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PHYSICO-CHEMICAL ATTRIBUTES OF FRESH AND DRIED INDIAN JUJUBE (*ZIZYPHUS MAURITIANA*) FRUITS

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The fruits of Indian jujube (*Zizyphus mauritiana* Lamk.) are commonly used as fresh. However, fresh fruits are vulnerable to decay after few days of picking due to high moisture content and thus need to be preserved through drying. Therefore, the current study was aimed to assess the effect of different drying methods on physico-chemical properties of fruits of various Indian jujube cultivars. Fruits of eleven cultivars were collected from Horticultural Research Station, Bahawalpur. Physical, organoleptic and biochemical attributes of the fruits were measured before drying. The drying treatments included were; sun dry, oven dry at 50 °C, oven dry at 60 °C and oven dry at 70 °C. Significantly greater (p = 0.05) fresh fruit weight was recorded in Dehli sufaid (29.61 g) and Pak white (29.58 g), while Dehli sufaid (6.02 g) followed by Pak white (5.94 g) also showed significantly greater fruit weight after drying. Significantly larger fruit length was measured in Sadqia (41.97 mm) before drying, while Umran-13 (34.94 mm) showed significantly larger fruit length after drying. Significantly larger fruit diameter was calculated in Pak white (37.11 mm), Dehli sufaid (36.85 mm) and Foladi (36.53 mm) before drying, while Pak white (20.68 mm) and Dehli sufaid (20.59 mm) exhibited significantly larger fruit diameter after drying. Significantly greater moisture contents were recorded in fresh fruits of Karella (82.99%), while Anokhi (20.95%) showed significantly greater moisture content after drying. Sensory evaluation revealed that fresh fruits of Yazman local had very good appearance and firmness, and were good after drying. Fruits of Mehmood wali had very liked color and taste before drying and liked after drying. Vitamin C contents were found significantly greater in fresh fruits of Akasha (72.51 mg/100 mL), while significantly greater vitamin C contents were in dried fruits of Sadqia (50.71 mg/100 mL). Drying methods were statistically significant for total phenolic content, and antioxidant activity and capacity. The maximum total phenolic content (305.40 µg GAE /mL) and antioxidant capacity (145.44 µM trolox/100 mL) were recorded in oven dried fruits at 70 °C.
Keywords: Drying methods, Indian jujube fruit, organoleptic analysis, phenolic content, antioxidant activity.

INTRODUCTION

Indian jujube, also famous as ber, belongs to *Rhamnaceae* family and indigenous to China, India and Pakistan (Khushk *et al*., 2003; Sharif *et al*., 2013). Among many species of genus *Zizyphus*, Indian jujube (*Z. mauritiana*) and Chinese jujube (*Z. jujuba*) are noticeably recognized as two economically important cultivated and domesticated species based on their visible variations in physico-chemical traits (Liu and Zhao, 2009). Indian jujube is grown almost all over the world i.e. Pakistan, India, China, Syria, Burma, Malacca, Malaya, Kazakhstan, Nepal, Australia, Western Sahara, Sri Lanka, Afghanistan, Iran, Kuwait, Qatar, Saudi Arabia and Russia (Khushk *et al*., 2003). Annual Indian jujube production is nearly 900,000 tons all over the world, enhanced in the last ten years due to much liability of food as well as pharmacological demands (Mukhtar *et al*., 2004; Li *et al*., 2005; Li *et al*., 2007). In Pakistan, jujubes are mostly cultivated in Punjab and Sindh provinces (Mukhtar *et al*., 2004) with area under cultivation of 1,272 hectares and production of 8,616 tons in Punjab (Anonymous, 2016).

The fruits of Indian jujube are usually consumed in fresh form, however, the fruits of Chinese jujube are also used in some other forms like dried, juice, candies and squashes. Both leaves and fruits of Indian jujube are rich source of mineral contents. Nutritionally, jujube fruits are richer in vitamin C, protein, calcium, phosphorus, sugars, antioxidants and carotene (Bhargava *et al*., 2005; Anjum *et al*., 2018). From earliest eras, plants as well as their fruits are consumed as food and used as remedies (Marwat *et al*., 2011). Usually, fruits of Indian jujube are used as fresh for food but dried fruits are considered as excellent source of medicines (Marwat *et al*., 2009; Marwat *et al*., 2011). The dried fruits have numerous medicinal properties i.e. anodyne, styptic, anticancer, pectoral, soothing, stomachic, refrigerant and tonic (Golmohammadi, 2013). Mostly sun dried fruits of Indian jujube are used in decoction.

Generally, the water contents of fruits as well as vegetables are more than 80%, which decrease their shelf life and make them vulnerable during storage as well as transportation. Drying is a traditional method to preserve food items for maintaining the best quality (Santos and Silva, 2008).

Drying is very common technique which is mostly used to preserve agricultural commodities after harvest (Sagar and Kumar, 2010). It is efficiently implemented to decrease biological activities, reduction of adequate level of moisture content, and to allow the storability of the product on distinctive temperatures (Doymaz, 2004; Goyal *et al*., 2007; Koyuncu *et al*., 2007). Several researchers have worked on the drying of fruits such as banana (Dandamrongrak *et al*., 2002), pistachio (Midilli *et al*., 2002), mangoes (Ndawula *et al*., 2004), fig (Babalis *et al*., 2006), litchi (Janjai *et al*., 2011), jujube (Gao *et al*., 2012), pomegranate (Sanchez *et al*., 2013), apricot (Turkyilmaz *et al*., 2014) etc.

Indian jujube fruits are consumed as fresh because these are perishable due to high moisture level as well as may decay easily in couple of days after picking. Hence, surplus/ unconsumed fruits need to be preserved for future use. The most common method to preserve the jujube fruits is by drying (Ndawula *et al*., 2004; Gao *et al*., 2012; Du *et al*., 2013; Sanchez *et al*., 2013). Several drying methods have been used for fruits preservation i.e. outside sun drying, infra-red drying, shower drying, vacuum drying, microwave drying (Chin *et al*., 2015), oven drying, freeze drying (Gao *et al*., 2012), explosion puffing (Du *et al*., 2013) and many others. Sun drying is the traditional as well as simple method for production of desiccated products as well as guarantee thorough preservation of jujubes (Slatnar *et al*., 2011; Gao *et al*., 2013). Oven drying has several advantages and thus attained much significance as compared to sun drying. Oven drying is successfully used to produce uniform and good product quality, reduced microbial infection, reduce labor costs and decrease drying time (Fang *et al*., 2009; Igual *et al*., 2012). After drying, fruits can easily be stored for long time, easy transportation with low cost, reduced packing costs, and their low water content reduce microbial decay. Drying of fruits of Chinese jujube is very common, however no attempts have been made to dry fruits of Indian jujube by different methods and study nutritional quality of the dried fruits. Therefore, under current scenario, it is urgent need to examine the drying effects on numerous physico-chemical attributes of Indian jujube fruits. In the present study, eleven Indian jujube cultivars fruits were dried through sun drying and oven drying methods to access impact of drying on various physical and biochemical of dried fruits.

MATERIALS AND METHODS

Fruits of eleven cultivars of Indian jujube i.e. Dehli sufaid, Pak white, Anokhi, Karella, Foladi, Mehmood wali, Sadqia, Akasha, Yazman local, Khobani and Umran-13 were harvested from Horticultural Research Station, Bahawalpur, Pakistan. Physical and biochemical attributes of fresh fruits were measured before drying, while drying treatments include sun dry (T_1), oven dry at 50°C (T_2), oven dry at 60°C (T_3) and oven dry at 70°C (T_4) (Ahmed *et al*., 2013). Drying was done till constant dry weight of fruits. Fresh fruits pictures are presented (Fig. 1). Dried fruits pictures under sundry (Fig. 2), oven dry at 50 °C (Fig. 3), oven dry at 60 °C (Fig. 4) and oven dry at 70 °C (Fig. 5) are presented.

Ten fruits, selected from each replication of each cultivar for fresh fruit weight were further dried through different drying methods. Their fresh and dry weights were estimated with a digital weighing balance (WT6002-D). Before and after drying, fruit length and diameter were calculated through a digital vernier caliper (IKKEGOL). Moisture content on fresh and dry basis of fruits were calculated with a method as described by Doymaz (2007) with little modifications. The moisture percentage before drying of jujube samples was calculated by the following formula.

Figure 1. Pictures of fresh fruits of different cultivars of Indian jujube.

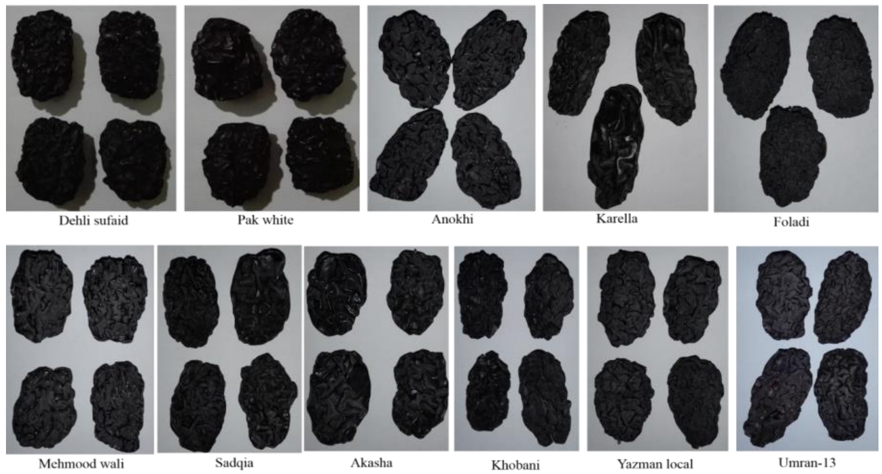

Figure 2. Pictures of sun dried fruits of different cultivars of Indian jujube.

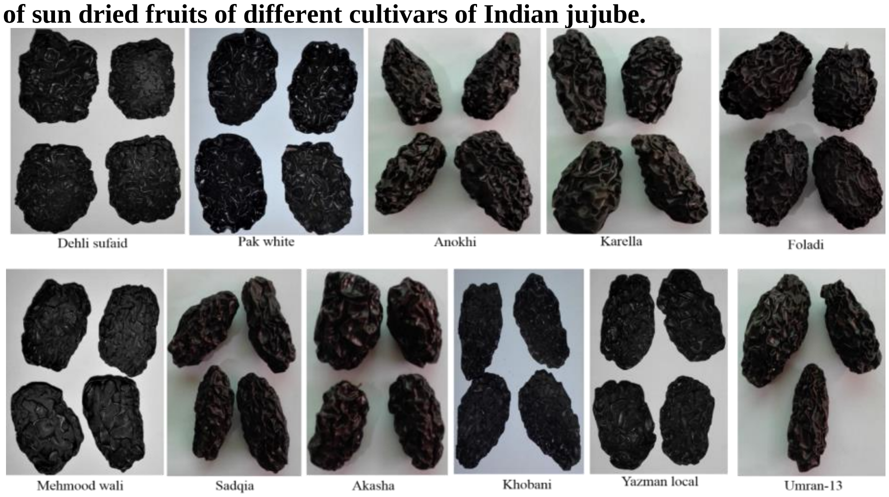

Figure 3. Pictures of oven dried (at 50 °C) fruits of different cultivars of Indian jujube.

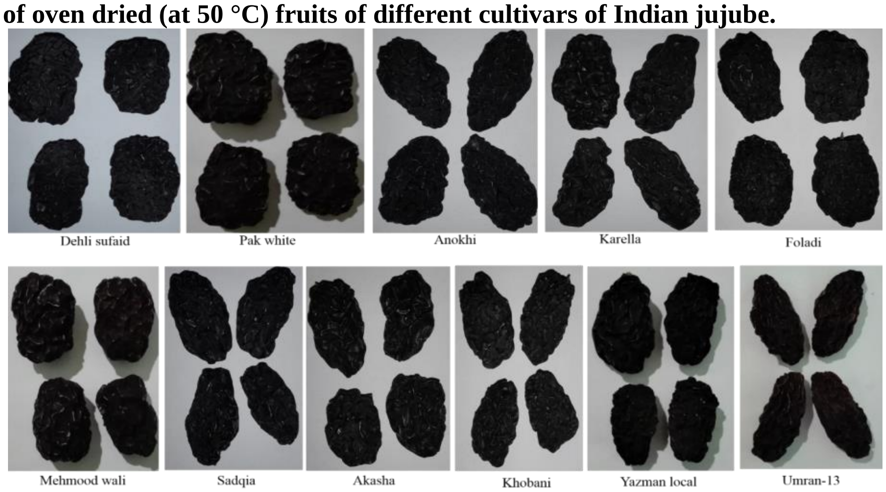

Figure 4. Pictures of oven dried (at 60 °C) fruits of different cultivars of Indian jujube.

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Whereas, W_1 represents average fresh fruit weight (g) and W_2 shows average dry fruit weight (g) of jujube fruits.

Moisture content percentage after drying of jujube samples was calculated by following formula.

$\text{Moisture \%} = 100 - \text{Moisture (\%) before dry}$

Sensory and organoleptic parameters of the fruit samples

Figure 5. Pictures of oven dried (at 70 °C) fruits of different cultivars of Indian jujube.

include overall appearance of fruits, fruit color, fruit shape, fruit firmness and fruit taste which were evaluated and ranked by a panel of 5 persons as extremely disliked or extremely bad (0-1), very disliked or very bad (1.1-2.0), disliked or bad (2.1-3.0), fair (3.1-4.0), liked or good (4.1-5.0), very liked or very good (5.1-6.0) and extremely liked or extremely good (6.1-7.0) (Normann *et al*., 2018).

Vitamin C content (mg/100 mL) was measured according to Ruck (1963) proposed method with little modifications. Following formula was used to calculate vitamin C content.

$$\text{Ascorbic acid (mg/100 mL juice)} = \frac{1 \times \text{R1} \times \text{V}}{R \times W \times V1} \times 100$$

Where, V_1 represents mL of filtered aliquot taken for titration. V is volume of aliquot made by 0.4% oxalic acid. R_1 denotes mL of dye used against V_1. R is mL of dye used to titrate standard ascorbic acid. W shows mL of juice taken.

Total phenolic content (µg GAE/mL), antioxidant capacity (µM Trolox/100 mL) and antioxidant activity (%) were determined as already described (Zieslin and Zaken, 1993; Williams *et al*., 1995; Jasass *et al*., 2015). Antioxidant activity was determined by the following formula.

$$\text{Antioxidant activity (\%)} = \frac{A_0 - A_1}{A_0} \times 100$$

Where, A_0 shows the absorbance of control sample. A_1 is the absorbance of juice sample. Methanol (80%) was used as blank, while control sample included methanol (80%) with 3 mL DPPH solution.

Statistical analysis**:** The collected data were examined by Statistix 8.1 (Tallahassee Florida, USA). For fresh fruits, one way analysis of variance and for dried fruits due to two factors; drying methods as well as cultivars, two-way analysis of variance was used. To analyze the treatment means, least significant difference (LSD) test at 5% probability level was applied (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Physical attributes of fresh Indian jujube fruits**:** The significantly greater fruit weight was recorded in Dehli sufaid (29.61 g), followed by Pak white (29.58 g) and Foladi (29.02 g) and these three cultivars behaved statistically alike, while lower was recorded in Umran-13 (11.15 g) and Khobani (Table 1). Godi *et al*. (2016) examined the greater fruit weight in Indian jujube cv. Kopargaon Selection and the lowest in Rahuri-3. Hence, the current study findings are in agreement with earlier results. The average fruit weight in Indian jujube is affected by different factors including cultivars, climatic conditions as well as fruit positioning on the tree. Fruit weight can also be improved or reduced through several cultural practices particularly nutrients application. The significantly larger fruit length was recorded in Karella (41.97 mm), followed by Umran-13 (41.54 mm), while smaller fruit length (28.50 mm) was in Khobani, which was significantly different from all other cultivars (Table 1). Differences in fruit length were also recorded by Razi *et al*. (2013), who found that Karella had the larger fruit length (4.69 cm) and the minimum was in Ghor (2.38 cm). Among the cultivars, fruit diameter was significantly greater in Pak white (37.11 mm), followed by Dehli sufaid (36.85 mm) and Foladi (36.53 mm); these three cultivars were statistically alike. The lowest fruit diameter was assessed in Khobani (26.17 mm), followed by Karella (26.29 mm) and Sadqia (27.04 mm) and these three cultivars were also statistically at par with one another (Table 1). Similarly, the maximum fruit diameter (3.27 cm) was recorded in Umran-9 and the minimum in unknown strain “Anonymous I” (1.96 cm) calculated by Razi *et al*. (2013). Several studies have been conducted on fruit weight, fruit length and fruit width which confirm wide variation in physical attributes of jujube cultivars (Ram *et al*., 2008; Rao and Subramanyam, 2010). Concerning the effect of cultivars, the significantly high moisture content of fresh fruits was found in Karella (82.99%), followed by Umran-13 (81.74%) and Yazman local (80.89%); these three cultivars were statistically similar. While, lower moisture contents of fresh fruits were in Anokhi (77.38%) and Akasha (77.67%), followed by Khobani (78.17%), Sadqia (78.61%), Foladi (78.70%), Dehli sufaid (79.70%), Pak white (79.89%) and Mehmood wali (80.00%) and these eight cultivars were statistically similar with one another (Table 1). Akbolat *et al*. (2008) studied moisture content of jujube fruits which varied among the cultivars.

***Sensory and organoleptic evaluation of fresh Indian jujube fruits*:** Organoleptic properties and sensory evaluation play an important role to determine the acceptability of Indian jujube fruits. Among the cultivars, overall appearance was very good in Foladi (6.00) and Yazman local (6.00), followed by Dehli sufaid (5.90) and Mehmood wali (5.90) which have good appearance. Mehmood wali had very liked fruit color (6.00) and taste (6.00). Fruit firmness of Yazman local (6.00) was very good as compared to other cultivars (Table 1). The fruits of all the studied cultivars significantly possessed better sensory and organoleptic properties i.e. overall appearance, color, taste and firmness. So, fruits of Indian jujube cultivars have high accessibility according to consumer demand. Ezz *et al*. (2011) also recorded the greater fruit firmness in Indian jujube which was 16.06% in Balahy and 12.63% in Tofahy. Similarly, Hernández, *et al*. (2016) also performed the sensory evaluation of jujube fruits for accessibility of market demand and customer need. Accordingly, Mishra and Krška (2017) also evaluated the accessibility of jujube fruits through organoleptic properties.

***Biochemical attributes of fresh Indian jujube fruits*:** The significantly greater vitamin C content (72.51 mg /100 mL) was found in Akasha, while the lower was in Pak white (22.20 mg /100 mL), Anokhi (24.05 mg /100 mL) and Yazman local (24.05 mg /100 mL) (Table 1). These results are in agreement with results of Koley *et al*. (2011), who calculated varying levels of ascorbic acid in different jujube cultivars. Total phenolic content was significantly higher in Umran-13 (243.04 µg GAE /mL) and Sadqia (239.23 µg GAE /mL); while lower amount was in Pak white (137.97 µg GAE /mL), followed by Yazman local (140.16 µg GAE /mL), Dehli sufaid (141.67 µg GAE /mL) and Foladi (149.49 µg GAE /mL). Krishna and Parashar (2012) observed the maximum phenolic content (196.34 µg GAE /mL) in ZG-3 cultivar. The difference in phenolic content might be linked with the influence of different external factors i.e. soil, location, climatic factors as well as light intensity. Antioxidant capacity was significantly greater (742.24 µM Trolox/100 mL) in Anokhi, while the lower (158.15 µM Trolox/100 mL) was in Umran-13 and in Khobani (204.59 µM Trolox/100 mL). The significantly high level of antioxidant activity was recorded in Sadqia (40.58%), and lower was in Anokhi (16.83%), followed by Dehli sufaid, Mehmood wali, Pak white, Akasha, Yazman local and Karella. Koley *et al*. (2011) also observed variation in antioxidant activity of 12 commercial jujube cultivars. The variations among the cultivars regarding antioxidant capacity and activity were probably due to genetic make-up of cultivars, different agronomic practices and position of fruits on the tree in respect to sunlight.

***Physical attributes of dried Indian jujube fruits*:** The significantly greater weight was recorded in Dehli sufaid (5.41 g), followed by Pak white (5.20 g), while the lesser fruit weight was recorded in Khobani (2.51 g), Umran-13 (2.63 g), Karella (2.70 g) and Sadqia (2.72 g) among all the studied cultivars after drying. The significantly highest fruit weight (4.09 g) was calculated in sun drying, while the lowest fruit weight (3.34 g) was recorded in oven drying at 70 °C among all the studied cultivars. The highest fruit weight was due to low moisture loss, while low fruit weight was due to high moisture loss. Regarding the interaction of cultivars and drying treatments, three cultivars Foladi (6.17 g), Dehli sufaid (6.02 g) and Pak white (5.94 g) had the

Table 1. Physical, sensory and biochemical attributes of fresh Indian jujube fruits of different cultivars.

Cultivars	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Moisture contents (%)	Fruit appea-rance	Fruit color	Fruit firmness	Fruit taste	Vit. C (mg /100 mL)	Total phenolics (µg GAE/mL)	Anti-oxidant capacity (µM Trolox/100 mL)	Anti-oxidant activity (%)
Dehli sufaid	29.61a	37.26de	36.85a	79.70bcd	5.90ab	5.80ab	5.55abc	5.30c-f	28.37d	141.67d	647.29b	18.83c
Pak white	29.58a	39.66c	37.11a	79.89bcd	5.60b	5.65abc	5.65ab	4.95ef	22.20e	137.97d	615.01b	19.67c
Anokhi	20.33b	40.13bc	30.98b	77.38d	5.00c	5.00de	5.15cd	5.05def	24.05e	152.64c	742.24a	16.83c
Karella	16.09d	41.97a	26.29de	82.99a	5.00c	4.90e	4.65e	4.85f	27.45d	196.29b	338.90de	26.95c
Foladi	29.02a	37.88d	36.53a	78.70cd	6.00a	5.65abc	5.65ab	5.00ef	27.45d	149.49cd	283.88ef	28.69b
Mehmood wali	18.33c	32.87f	31.97b	80.00bcd	5.90ab	6.00a	5.75ab	6.00a	48.13c	160.36c	616.11b	19.64c
Sadqia	14.16e	35.91e	27.04de	78.61cd	4.75d	5.60abc	5.35bc	5.75abc	39.22d	239.23a	250.16f	40.58a
Akasha	14.63de	34.02f	28.75c	77.667d	5.60b	5.60abc	4.80de	5.35b-e	72.51a	152.80c	525.82c	22.02c
Yazman local	18.92bc	37.34de	30.80b	80.89abc	6.00a	4.90e	6.00a	5.80ab	24.05e	140.16d	393.75c	25.50c
Khobani	11.89f	28.50g	26.17e	78.17cd	5.10c	5.35cd	5.15cd	5.35b-e	63.87b	165.66c	204.59fg	30.49b
Umran-13	11.15f	41.54ab	27.48cd	81.74ab	5.10c	5.50bc	5.35bc	5.50bcd	49.36c	243.04a	158.15g	32.03b

* Means sharing similar letter(s) in a column are statistically non-significant at $p = 0.05$ (LSD test)

Table 2.1. Physical attributes of dried Indian jujube fruits of different cultivars as affected by drying methods.

	Fruit weight (g)					Fruit length (mm)				
Cultivars	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
Dehli sufaid	6.02a	5.32cd	5.05cde	5.25cd	**5.41a**	29.83fgh	29.73fgh	28.33g-j	26.47klm	**28.59d**
Pak white	5.94ab	5.38bc	5.10cde	4.37fgh	**5.20ab**	30.31f	29.90fg	29.71fgh	29.77fgh	**29.92c**
Anokhi	4.60efg	4.143ghi	4.42fgh	3.43j-n	**4.15c**	34.54abc	32.65de	32.59de	33.38cze	**33.29b**
Karella	2.75p-u	2.66q-v	2.80p-t	2.61q-v	**2.70f**	36.03a	33.95b-e	34.10bcd	32.32e	**34.10b**
Foladi	6.17a	4.77def	4.37fgh	4.33fgh	**4.91b**	29.98fg	27.87ijk	28.65f-j	27.10jkl	**28.40de**
Mehmood wali	3.68ijk	3.91hij	3.39j-o	3.56j-m	**3.64d**	25.64lm	26.33klm	25.05mn	25.58lm	**25.65f**
Sadqia	3.02m-s	2.83o-t	2.53r-v	2.48s-v	**2.72f**	29.68fgh	29.62fgh	30.23f	30.31f	**29.96c**
Akasha	3.26k-q	3.05l-r	3.17k-q	2.98n-t	**3.12e**	28.20hij	27.05jkl	27.83ijk	27.63ijk	**27.68e**
Yazman local	3.63i-l	3.40j-o	3.08l-r	3.38j-o	**3.37de**	29.67fgh	28.86f-i	27.59ijk	29.04f-i	**28.79d**
Khobani	2.60q-v	2.80p-t	2.51r-v	2.12v	**2.51f**	23.59no	23.11o	23.27o	23.18o	**23.29g**
Umran-13	3.32k-p	2.44t-v	2.55r-v	2.19uv	**2.63f**	34.10bcd	35.13ab	35.86a	34.66abc	**34.94a**
Mean	**4.09a**	**3.70b**	**3.54b**	**3.34c**		**30.14a**	**29.47b**	**29.38b**	**29.04b**	

* Means sharing similar letter(s) in a group are statistically non-significant at p = 0.05 (LSD test)
T_1 = Sun dry, T_2 = Oven dry at 50 °C, T_3 = Oven dry at 60 °C, and T_4 = Oven dry at 70 °C

Table 2.2. Physical attributes of dried Indian jujube fruits of different cultivars as affected by drying methods.

	Fruit diameter (mm)					Moisture content (%)				
Cultivars	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
Dehli sufaid	21.46ab	20.92abc	20.48bc	19.49cd	**20.59a**	20.30b-j	18.77h-n	18.19k-o	17.23m-q	**18.62de**
Pak white	20.28bc	22.45a	19.10bc	20.01bc	**20.68a**	20.11c-k	17.70l-p	17.60l-p	15.35qrs	**17.69e**
Anokhi	17.75efg	17.01e-i	19.47cd	16.53f-k	**17.69b**	22.62a	20.88a-g	21.88abc	18.42i-o	**20.95a**
Karella	14.23mno	14.47l-o	14.00mno	13.03op	**13.93f**	17.01n-r	18.32i-o	18.31i-o	17.02n-r	**17.66e**
Foladi	18.30de	17.32e-i	17.21e-i	17.31e-i	**17.54b**	21.30a-e	16.50o-s	16.51o-s	16.54o-s	**17.72e**
Mehmood wali	17.90def	17.38e-h	17.63e-h	17.52e-h	**17.61b**	20.00c-k	21.19a-f	19.53e-l	20.69a-h	**20.35abc**
Sadqia	14.98j-m	14.83lm	14.83lm	14.85klm	**14.87de**	21.39a-e	20.00c-k	18.93g-n	18.85g-n	**19.79bc**
Akasha	15.64i-m	16.55f-j	16.15g-l	16.02h-l	**16.09c**	22.33ab	20.67a-h	20.36b-i	19.79d-k	**20.79ab**
Yazman local	14.52l-o	18.30de	15.29j-m	14.72lmn	**15.71cd**	19.11g-m	18.19k-o	17.33m-q	16.06p-s	**17.67e**
Khobani	15.12j-m	16.60f-j	14.82lm	14.92j-m	**15.37cd**	21.83a-d	19.20f-m	18.92g-n	17.35m-q	**19.33cd**
Umran-13	13.12nop	18.31de	13.10nop	12.18p	**14.18ef**	18.26j-o	15.06rs	14.90s	11.81t	**15.01f**
Mean	**16.66b**	**17.65a**	**16.63b**	**16.05c**		**20.39a**	**18.77b**	**18.41b**	**17.19c**	

* Means sharing similar letter(s) in a group are statistically non-significant at p = 0.05 (LSD test)
T_1 = Sun dry, T_2 = Oven dry at 50 °C, T_3 = Oven dry at 60 °C, and T_4 = Oven dry at 70 °C

highest fruit weight after sun drying, while the lowest fruit weight (2.12 g) was recorded in Khobani after oven drying at 70 °C (Table 2.1). Current study results were in agreement with the results of Fang *et al*. (2009), who dried the jujube fruits at different temperatures and found that the fruits were dried rapidly and also the greatest rehydration process occurred at 70 °C.

The significantly larger fruit length was in Umran-13 (34.94 mm), while the lesser was recorded in Khobani (23.29 mm) among all the studied cultivars after drying. The significantly larger fruit length (30.14 mm) was recorded in sun drying, while the smaller fruit length was in oven drying at 70 °C (29.04 mm), followed by 60 °C (29.38 mm) and 50 °C (29.47 mm). Regarding the interaction of drying methods and cultivars, the significantly greater fruit length was recorded in Karella after sun drying (36.03 mm) and Umran-13 after oven drying at 60 °C (35.86 mm), while the lesser fruit length was in Khobani after oven drying at 50 °C (23.11 mm), 70 °C (23.18 mm), 60 °C (23.27 mm) and when sun dried (23.59 mm) (Table 2.1). Similarly, Fang *et al.* (2009) also recorded reduction in fruit length when Chinese jujube fruits were dried under different temperatures.

Fruit diameter was significantly larger in two cultivars Pak white (20.68 mm) and Dehli sufaid (20.59 mm), while smaller was noted in Karella (13.93 mm) and Umran-13 (14.18 mm) among all the studied cultivars after drying. Regarding the drying methods, significantly larger fruit diameter (17.65 mm) was recorded after oven drying at 50 °C, while smaller (16.05 mm) was noted in oven drying at 70 °C. Concerning the combined effect of drying methods and cultivars, significantly larger fruit diameter was recorded in Pak white when oven dried at 50 °C (22.45 mm), followed by Dehli sufaid after sun drying (21.46 mm), while shorter fruit diameter was noted in Umran-13 after oven drying at 70 °C (12.18 mm), oven drying at 60 °C (13.10 mm) and sun drying (13.12 mm) (Table 2.2). Current study results are in accordance with several previous studies which confirmed that the higher temperature (70 °C) possibly enhanced the volumetric shrinkage and ultimately fruit length and fruit diameter were reduced (Fang *et al*., 2009; Yi *et al*., 2012; Kumari *et al*., 2015).

The significantly greater moisture content was noted in Anokhi (20.95%), while the lesser moisture content was observed in Uman-13 (15.01%) among all the studied cultivars after drying. Significantly high value of moisture content (20.39%) was present in sun dried fruits, while the low moisture content (17.19%) was found after oven drying at 70 °C among all the studied treatments. Under the combined effect of drying treatments and cultivars, the significantly high amount of moisture content was calculated in Anokhi (22.62%), followed by Akasha (22.33%), Khobani (21.83%), Sadqia (21.39%) and Foladi (21.30%) when sun dried. Umran-13 exhibited significantly the lowest moisture content (11.81%) after oven drying at 70 °C (Table 3). Current study results are in accordance with finding of previous studies (Doymaz, 2007; Fang *et al*., 2009; Sharif *et al*., 2019). Doymaz (2007) found that by reducing drying time as well as enhancing drying temperature, the drying rate of samples can be enhanced. Correspondingly, Fang *et al*. (2009) observed that when temperature was increased, it reduced the moisture content in jujube fruits.

***Sensory and organoleptic evaluation of dried Indian jujube fruits*:** Regarding the overall appearance, two cultivars Yazman local (4.05) and Foladi (3.95) were found to be good and fair, respectively among all the studied cultivars. Regarding the drying treatments, all the drying treatments caused significant effect on overall appearance of the fruits. Overall appearance of fruits of all the cultivars was significantly fair and seems not to attain much accessibility (Table 3.1). There is possible that under high temperature overall appearance of fruits was damaged and was not appreciated by members of the panel.

The fruit color of Mehmood wali was found to be good (4.10) and another cultivar Yazman local showed fair color (4.00) among all the studied cultivars. The fruit color of Karella was bad looking (3.00) and was unable to fetch the accessibility. The significantly fair color of fruits was fair after oven drying at 50 °C (3.78) and 60 °C (3.76). These two treatments performed better as compared to other treatments. Fruits color after sun drying and oven drying at 70 °C was comparatively poor (Table 3.1). Similarly, several previous studied showed that fruit color can be deformed

Table 3.1. Sensory evaluation of dried Indian jujube fruits of different cultivars as affected by drying methods.

	Overall fruit appearance					Fruit color				
Cultivars	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
Dehli sufaid	3.80a	4.20a	3.80a	3.40a	**3.80ab**	3.80a	4.20a	4.20a	3.40a	**3.90ab**
Pak white	3.60a	3.60a	4.00a	2.80a	**3.50b**	3.60a	3.60a	4.20a	3.60a	**3.75abc**
Anokhi	2.80a	2.20a	3.60a	3.00a	**2.90c**	3.20a	2.80a	3.60a	2.80a	**3.10de**
Karella	2.80a	2.80a	3.20a	2.80a	**2.90c**	3.20a	3.00a	2.80a	3.00a	**3.00e**
Foladi	4.00a	4.40a	3.60a	3.80a	**3.95a**	3.60a	4.00a	3.60a	3.80a	**3.75abc**
Mehmood wali	3.80a	3.80a	4.20a	3.40a	**3.80ab**	3.80a	4.20a	4.40a	4.00a	**4.10a**
Sadqia	3.20a	4.20a	3.80a	3.40a	**3.65ab**	3.60a	4.40a	3.40a	3.40a	**3.70abc**
Akasha	3.20a	3.60a	4.00a	3.20a	**3.50b**	3.00a	4.40a	4.00a	3.40a	**3.70abc**
Yazman local	4.00a	4.20a	4.20a	3.80a	**4.05a**	2.80a	4.20a	4.20a	3.40a	**4.00ab**
Khobani	3.00a	2.60a	3.40a	3.00a	**3.00c**	3.20a	3.40a	3.60a	3.60a	**3.45cd**
Umran-13	2.80a	3.00a	2.80a	3.40a	**3.00c**	3.80a	3.40a	3.40a	3.80a	**3.60bc**
Mean	**3.36b**	**3.51ab**	**3.70a**	**3.27b**		**3.55ab**	**3.78a**	**3.76a**	**3.47b**	

* Means sharing similar letter(s) in a group are statistically non-significant at $p = 0.05$ (LSD test)

T_1 = Sun dry, T_2 = Oven dry at 50 °C, T_3 = Oven dry at 60 °C, and T_4 = Oven dry at 70 °C

Table 3.2. Sensory evaluation of dried Indian jujube fruits of different cultivars as affected drying methods.

	Fruit firmness					Fruit taste				
Cultivars	T_1	T_2	T_3	T_4	Mean	T_1	T_2	T_3	T_4	Mean
Dehli sufaid	4.80b-e	4.60b-f	4.60b-f	4.60b-f	**4.65abc**	4.40c-g	4.40c-g	4.40c-g	4.40c-g	**4.40c-f**
Pak white	4.60b-f	4.40c-g	4.60b-f	5.40ab	**4.75ab**	4.00e-h	4.00e-h	4.20d-h	4.00e-h	**4.05ef**
Anokhi	4.60b-f	3.80fg	4.00efg	4.60b-f	**4.25cd**	3.800fgh	3.80fgh	5.20abc	3.80fgh	**4.15def**
Karella	3.80fg	3.80fg	3.60g	3.80fg	**3.75e**	3.80fgh	4.00e-h	4.20d-h	3.80fgh	**3.95f**
Foladi	4.40c-g	4.60b-f	4.80b-e	5.20abc	**4.75ab**	4.80b-e	3.60gh	4.40c-g	3.60gh	**4.10ef**
Mehmood wali	4.40c-g	4.80b-e	5.20abc	5.00a-d	**4.85ab**	5.60ab	4.80b-e	5.20abc	4.80b-e	**5.10a**
Sadqia	4.20d-g	3.60g	5.40ab	4.60b-f	**4.45bc**	4.80b-e	6.00a	4.40c-g	4.20d-h	**4.85abc**
Akasha	3.60g	2.40h	5.40ab	4.20d-g	**3.90de**	4.60c-f	5.60ab	4.20d-h	3.40h	**4.45b-e**
Yazman local	4.80b-e	5.80a	4.60b-f	5.20abc	**5.10a**	5.20abc	5.20abc	5.20abc	4.00e-h	**4.90ab**
Khobani	3.60g	4.60b-f	4.20d-g	4.60b-f	**4.25cd**	4.00e-h	4.60c-f	5.00bcd	4.20d-h	**4.45b-e**
Umran-13	4.20d-g	5.20abc	4.40c-g	4.00efg	**4.45bc**	5.00bcd	4.20d-h	5.00bcd	4.20d-h	**4.60bcd**
Mean	**4.27b**	**4.33b**	**4.62a**	**4.65a**		**4.55a**	**4.56a**	**4.67a**	**4.04b**	

* Means sharing similar letter(s) in a group are statistically non-significant at $p = 0.05$ (LSD test)

T_1 = Sun dry, T_2 = Oven dry at 50 °C, T_3 = Oven dry at 60 °C, and T_4 = Oven dry at 70 °C and damaged due to high temperatures (Fang *et al*., 2009; Helmy *et al*., 2012; Yi *et al*., 2012).

The significantly greater fruit firmness was showed by Yazman local (5.10), followed by Mehmood wali (4.85), Foladi (4.75), Pak white (4.75) and Dehli sufaid (4.65), while the lowest was in Akasha (3.90) among all the studied cultivars after drying. Yazman local was very liked and Mehmood wali, Foladi, Pak white and Dehli sufaid were liked, while Akasha also showed fair firmness in their fruits. All the studied cultivars showed good accessibility on the basis of their fruit firmness. The significantly greater fruit firmness was recorded after oven drying at 70 °C (4.65) and at 60 °C (4.62), while the lesser fruit firmness was noted in sun drying (4.27) and oven drying at 50 °C (4.33). All the drying treatments significantly resulted in good firmness. Yazman local had the significantly greater fruit firmness (5.80) after oven drying at 50 °C, followed by Pak white (5.40) after oven drying at 70 °C, while the lesser fruit firmness was noted in Akasha (2.40) after oven drying at 50 °C (Table 3.2). Fruit firmness depends upon moisture content. Higher the moisture content, the fruits will have lesser firmness.

Fruit taste was significantly greater in Mehmood wali (5.10), followed by Yazman local (4.90) and Sadqia (4.85), while the lesser was in Karella (3.95), followed by Pak white (4.05), Foladi (4.10), Anokhi (4.15) and Dehli sufaid (4.40) among all the studied cultivars after drying. Fruit taste of Mehmood wali was significantly very liked after drying. Fruit taste of other nine cultivars i.e. Dehli sufaid, Pak white, Anokhi, Foladi, Sadqia, Akasha, Yazman local, Khobani and Umran-13 was liked by panel and considered as god fruit taste. Karella also had fair fruit taste when dried at different temperatures. The significantly greater fruit taste was attained after oven drying at 60 °C (4.67), at 50 °C (4.56) and sun drying (4.55), while lower was after oven drying at 70 °C (4.04). Fruit taste was valued and positively appreciated by consumers. Sun drying and oven drying at different temperatures are considered as most suitable and efficient techniques for Indian jujube fruits preservation because taste of dried fruits was liked by panel and had greater accessibility. The combined effect of treatment and cultivars showed that the greater fruit taste was recorded in Sadqia after oven drying at 50 °C (6.00) and was liked very much, while the lesser fruit taste was noted in Akasha dried in oven at 70 °C (3.40) and was recorded as fair (Table 3.2). In a previous study, Helmy *et al*. (2012) also stated that the taste of dried jujube fruits was good.

***Biochemical attributes of dried Indian jujube fruits*:** Vitamin C was significantly in higher amount in Sadqia fruits (50.71 mg/100 mL), followed by Dehli sufaid (49.29 mg/100 mL), Khobani (47.86 mg/100 mL), Pak white (46.43 mg/100 mL) and Anokhi (46.43 mg/100 mL), while the lower amount of Vitamin C was recorded in Foladi (35.00 mg/100 mL) and Akasha (35.00 mg/100 mL), followed by Mehmood wali (39.29 mg/100 mL). The highest vitamin C content was significantly calculated after oven drying at 50 °C (57.14 mg/100 mL), while the lowest was noted after sun drying (31.69 mg/100 mL). All the drying treatments significantly affected vitamin C content in the studied cultivars. Regarding the interaction of drying treatments and cultivars, the highest vitamin C content was found in Khobani after oven drying at 50 °C (77.14 mg/100 mL). The lowest vitamin C content was (25.71 mg/100 mL) was found in three cultivars Anokhi, Foladi and Yazman local after sun drying (Table 4.1). Vitamin C content is reduced under higher temperature due to deprivation of naturally active compounds due to chemical, enzymatic and thermal decay (Kamiloglu *et al*., 2014; Wojdylo *et al*., 2014).

The significantly higher total phenolic content was recorded when fruits were oven dried at 70 °C (305.40 µg GAE/mL), followed by at 60 °C (302.16 µg GAE/mL) and 50 °C (263.59 µg GAE/mL). The significantly lower phenolic content was after sun drying (211.83 µg GAE/mL) (Table 6). Similarly, Gao *et al*. (2012) also estimated the lowest

Table 4.1. Biochemical attributes of dried Indian jujube fruits of different cultivars as affected by drying methods.

	Vitamin C content (mg /100 mL)					Total phenolic content (µg GAE/mL)				
Cultivars	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
Dehli sufaid	37.14g-k	68.57abc	45.72fgh	45.72fgh	**49.29ab**	196.92a	194.30a	270.47a	277.19a	**234.72a**
Pak white	34.29h-k	74.28ab	45.72fgh	31.43ijk	**46.43abc**	180.07a	278.28a	280.80a	262.67a	**250.45a**
Anokhi	25.71k	51.43def	62.86bcd	45.72fgh	**46.43abc**	210.01a	261.98a	318.79a	258.62a	**262.35a**
Karella	31.43ijk	60.00cde	51.43def	34.29h-k	**44.29bcd**	265.88a	272.89a	312.81a	292.31a	**285.97a**
Foladi	25.71k	34.29h-k	40.00f-j	40.00f-j	**35.00e**	165.89a	287.52a	264.79a	325.21a	**260.85a**
Mehmood wali	28.57jk	45.72fgh	45.72fgh	37.14g-k	**39.29de**	240.69a	252.44a	342.70a	314.59a	**287.60a**
Sadqia	40.00f-j	62.86bcd	48.57efg	51.43def	**50.71a**	176.07a	263.31a	333.11a	236.83a	**252.33a**
Akasha	28.57jk	28.57jk	40.00f-j	42.86f-i	**35.00e**	253.97a	316.42a	302.83a	373.03a	**311.56a**
Yazman local	25.71k	60.00cde	37.15g-k	48.57efg	**42.86cd**	210.40a	244.14a	329.65a	348.43a	**283.16a**
Khobani	37.15g-k	77.14a	37.15g-k	40.00f-j	**47.86abc**	223.74a	311.23a	284.11a	364.68a	**295.94a**
Umran-13	34.29h-k	65.71abc	42.86f-i	34.29h-k	**44.29bcd**	206.45a	217.02a	283.71a	305.89a	**253.27a**
Mean	**31.69d**	**57.14a**	**45.20b**	**41.04c**		**211.83b**	**263.59a**	**302.16a**	**305.40a**	

* Means sharing similar letter(s) in a group are statistically non-significant at p = 0.05 (LSD test)

T_1 = Sun dry, T_2 = Oven dry at 50 °C, T_3 = Oven dry at 60 °C, and T_4 = Oven dry at 70 °C

Table 4.2. Biochemical attributes of dried Indian jujube fruits of different cultivars as affected by drying methods.

	Antioxidant capacity (µM Trolox/100 mL)					Antioxidant activity (%)				
Cultivars	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
Dehli sufaid	107.18a	115.13a	105.16a	139.56a	**116.76a**	56.80a	60.12a	55.96a	70.31a	**60.80a**
Pak white	56.42a	119.06a	114.13a	130.82a	**105.11a**	35.62a	61.76a	59.70a	66.67a	**55.94a**
Anokhi	73.79a	131.38a	132.17a	118.83a	**114.04a**	42.87a	66.90a	67.23a	61.66a	**59.67a**
Karella	89.81a	92.95a	135.64a	139.67a	**114.52a**	49.56a	50.86a	68.68a	70.36a	**59.86a**
Foladi	86.45a	75.69a	134.52a	134.07a	**107.68a**	48.15a	43.66a	68.21a	68.02a	**57.01a**
Mehmood wali	67.63a	129.03a	149.31a	138.44a	**121.10a**	40.30a	65.92a	74.38a	69.85a	**62.61a**
Sadqia	97.09a	103.03a	109.76a	139.45a	**112.33a**	52.60a	55.07a	57.88a	70.27a	**58.95a**
Akasha	94.52a	93.17a	139.67a	161.75a	**122.28a**	51.52a	50.96a	70.36a	79.57a	**63.10a**
Yazman local	101.46a	116.14a	143.37a	173.40a	**133.59a**	54.42a	60.54a	71.90a	84.43a	**67.82a**
Khobani	103.82a	97.99a	105.05a	175.53a	**120.60a**	55.40a	52.97a	55.91a	85.32a	**62.40a**
Umran-13	114.13a	75.69a	139.78a	148.30a	**119.48a**	59.70a	43.67a	70.41a	73.96a	**61.93a**
Mean	**90.21c**	**104.48bc**	**128.05ab**	**145.44a**		**49.72c**	**55.68bc**	**65.51ab**	**72.77a**	

* Means sharing similar letter(s) in a group are statistically non-significant at $p = 0.05$ (LSD test)

T_1 = Sun dry, T_2 = Oven dry at 50 °C, T_3 = Oven dry at 60 °C, and T_4 = Oven dry at 70 °C

amount of total phenolic content in sun dried jujube fruits. Environmental factors may possibly affect the sun drying and resulting in uneven loss of total phenolic content. In another study, total phenolic content was enhanced in oven dried fruits as compared to fresh fruits (Gumusay *et al*., 2015).

The significantly greater antioxidant capacity was found in fruits after oven drying at 70 °C (145.44 µM Trolox/100 mL), followed by oven drying at 60 °C (18.05 µM Trolox/100 mL). The significantly low antioxidant capacity was recorded after sun drying (90.21 µM Trolox/100 mL), followed by oven drying at 50 °C (104.48 µM Trolox/100 mL) (Table 4.2). Reduction in antioxidant capacity was also observed in several previous studies after drying different fruits (Chottamom *et al*., 2012; Turkyilmaz *et al*., 2014). However, in the present study different cultivars of Indian jujube did not vary in their antioxidant capacity.

The significantly high antioxidant activity was recorded in fruits after oven drying at 70 °C (72.77%), followed by oven drying at 60 °C (65.51%), while less antioxidant activity was found after sun drying (49.72%), followed by oven drying at 50 °C (55.68%) (Table 4.2). Reduction in antioxidant activity and capacity was also observed by Gao *et al*. (2012) in Chinese jujube fruits after drying.

Sun drying is considered as one of the basic and traditional method for preservation of food products. The drying constraints of the product cannot be measured and controlled due to direct contact to solar radiations. Hence, sun drying is not same and consistent that may burn or scab the final product depending upon the behavior of the item. Color as well as taste of Indian jujubes may also be damaged by this technique (Shofian *et al*., 2011; Slatnar *et al*., 2011; Gao *et al*., 2012; Wojdylo *et al*., 2014). Under oven drying, water is mostly evacuated by dissipation. The use of oven drying is increasing with the passage of time due to several advantages such as controlled drying characteristics which provide very good and uniform quality items by decreasing the microbial infection, cheap labor charges and shorter drying time (Shofian *et al*., 2011; Igual *et al*., 2012). Oven drying can reduce the drying cycle as well as may also increase the quality of dried fruits (Nicoli *et al*., 1999; Fang *et al*., 2009).

***Conclusion*:** Indian jujube fruits are consumed as fresh because these are perishable due to high moisture level and may decay easily in couple of days after picking. Hence, there is an urgent need to preserve these fruits. Drying is famous as one of the most common methods to preserve the Indian jujube fruits. Oven drying is successfully used to produce uniform and good product quality, reduce labor costs and decrease drying time as compared to sun drying. Current study proved that Indian jujube can be preserved efficiently through oven drying at 50 - 70 °C. However, the fruits dried at 50 °C had higher vitamin C content, while those dried at 60 and 70 °C had higher antioxidant capacity as well as activity. So, current study is helpful to store fruits for long time, easy transportation with low cost, reduced packing costs, and their low water content reduce microbial decay.

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