b]	1.09±.01[b]	1.06±.02[b]
5	Porosity (□)	0.09±.018[b]	0.08±.01[b]	0.06±.02[b]
6	Rehydration Ratio (RR)	2.72±27[b]	2.58±.38[b]	4.48±.31[a]
7	Coefficient Rehydration Ratio (COR)	0.41±.04[b]	0.41±.06[b]	0.70±.05[a]
8	Dehydration Ratio (DR)	4.93±.73[c]	6.59±.84[b]	10.21±.46[a]
9	Hygroscopicity (g/100g)	23.47±0.47	24.41±0.01	26.42±0.94

Physical properties of Indian variety of loquat slice are shown in Table 2. Observed significant difference was ($p \leq 0.05$).

Table 3: Effect of drying methods on color quality and Brov Index, of dried loquat slice.

	Fresh loquat	TD	VD	FD
L-value	47.74±.86[c]	52.12±1.96[b]	54.79±1.92[b]	59.48±1
a-value	5.65±.12[c]	11.82±.15[b]	12.51±2.6[b]	16.24±1
b-value	27.30±1.78[a]	21.19±.29[b]	20.17±1.04[b]	20.67±2
TCD	54.17±.67[a]	43.10±1.66[c]	45.14±.38[b]	40.72±1
Hue	78.29±.79[a]	60.81±.10[b]	57.99±.01[c]	62.61±
Croma	27.78±1.61[a]	24.06±.20[b]	23.16±.51[b]	27.85±
BI	86.58±7.29[a]	70.59±.93[b]	61.89±.40[c]	60.67±

Mean values of same column with different superscripts (a, b, c) significantly on the (Duncan's LSD test, p d" 0.05). BI (browning index), TCD (Total color difference); TD (Tray Drying); VD (vacuum Drying); FD (Freeze Drying).

followed by vacuum dried sample. On the other hand, b* value, total colour difference (TCD), hue and BI(browning index) of fresh loquat were higher than dried loquat sample. This result indicates the degradation of the carotene content during drying. The drying principle of Freeze-drying is sublimation, which is perform at very low temperature, thus preventing browning reactions during drying. Maximum value of b* in freeze-dried samples indicate high retention of carotene.

Texture Measurement

Fracture property of dried food products is a complex phenomenon that depends on the microstructure and components of food materials. Hardness value of tray dried, vacuum dried and freeze-dried were 3350 g, 4219 g and 4027 g respectively. This is depicted that vacuum dried shows highest hardness. Hardness of dehydrated and rehydrated slices are shown in graph 1.It is found that freeze-dried rehydrated sample reflect lowest hardness than other rehydrated samples. This may be due to the fact that porous structure in freeze-dried loquat slices can contribute to the hardness reduction of rehydrated samples (P.P. Lewicki, 1998). In vacuum drying and tray drying, the most compact and denser porous structure might be formed and reflect highest hardness.

Conclusion

This comparative study of drying temperatures of loquat fruit was carried out and subsequently its effects on physical colour and textural quality were studied. It was found that freeze-dried slices showed good physical and rehydration quality than other methods. Flowability and colour quality of the slices was significantly affected by drying temperature. It was observed that freeze-dried sliced had not affected significantly the colour characteristics. After the result was analysed, it may be concluded that freeze-dried slices could be commercialize in food sector due to their richness in nutrient components and better physical and textural quality and longer shelf life.

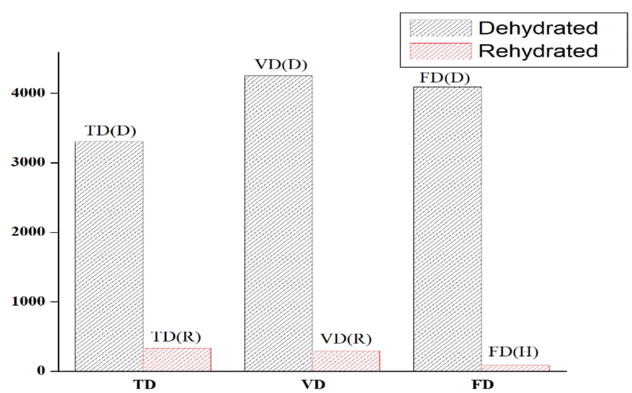

Fig. 1: Hardness of loquat slices by different drying methods and rehydrated slice soaked in water for 5 min. Different drying methods reflect significant differences at $p \leq 0.05$.

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