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Applying dehydro-freezing method to extend shelf-life of Barhi date fruits growing at Qassim Region, Kingdom of Saudi Arabia

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Abstract

Barhi date fruits are good source of fiber, carbohydrates, minerals and vitamins and have a sweet taste and are popular in marketing. Fresh date fruits, especially Barhi cultivar, are favored and widely consumed at the Khalal maturity stage (first color edible stage). These fruits are seasonal and perishable and there is a need for extending their shelf life. The present study was carried out to improve the quality and the shelf-life of Barhi date fruits during storage time using steamed or/and dehydration, before freezing storage at (-18 ± 2°C) for 0, 3, 6 and 9 months and investigate the effect of these treatments on the physicochemical and sensory properties of the Barhi date fruits. The statistical analysis of results indicated that the treatments and storage periods influenced significantly the total acceptability of Barhi dates while the interaction between them was not significant. However, the highest total acceptability score was recorded for steamed and dehydrated samples followed by dehydrated samples which significantly differed from either steamed or control date samples. These results suggest that steaming and partial drying or only partial drying before frozen storage of Barhi date fruits could be used as an alternative method for improving fruit quality, as well as prolonging the marketable period of date fruits.

Key words: Barhi dates, dehydro-freezing, keeping quality, physicochemical, sensory properties.

Introduction

The date palm (*Phoenix dactylifera* L.) is one of the oldest fruit trees in the world and has been closely associated with the sustenance and culture of the people in the Middle East since ancient times. Egypt is the world's largest producer of dates, followed by Iran, Saudi Arabia, Algeria and Iraq. The date production in Saudi Arabia as the 3rd world producer of date was 1.065 tons in 2013 [20] representing about 13.21% of the total world production of date fruits (~8.06 million tons). Many of 1,500 varieties of date palm are cultivated in some limited regions of the world. In Saudi Arabia, there are more than 400 date palm varieties, of which only about 40 varieties with an economic value, spread in 7 Saudi provinces characterized by fitting climate for the growth and fruiting of the date palm. Riyadh, Qassim, eastern province, and Medina are the most famous production areas in SA. Sukkary, Saquee, Ekhlass, Ajwa, Barhee, Anbara, Safawi, Rothana, Rashodya, and Khedry are the most economic well-known cultivars in SA [7]. However, a significant portion of dates are wasted in date producing countries (e.g. 30% loss of total production) due to its inferior quality, damage, and undersized fruit of unattractive appearance[16]. It is also reported that dates are wasted during sorting, storage and conditioning processes [11]. The non-use of less-quality dates for human food constitutes is a real economic loss since this waste is rich in bioactive compounds which can be extracted and used as valuable materials [17]. Presently global production, consumption and industrial development of dates are constantly growing as date fruits are important source of energy and essential nutrients and possess some medicinal benefits [1, 2, 10]. However, this increase in date production is not associated with an increase in date palm processing development and marketing. The date industry is not yet fully developed and concerted efforts are still needed to fully utilize the tremendous potential of date substances in processed foods for export and the local market [5].

Quality of date fruits is greatly affected by post-harvest treatments and storage conditions. In fruit industry, proper storage control is one the key prerequisites for further processing of fresh and successful marketing [23, 26]. Various storage approaches had been applied to increase date fruits quality and extend shelf-life [14]. There is a strong consumer demand for high-quality dates with fresh like characteristics. Important quality criteria for producers of dates are not that lead to consumer satisfaction, but also those leading to economic turnover for date's industry[25].

Extending the shelf-life of soft date fruits by storage at low temperatures was studied by many researchers [19, 27, 31, 33]. Freezing and frozen storage can be utilized for the long-term preservation of some fruits and vegetables. Freezing decreases the water activity, inhibits microorganism growth and reduces enzymatic activity resulting in extending the shelf life of the product [21, 24]. Many published research works have confirmed the close

relationship between quick freezing and high quality frozen products and the resulting increase of shelf life with maximum preservation of initial quality [35, 38]. Dawood *et al*.[13] found that the frozen Samani, Amhat and Hayani date fruits lost some of their original moisture content during thawing. Total sugar, protein, lipids, fiber and ash contents were slightly increased after 6 months of storage at -20°C. Although, the color of the frozen date was darkened and the fruits were developed a soft texture upon thawing, all the frozen fruits of the three date cultivars were maintained acceptable sensory quality up to six months of storage period. Al-Yahyai and Al-Kharusi [8] introduced a modern technology in traditional date farming communities; frozen storage provides a supplemental and alternative storage option that allows for the consumption of dates at any time of the year. Also, El-Samahy *et al*. [18] preserved the Samani date fruits by dehydro-freezing.

Barhi is a mid-season cultivar extensively cultivated in the Saudi Arabia. Barhi dates are different than other cultivars in which fruit are marketed and consumed fresh at the mature full yellow (bisir) stage as a crispy apple-like fruit due to low contents of soluble tannins [9]. At the Rutab stage (ripe), fruit become softer and sweeter but their market value decreases. Under the conditions of the Kingdom of Saudi Arabia, Barhi dates reach the bisir stage during the extremely hot dry summer (early to mid-July). After harvest, fruit ripen rapidly, especially in ambient conditions, and thus lose much of their marketing value. Barhi dates can be eaten either in their unripe state or when fully ripe [30].

The ability to control fruit ripening following harvest and thus extending the shelf-life is a critical requirement in order to market the harvested bisir fruit with minimal physiological and physical disorders [6]. Fresh dates, such as Barhi cultivar, are popular and widely consumed at the Khalal stage of maturity (first edible stage, crunchy and sweet) during the date production season. One of the primary technical challenges in marketing fresh Barhi fruits at the Khalal stage of maturity is the preservation of quality for the longest possible period after harvesting and during the marketing process.

Due to the short life of the Barhi fruits, the aim of this study was to improve the shelf-life stability of Barhi date fruits by applying dehydro-freezing method and investigate their effect on organoleptic properties, color attributes, texture and total phenolic compounds of Barhi date fruits which considers an important variety grown at Qassim region, Saudi Arabia.

Materials and Methods

Materials: Fresh date fruits (Barhi cultivar) at late Khalal stage of maturity (maximum yellow color and firm texture) were obtained from a local market at Qassim, Saudi Arabia during season 2014.

Preservation of Barhi date fruits by dehydro-freezing: Dehydro-frozen Barhi date fruits were prepared according to method described by El-Samahy *et al.*[18], with some modifications as follows: Barhi date fruits were uniform to a great extent in size and color as well as free from visible blemishes, washed with tap water to remove dust and any adhering dirt and then air dried to remove moisture on top fruit surface. Fruits were divided into four parts, each weighing 8 kg. The first part was taken as control (without treatment), where the fruits were packed in foam trays and wrapped with polyethylene films after being divided to four groups, each weighing 2 kg. The second part was steamed for 5 min and suddenly cooled to room temperature for inhibiting the enzyme activities. Steamed fruits were divided to four groups and packed in foam trays and wrapped with polyethylene films. The third part of sample was partially dehydrated in hot-air dryer at 70°C until reducing the weight with 10–15%, without affecting on the fruit appearance. The fourth part of sample was steamed for 5 min, cooled and partially dehydrated at 70°C until reducing the weight with 10–15%. The fruits were divided and packed as aforementioned. All fruit parts were stored by freezing at -18 ± 2°C for 9 months. The samples were evaluated physically, chemically and organoleptically after freezing, 3, 6 and 9 months of storage and during thawing at room temperature (25 ± 2°C) for 24 h.

Determination of color attributes: The color of samples was measured with a Minolta Color Reader CR-10 (Minolta Co. Ltd., Osaka, Japan) according to the method described in Francis [22]. Color was expressed by CIE L* (whiteness or brightness), a* (redness/greenness), and b* (yellowness/blueness) coordinates. Measurements were replicated five times and the results were averaged.

Determination of texture: Texture of fruits samples was measured using Texture Analyzer (QTS 25, Brookfield AMETEK, Massachusetts, USA).

Determination of total phenolic content: Total phenolic content was estimated in the methanolic extracts, according to the Folin-Ciocalteu method with slight modifications [12]. The results were expressed as mg of gallic acid equivalents per 100 g of dry weight (mg GAE/g DW). All measurements were done in triplicate and the results averaged.

Sensory evaluation of dehydro-frozen Barhi fruits: The sensory evaluation of dehydro-frozen Barhi date fruits was carried out by trained panelists from College of Agriculture and Veterinary Medicine, Qassim University, Qassim, Saudi Arabia. Dehydro-frozen Barhi date fruits were evaluated for taste (30), color (20), odor (20), peel adhesion (10), texture (20) and overall acceptability (100) after treatments and during frozen storage periods after 24 h from thawing according to described method by El-Samahy *et al.*[18].

Statistical analysis: The data are presented as the mean of three (ten for sensory evaluation) determinations ± standard deviation and were analyzed by SPSS (version 17.0 SPSS Inc). The data were analyzed by ANOVA (2-ways completely randomized). Significant differences between the means were determined by Duncan's Multiple Range test. $P \leq 0.05$ was considered as a level of significance.

Results and Discussion

Organoleptic properties of frozen innovative date products: Sensory evaluation of food products is an important criterion by which its consumer acceptability can be assessed.

*Peel adhesion:*The effect of treatments of Barhi date on peel adhesion is presented in Table 1. There was a significant difference ($P \leq 0.05$) between all treatments. The highest peel adhesion score

was recorded for steamed and dehydrated date (7.50) followed by dehydrated (7.23) and steamed date (6.85). During storage periods, the peel adhesion property was significantly decreased ($P \leq 0.05$) in treated and untreated samples. There was no significant impact for the interaction between treatments and storage periods.

Texture as sensory property: Texture of treated and untreated date samples is presented in Table 2. The treatment and storage were affected significantly ($P \leq 0.05$) while the interaction between them had no significant importance. However, the untreated date sample significantly differed from all treated date samples. Gradual decreases were observed with extending the storage period in both treated and untreated date samples.

Color as sensory property: Color is a property which has an important role in consumer attraction and may indicate for vitamins content. The results for untreated and treated dates color are tabulated in Table 3 and shown in Fig. 1. The treatment and storage were affected significantly ($P \leq 0.05$) while the interaction between them was not significant. A color score was significantly decreased with extending the storage period in both untreated and treated date samples. The decrease percentage was 5.32, 7.95 and 14.50%, respectively. The color score of dehydrated fruits recorded significantly higher (16.40) than untreated fruits (12.83). The most preferable color for the panelists was recorded for dehydrated date when compared to untreated date. This significant decrease ($P \leq 0.05$) was remarked 27.83% in mean color value of untreated date compared to dehydrated fruit samples. The changes of mean values of color score were 21.59, 27.83 and 24.94%, for steamed, dehydrated and steamed-dehydrated date fruits, respectively.

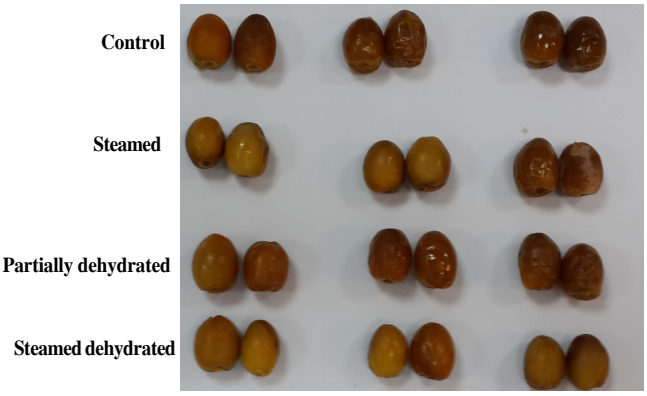

Figure 1. Appearance of steamed or/and dehydrated Barhi date fruits after thawing at different periods.

Table 1. The peel adhesion of treated and untreated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	7.4±1.35	6.9±0.74	6.7±0.95	5.4±0.84	6.60^{c}
Steamed	7.3±1.64	6.9±0.99	6.8±0.79	6.4±0.97	6.85^{bc}
Dehydrated	7.6±0.84	7.3±0.67	7.1±0.74	6.9±0.88	7.23^{ab}
Steamed and dehydrated	8.0±1.41	7.5±0.85	7.3±0.82	7.2±0.79	7.50^{a}
Mean	7.58^{A}	7.15^{AB}	6.98^{B}	6.48^{C}	

Data are the mean ± SD, n = 10, There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

Table 2. The texture of treated and untreated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	13.3±3.40	12.7±3.09	11.7±2.79	10.4±2.72	12.03^{b}
Steamed	16.7±2.58	15.8±2.30	15.0±2.31	13.9±2.02	15.35^{a}
Dehydrated	17.0±1.82	16.1±1.20	15.2±1.03	14.8±1.03	15.78^{a}
Steamed and dehydrated	16.5±3.06	15.9±2.96	15.2±2.35	14.5±1.78	15.53^{a}
Mean	15.88^{A}	15.13^{AB}	14.28^{BC}	13.40^{C}	

Data are the mean ± SD, n = 10, There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

Table 3. The color of untreated and treated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	14.4±2.32	13.1±1.97	12.7±1.49	11.1±1.37	12.83^{b}
Steamed	16.5±1.90	15.6±1.71	15.6±2.17	14.7±1.64	15.60^{a}
Dehydrated	17.6±2.17	16.8±1.62	16.1±1.20	15.1±1.45	16.40^{a}
Steamed and dehydrated	16.9±2.13	16.4±1.78	15.8±1.23	15.0±1.49	16.03^{a}
Mean	16.35^{A}	15.48^{B}	15.05^{B}	13.98^{C}	

Data are the mean ± SD, n = 10, There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

Table 4. The taste of untreated and treated Barhi date samples during storage of nine months under freezing condition (-18±2 ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	18.6±6.50	18.3±5.19	17.0±4.37	14.6±3.10	17.13^{c}
Steamed	22.5±5.32	20.6±3.34	19.1±2.85	17.2±2.20	19.85^{b}
Dehydrated	25.6±4.97	22.7±3.74	21.0±3.37	19.1±2.13	22.10^{a}
Steamed and dehydrated	24.7±4.47	23.2±3.68	21.9±2.88	21.3±1.83	22.78^{a}
Mean	22.85^{A}	21.20^{AB}	19.75B^{C}	18.05^{C}	

Data are the mean ± SD, n = 10, There is no significant difference (p≤0.05) between means within the same column has the same superscript letter (A, B). There is no significant difference (p≤ 0.05) between means within the same row has the same superscript letter (a, b).

Taste: Taste is considered as an important property with good utility to differentiate between date varieties or even evaluate the date quality. Table 4 indicates the taste score which was similarly affected during storage period of 9 months. The treatment and storage were affected significantly (P≤ 0.05) while the interaction between them was not significant. The mean score of taste was significantly decreased after 6 and 9 months compared to zero time. The decrease percentage was 13.57 and 21.01%, respectively. The most acceptable taste for the panelists was remarked for steamed-dehydrated date when compared to untreated date. The mean values of steamed-dehydrated (22.78) and dehydrated date (22.10) were significantly (P≤ 0.05) higher than for both steamed and untreated date sample (17.13). Consequently, a significant (P ≤ 0.05) difference was found between steamed and untreated dates. This significant increase in steamed-dehydrated was up to 32.98% in mean taste score value when compared to untreated sample.

Odor: Results of odor illustrated that there is non-significant impact of the treatment on the date odor while later the storage period changed the mean value of odor significantly (P≤0.05) (Table 5). The mean value of odor was significantly decreased after 6 and 9 months compared to zero time. This decrease percentage was up to 5.48 and 9.69%, respectively. Again, the mean values of treated samples showed non-significant differences among the all treatments.

Overall acceptability: Table 6 illustrates the overall acceptability score of untreated and treated date fruit samples which significantly (P≤ 0.05) decreased during the storage period. The results showed that the treatment and storage affected significantly while the interaction between them had no significant impact. There were significant differences between steamed and dehydrated (79.75) and untreated (66.38) fruits for overall acceptability, but non-significant difference with dehydrated (79.68) fruits. These results are in accordance with El-Samahy *et al.* [18].

Color parameters of dehydro-frozen Barhi date fruits: Color can be an important factor in terms of consumer acceptance of dates. The *L*, a** and *b** Hunter Lab color values, are presented in Tables 7- 9. The statistical analysis of *L** value confirmed that the storage affected the color significantly while both treatment and the interaction between them had no significant effect (Table 7). A decremented rate in mean *L** value was 21.70, 24.40 and 28.27% at 3, 6 and 9 months, respectively. No significant difference could be noticed among all studied treatments. These results are in accordance with El-Samahy *et al.*[18]. Color plays a fundamental part in the consumers' evaluation of the food quality. Color changes are considered as the major quality attribute that affects consumers' selection [38]. Enzymatic oxidation of phenolic substances is the main reason that induces color changing (browning). Ice crystals formed during freezing will enhance

Table 5. The odor of untreated and treated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	18.4±2.01	18.6±2.72	17.9±2.77	16.3±2.98	17.80^{a}
Steamed	19.0±1.49	18.2±1.32	17.6±1.26	16.5±0.85	17.83^{a}
Dehydrated	19.0±1.41	18.3±1.34	17.8±0.79	17.6±0.97	18.18^{a}
Steamed and dehydrated	18.7±1.83	17.8±1.48	17.7±1.25	17.5±0.85	17.93^{a}
Mean	18.78^{A}	18.23^{AB}	17.75^{B}	16.98^{C}	

Data are the mean ± SD, n = 10, There is no significant difference (p≤0.05) between means within the same column has the same superscript letter (A, B). There is no significant difference (p≤ 0.05) between means within the same row has the same superscript letter (a, b).

Table 6. The overall acceptability of untreated and treated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	72.1±9.24	69.6±9.01	66.0±7.92	57.8±6.76	66.38^{c}
Steamed	82.0±8.72	77.1±5.92	74.1±4.91	68.7±4.62	75.48^{b}
Dehydrated	86.8±8.98	81.2±5.96	77.2±4.13	73.5±2.88	79.68^{a}
Steamed and dehydrated	84.8±9.34	80.8±8.44	77.9±6.44	75.5±4.35	79.75^{a}
Mean	81.43^{A}	77.18^{B}	73.80^{C}	68.88^{D}	

Data are the mean ± SD, n = 10, There is no significant difference (p≤0.05) between means within the same column has the same superscript letter (A, B). There is no significant difference (p≤ 0.05) between means within the same row has the same superscript letter (a, b).

Table 7. Lightness (*L**) value of untreated and treated Barhi date samples during storage of nine months under freezing condition at (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	47.48±1.19	28.02±9.59	27.52±6.26	28.87±3.37	32.97[a]
Steamed	40.59±3.48	35.85±4.75	35.91±4.81	32.41±6.70	36.19[a]
Dehydrated	42.96±0.35	34.27±5.91	32.17±4.05	30.11±3.18	34.88[a]
Steamed and dehydrated	38.59±5.53	34.65±5.30	32.65±6.03	30.30±5.51	34.05[a]
Mean	42.41[A]	33.20[B]	32.06[B]	30.42[B]	

Data are the mean ± SD, n = 3. There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

Table 8. Redness (*a**) value of untreated and treated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	5.88±0.48	6.37±0.57	6.25±0.61	6.82±0.92	6.33[a]
Steamed	7.07±2.97	5.14±0.81	7.02±1.76	6.36±0.63	6.40[a]
Dehydrated	6.5±0.68	6.49±2.28	6.87±2.19	7.59±1.67	6.87[a]
Steamed and dehydrated	5.38±0.44	5.98±2.97	4.24±1.01	7.24±1.14	5.71[a]
Mean	6.21[A]	6.00[A]	6.10[A]	7.00[A]	

Data are the mean ± SD, n = 3. There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

enzymatic oxidation due to the destruction of the cells and tissues of the product and therefore increased contact between phenolics, oxygen and enzymes [32].

The data of *a** value for untreated and treated date sample are presented in Table 8. The results showed that *a** value had non-significant differences of storage and treatment and even the interaction between them on *a** value. Obviously, the undertaken treatments had no effect on *a** value of untreated and treated date sample. These results may be in accordance with El-Samahy *et al.* [18].The results of *b** value confirmed that the treatment and storage affected the color significantly while the interaction between them was not significant (Table 9). A significant difference was found between all treatments and untreated date. These results may be in accordance with El-Samahy *et al.* [18]. The mean values of the basic color parameters *L*, a** and *b** of the fresh Barhi fruits were 47.48, 5.88 and 32.51, respectively. These values show that Barhi fresh fruits at Khalal stage of maturity are characterized with their bright yellow color. From Fig. 1 it is clear that the *L*, a** and *b** values had changed for all treatment on Barhi frozen fruits with the period of frozen storage which extended for nine months. The observed changes in yellowness were probably due to oxidant reactions during storage and the decrease in yellow pigment which was greatly contributed to yellowness values [4].

Determination of texture of dehydro-frozen Barhi date fruits: Textural parameters of frozen foods play an essential part in determining the acceptability of these products by consumers. Higher values of hardness, chewiness and resilience of the pulp indicate better quality products [28, 29, 38]. Several researchers have studied the effects of freezing on textural quality of fruits [15, 34, 36]. Table 10 shows that the texture values of the date fruits significantly decreased during frozen storage for 9 months. It ranged from 3.93 kg cm^{-2} at zero time of storage to 1.68 kg cm^{-2} after 9 months of frozen storage at -18 ± 2 °C. Regarding to the effect of treatments, untreated fruits had the highest value (3.12 kg cm^{-2}). The texture values significantly decreased among treated samples. The decrease of texture value of steamed fruits (2.14 kg cm^{-2}) was higher than that for steamed-dehydrated (2.44 kg cm^{-2}) and dehydro-frozen fruits (2.44 kg cm^{-2}). Texture values of dehydro-frozen fruits had higher resistance to decrease than that for steamed and steamed-dehydrated fruits. This may be due to the reduction of freezing damage, which referred to reduction of moisture content of dehydro-frozen fruits. The high decreasing rate in texture of unsteamed fruit during thawing may be due to the activity of pectic enzymes, which cause a softening in the texture [18].

Total phenols of dehydro-frozen Barhi date fruits: Total phenol contents of treated Barhi fruits are presented in Table 11. Total

Table 9. Yellowness (*b**) value of untreated and treated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	32.51±3.35	18.76±9.49	16.52±5.07	13.83±4.70	20.41[b]
Steamed	36.05±1.21	29.10±8.19	19.13±0.61	18.36±4.71	25.66[a]
Dehydrated	33.39±1.94	32.75±4.03	18.84±9.01	13.63±3.30	24.65[ab]
Steamed and dehydrated	31.78±2.86	33.69±3.82	21.25±7.22	19.41±2.66	26.53[a]
Mean	33.43[A]	28.57[B]	18.94[C]	16.31[C]	

Data are the mean ± SD, n = 3. There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

Table 10. Texture (kg cm^{-2}) of treated and untreated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	4.30±1.03	3.69±0.80	2.84±0.34	1.63±0.27	3.12[a]
Steamed	3.17±0.44	2.04±0.43	1.86±0.33	1.49±0.33	2.14[b]
Dehydrated	4.05±1.48	2.62±0.81	2.21±0.50	1.73±0.24	2.65[ab]
Steamed and dehydrated	4.18±0.38	1.91±0.42	1.81±0.43	1.87±0.40	2.44[b]
Mean	3.93[A]	2.57[B]	2.18[BC]	1.68[C]	

Data are the mean ± SD, n = 3. There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

Table 11. Total phenolic content (mg GAE g^{-1}) of treated and untreated Barhi date samples during storage of nine months under freezing condition (-18±2ºC).

Treatment	Storage period (month)				Mean
	0	3	6	9	
Untreated	43.08±0.37	24.82±0.31	20.68±0.42	18.01±0.49	26.65c
Steamed	30.60±0.07	28.98±0.35	25.79±0.37	23.77±0.77	27.29b
Dehydrated	33.18±0.35	30.38±0.57	28.23±0.39	26.01±0.39	29.45a
Steamed and dehydrated	28.78±0.30	26.56±0.41	23.81±0.29	24.08±0.59	25.81d
Mean	33.91A	27.68B	24.63C	22.97D	

Data are the mean ± SD, n = 3. There is no significant difference ($p \leq 0.05$) between means within the same column has the same superscript letter (A, B). There is no significant difference ($p \leq 0.05$) between means within the same row has the same superscript letter (a, b).

phenol content was significantly higher in dehydrated date fruits compared with those in steamed-dehydro-frozen and untreated date fruits. The mean values of total phenols (mg GAE g^{-1}) were 29.45 for steamed-dehydrated fruits, 27.29 for steamed fruits, 25.81 for steamed-dehydro-frozen fruits and 26.65 for untreated fruits, respectively. These results are in agreement with Al-Harthi *et al*.[3].

Conclusions

Treating Barhi date fruits with steam and partial dehydration or only partial drying before frozen storage (dehydro-freezing) was successful treatment, it improved the quality of fruits during freezing storage and thawing. Dehydro-frozen fruits as well as dehydrated fruits had the highest texture values and total phenols. They had also the highest scores of taste and peel adhesion. This indicated the possibility of using dehydro-freezing process in improving the quality of frozen Barhi date fruits.

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