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FULL LENGTH ARTICLE

Effect of postharvest hot-water and heat treatment on quality of date palm (cv. Stamaran)

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Abstract In this research, fresh harvested date palm (*Phoenix dactylifera* L.) cv. "Stamaran" was treated with hot water rinsing and dried (HWR) at 50 °C (HWR-50), 60 °C (HWR-60) and 70 °C (HWR-70). The effect of these heat treatments on fruit quality was investigated during 6 months at ambient temperature storage (25 °C of temperature and 75% of humidity). Moisture, pH, color, weight loss, Brix and firmness of the samples were studied. Results indicated that during storage the moisture content and color changed significantly. The major change was observed for firmness where a maximum force for puncture test varied from about 3.5 to 2 N forces for all samples after 6 months of storage at 25 °C. Harvesting at Tamr stage followed by treating the fruits with hot water, drying and storing at 25 °C (Especially HWR-70) showed to be a promising method for maintaining date palm fruit storage quality.

1. Introduction

Date palm fruit (*Phoenix dactylifera* L.) is an important agricultural product of Iran and many Arabic countries. Dates are rich in certain nutrients and provide a good source of rapidly available energy due to their high carbohydrate content (70–80%). Most of the carbohydrates in dates are in the form of fructose, glucose and sucrose, which are easily digested by the human body. The good nutritional value of dates is also based on their dietary fiber content, which makes them suitable for the preparation of fiber-based foods and dietary supplements (Al-Frasi et al., 2005). Date palm cultivars are of three main types according to their fruit moisture content i.e. soft, semi-dry and dry cultivars (Selim et al., 1970). Ismail et al. (2006) reported that chemical and physical characteristics of the fruits influenced their mechanical and rheological properties, which in turn can be indicators of firmness and ultimately of quality. Also, it revealed new and essential information for better understanding of the date fruit that helps to enhance industrialization and propagation of the best date

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varieties that satisfy producers as well as consumers' demands. Stamaran is considered one of the main date cultivars of Iran, particularly in the southern provinces e.g. Khuzestan. Stamaran date is classified as a semi-dry variety and it is the most valuable variety of the dates in Iran.

Postharvest heat treatment offers a pesticide-free method to kill or weaken plant pathogens, control insect infestations and maintain fruit storage quality (Barkai-Golan and Phillips, 1991; Shao et al., 2007). A new technology has been proposed for simultaneously cleaning and disinfecting fruits using hot water rinsing (HWR). Recently, HWR treatments are studied extensively because of their higher temperature and shorter exposure time than traditional hot water immersions or dips. HWR treatments could not only remove the heavy dirt, pesticides and fungal spores on the freshly harvested produce, but could also improve general product appearance and maintain product quality (Fallik, 2004). Because this technology has been designed to be a part of the commercial packing house sorting line and successfully used on the postharvest freshkeeping treatment of sweet pepper (Fallik et al., 1999) and mango (Prusky et al., 1999), HWR treatments would be desirable for treating freshly harvested produce on a commercial scale (Porat et al., 2000).

The effectiveness of sodium chloride and acetic acid for the initiation/acceleration of the ripening of Dhakki dates has been investigated by Saleem et al., 2005. They treated Pakistani Dhakki date fruits individually and/or in a combined form at different proportions varying from 0.25% to 3.5% and from 0.25% to 2.5% for sodium chloride and acetic acid, respectively. All of the treatments, whether applied as a single treatment or in a combined form, tended to induce ripening by causing changes in the selected quality parameters. The results of the controlled ripening of date fruits were reported to be satisfactory (Saleem et al., 2005).

Kalra and Jawanda harvested date fruits of Khudrawi and Shamran varieties at their hard stage and treated them with NaCl at 0.5–2.0% and acetic acid at 0.5–2% alone and in combination. They packed the dates in wooden boxes lined with paper and stored at room temperature for 18–24 h, after which fruit ripening was assessed. Fruits of Khudrawi and Shamran treated with 2.0% NaCl alone achieved 72% and 75% ripening as determined by weight, respectively (Kalra and Jawanda, 1974).

Shamshiri and Rahemi determined the effect of post harvest treatment on the ripening and quality of Mazafati date fruits using acetic acid (2%), sodium chloride (2%), or a combination of 2% acetic acid with sodium chloride. Either separately or combined sodium chloride and acetic acid significantly increased total soluble solids (TSS), but reduced fruit firmness and moisture content. Acetic acid at 2% had a greater effect on fruit ripening than sodium chloride, but fruits that were treated with sodium chloride were better in appearance (Shamshiri and Rahemi, 1999).

To our knowledge, however, there is a little or no report on the effect of HWR treatments on date palm under different storage durations (particularly color and appearance). Thus, the main aim of this work was to study Stamaran date fruit quality properties at Tamr stage affected by HWR treatments and determine whether HWR treatments are suitable to be used as practical postharvest treatments and commercial implementations for date palm fruit and to improve its appearance.

2. Materials and methods

2.1. Materials

In the current research project date fruits (variety, Stamaran) were collected from a commercial date farm in Khuzestan (southern Iran) at the Tamr stage in September 2012. Healthy and uniform date fruits were selected and transferred to the Department of Food Science and Technology of Tarbiat Modares University to be kept at 4 °C before other treatments (up to one day). After rinsing (a few seconds) the date with hot water (60 °C), the samples were dried by deferent temperature (50, 60 and 70 °C) until reaching to the initial moisture. Then, they were picked out and randomly distributed into three batches. The codes of the treatments are given in Table 1. Each sample was then packed in a perforated polystyrene plastic box and incubated for up to 6 months in ambient temperature storage (25 °C of temperature and 75% of humidity). The samples were collected at 0, 0.5, 1, 3, and 6 months of incubation times and further experiments were carried out. Each batch for every time contained 100 fruits.

2.2. Methods

Moisture content, pH, Brix, Hunter color parameters (L^*, a^*, and b^* values) and fruit firmness (texture) were estimated at 0, 0.5, 1, 3 and 6 months at 25 °C storage.

2.3. Chemical and physical analysis of date samples

2.3.1. Moisture content and pH

Moisture content and pH were quantitatively determined according to AOAC methods in triplicate (AOAC, 2012).

2.3.2. Weight loss

Thirty fruits of each batch were used for measurement of weight loss. The fruits were weighted and the results were expressed as percentage of weight loss over the initial value (Vicente et al., 2003).

2.3.3. Color and firmness

Ten fruits of each treatment were used to measure both color and firmness. Two readings per fruit were taken on opposite checks of the date palm. Firmness was measured using a Texture Analyzer (Stevens-Lfra, England). The texture of all date samples was evaluated with a cylindrical puncture probe with the diameter of 7 mm at room temperature (about 25 °C). To minimize variations, it was tried to use samples with almost similar thickness. The moving speed of the probe and the

Table 1 The codes and treatment of four date samples used in this research.

Sample code	Treatment
HWR-50	Rinsing with water 60 °C and drying at 50 °C
HWR-60	Rinsing with water 60 °C and drying at 60 °C
HWR-70	Rinsing with water 60 °C and drying at 70 °C
Control	No treatment

puncture distance of all tests were 30 mm/min and 5 mm, respectively. Maximum forces (N) recorded during the punching process were reported as indications of the firmness of the date texture. External color of fruit was measured with a Minolta Chromameter (Model CR-300; Minolta, Japan) in CIE $L^* a^* b^*$ mode under CIE Standard Illuminant C. Hue angle was equal to $\tan^{-1}(b^*/a^*)$ (Fallik, 2004).

2.3.4. Total soluble solids (Brix, %)

Total soluble solids (TSS) were measured with juice obtained from 30 fruits per treatment by a method modified from Lara et al. (2006). TSS was determined with a hand refractometer (Model DR-A1; Atago, Japan), and results were expressed as percent of total soluble solids (Brix, %) in juice at 25 °C.

2.4. Statistical analysis

The treatments were performed using a completely randomized design and all experiments were carried out at least in triplicate. The experimental data were subjected to analysis of variance followed by a multiple range Duncan's test. Significance was defined at $P < 0.05$. The SPSS 19 program was used for all statistical analysis.

3. Results and discussion

Date fruits of the Stamaran variety at the Tamr stage of ripening were treated in this research project. The treatments were performed at room temperature by rinsing the date fruits with hot water and drying them. Totally, four samples (see Table 1 for the sample codes) were obtained for further physicochemical and textural experiments.

3.1. Moisture content

The changes in moisture content of the samples during storage at 25 °C are presented in Table 2. The moisture content of the samples before storage was 18.3% which decreased significantly during the storage for all samples. After 6 months of storage, the moisture reduction for the control was about 1%, but the moisture loss of the sample treated with HWR-50 was about 1.4% while this value for HWR-60 sample was about 1.8% and for HWR-70 sample was about 1.9%.

Practically, the moisture content of the samples reduced considerably during storage. Controlling the moisture content of the date samples is a key issue for their storage. The greatest moisture loss was for the sample treated with the HWR-70 and HWR-60. Statistical analysis showed that the effect of storage time was greater than the treatment in reducing the moisture level of the treated samples.

Ali (1989) studied the effect of hot solutions on the curing of dates and concluded that the fruit undergoing storing lost its weight through moisture evaporation and spoilage was considerably reduced in the treated sample during curing.

3.2. Total soluble solids (Brix)

Table 3 shows the Brix of date samples treated with HWR. As seen in this table, HWR treatments showed high Brix when compared with the control, and the difference was significant after 6 months of storage. The storage of dates at 25 °C had significant effects on their Brix. For all treatments, the total soluble solids (Brix, %) of fruit stored at 25 °C were increased significantly ($P < 0.05$) as the storage period increased. The total soluble solids after 6 months of storage at 25 °C increased from 72.87% to 75.73% for the sample treated with HWR-50

Table 2 The moisture content (wet basis) changes of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$18.3 \pm 1.02^{D}_{b}$	$18.17 \pm 0.99^{E}_{ab}$	$18.19 \pm 0.98^{E}_{ab}$	$18.11 \pm 0.92^{C}_{a}$
0.5	$18.13 \pm 0.97^{D}_{b}$	$17.8 \pm 0.92^{D}_{a}$	$17.69 \pm 0.94^{D}_{a}$	$17.6 \pm 0.87^{B}_{a}$
1	$17.88 \pm 0.91^{C}_{b}$	$17.4 \pm 0.91^{C}_{a}$	$17.26 \pm 0.89^{C}_{a}$	$17.2 \pm 0.83^{B}_{a}$
3	$17.6 \pm 0.89^{B}_{b}$	$17.1 \pm 0.87^{B}_{ab}$	$16.84 \pm 0.85^{B}_{a}$	$16.7 \pm 0.84^{A}_{a}$
6	$17.29 \pm 0.83^{A}_{d}$	$16.71 \pm 0.84^{A}_{c}$	$16.41 \pm 0.82^{A}_{b}$	$16.22 \pm 0.81^{A}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

Table 3 Brix of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$72.87 \pm 1.22^{A}_{a}$	$72.98 \pm 1.26^{A}_{a}$	$73.77 \pm 1.29^{A}_{b}$	$74.18 \pm 1.34^{A}_{c}$
0.5	$73.42 \pm 1.31^{B}_{a}$	$73.57 \pm 1.39^{B}_{a}$	$74.42 \pm 1.42^{B}_{b}$	$74.7 \pm 1.46^{B}_{b}$
1	$73.95 \pm 1.39^{C}_{a}$	$74.07 \pm 1.47^{B}_{a}$	$75.13 \pm 1.51^{C}_{b}$	$75.32 \pm 1.57^{C}_{b}$
3	$74.58 \pm 1.45^{D}_{a}$	$74.8 \pm 1.58^{C}_{a}$	$75.98 \pm 1.64^{D}_{b}$	$76.3 \pm 1.69^{D}_{b}$
6	$75.23 \pm 1.58^{E}_{c}$	$75.73 \pm 1.66^{D}_{b}$	$76.98 \pm 1.77^{E}_{c}$	$77.34 \pm 1.85^{E}_{c}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

Table 4 The pH of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$6.14 \pm 0.78^{D}{}_{b}$	$6.1 \pm 0.69^{D}{}_{ab}$	$6.09 \pm 0.64^{E}{}_{ab}$	$6.08 \pm 0.54^{E}{}_{a}$
0.5	$6.09 \pm 0.71^{CD}{}_{c}$	$6.06 \pm 0.61^{D}{}_{bc}$	$6.03 \pm 0.58^{D}{}_{ab}$	$6 \pm 0.48^{D}{}_{a}$
1	$6.05 \pm 0.59^{BC}{}_{c}$	$6 \pm 0.55^{C}{}_{b}$	$5.95 \pm 0.53^{C}{}_{ab}$	$5.94 \pm 0.43^{C}{}_{a}$
3	$6.01 \pm 0.51^{B}{}_{c}$	$5.91 \pm 0.46^{B}{}_{b}$	$5.88 \pm 0.49^{B}{}_{ab}$	$5.85 \pm 0.44^{B}{}_{a}$
6	$5.95 \pm 0.47^{A}{}_{c}$	$5.82 \pm 0.48^{A}{}_{b}$	$5.78 \pm 0.46^{A}{}_{ab}$	$5.75 \pm 0.41^{A}{}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

and to 77.35% for the sample treated with HWR-70. These results are consistent with reports by other researchers (Dull, 1971; Nerd et al., 1999). The effect of storage time was greater than the treatment solutions in reducing the TSS (%) of the treated samples. The major reasons for the increase of Brix would be the escape of water over storage time at 25 °C and enzymatic conversion of large polysaccharides into small sugars. At every time of storage, treatment of HWR-70 sample was significant high Brix when compared with other sample (except the HWR-60 after 0.5 month).

3.3. pH

One of the important parameters determining the microbial stability and hence the shelf life of date fruits is their pH. Table 4 presents the pH changes of date fruits during storage (0–6 months) after being treated with hot water and different dry temperatures. Both storage and treatments caused significant changes in the pH of the fruit. The minimum and maximum pH values before the storage were 6.08–6.14 and after 6 months of storage with 5.4% and 3.1% reduction were 5.75–5.95 for HWR-70 and control sample, respectively. It also reveals that during the storage process each treatment resulted in a different pH compared to the control sample, e.g. the final pH of the sample treated with the HWR-70 was 5.75 while this value for the date fruits treated with HWR-50 was 5.82. Then, pH value decreased as the time of storage increased. Even though the respiration rate is low inside the fruit, prolong submerging and storing period will also cause changes to the level of organic acid (Echeverria and Valich, 1988).

3.4. Firmness

As one of the main quality parameters in sensory acceptance of date fruits by the consumers, texture was evaluated quantitatively using a Texture Analyser instrument. Firmness values (maximum force of puncture test) of date fruits during storage (0–6 months) after being treated with different HWR are presented in Table 5. As the table shows, during 6 month storage firmness (maximum force) of the fruits decreased for all treatments significantly. For example, the firmness of the fruits treated with the HWR-70 changed with 44.2% reduction from 2.83 to 1.68 (N force) for the storage times of 0 and 6 months, respectively. After HWR treatments, the high heat-treated fruits showed low firmness when compared with the control, and the difference was significant before storage (Table 5). The firmness of control fruits had obvious changes after storage, but those of heat-treated fruits had lower firmness than control after ambient temperature storage ($P < 0.05$). There was a significant difference of firmness between the three treatments after storage ($P < 0.05$). Thus, HWR treatments decreased fruit firmness after ambient storage and these results were in accordance with report of other researches (Lum and Norazira, 2011; Garcia et al., 1995).

There were also significant differences between the treatments up to the storage time of 6 months in terms of the maximum force required for the puncture tests. Up to 6 months of storage, HWR-70 treatment was more effective than other treatments, e.g. the firmness of HWR-70, HWR-60 and HWR-50 were 1.68, 1.93 and 2.24 (N force), respectively. Increasing of drying temperature and storage period has showed a decrease in date palm fruit firmness significantly. As reported by many authors, the firmness loss could also be linked to the action of the softening promoting enzymes, such as polygalacturonase (Lazan et al., 1986). The high water temperature caused disturbance in cell structure and membrane damage in fruit samples which was the source of a decrease in fruit firmness (Wills et al., 1989). Fruit structure will decline with a long storage period (Rohrbach et al., 2003). Fruit structure declines fast during storage period (Pantastico et al., 1995).

Table 5 Firmness (maximum force required for texture test, N) of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$3.73 \pm 0.37^{E}{}_{b}$	$3.51 \pm 0.35^{E}{}_{b}$	$3 \pm 0.31^{E}{}_{a}$	$2.83 \pm 0.28^{D}{}_{a}$
0.5	$3.45 \pm 0.33^{D}{}_{b}$	$3.32 \pm 0.32^{D}{}_{b}$	$2.76 \pm 0.29^{D}{}_{a}$	$2.53 \pm 0.22^{C}{}_{a}$
1	$3.13 \pm 0.31^{C}{}_{c}$	$2.94 \pm 0.29^{C}{}_{c}$	$2.55 \pm 0.27^{C}{}_{b}$	$2.26 \pm 0.19^{BC}{}_{a}$
3	$2.83 \pm 0.26^{B}{}_{b}$	$2.6 \pm 0.25^{B}{}_{b}$	$2.23 \pm 0.23^{B}{}_{a}$	$2.06 \pm 0.17^{B}{}_{a}$
6	$2.57 \pm 0.21^{A}{}_{d}$	$2.24 \pm 0.22^{A}{}_{c}$	$1.93 \pm 0.17^{A}{}_{b}$	$1.68 \pm 0.14^{A}{}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

3.5. Weight losses

Progressive increase in fresh weight loss percentage occurred for date fruit cv. Stamaran throughout postharvest storage and hot water treatments (Table 6). Significantly, the highest fresh losses in date palm fruits were observed at the end of storage period from about 0.6 to 10.08, 11.89% and 14.1% due to storage treatments for different HWRs, respectively. Meanwhile, untreated fruits (control) recorded the highest fresh weight loss percentage at the end of storage at 25 °C from 0.0% to 4.73%. These results confirm the findings of Park and Jung (1996) and Schirra et al. (1997) who reported a rapid weight loss in citrus fruit exposed to heat treatments and also our results are further in line with Perez et al. (2004) in avocado fruits. This is the natural characteristic for horticulture commodity. When the fruit is harvested, it no longer depends on its root system. Therefore, water loss in fruit cannot be replaced from the root (Pantastico et al., 1995). Weight loss in guava fruit also increased with the storage period from day one to day 8 (Renato et al., 2005). The interaction between treatment and the period of storage will also influence the weight loss of date palm fruit. Fruit that is treated with HWR-70 after 6 months has the highest weight loss percentage (14.1%). High temperature is the cause of the high weight loss (Smock, 1977).

3.6. Color

The fruit color plays a key role in the marketing value and quality index. Similarly, color variation is closely associated with the ripening progress. Nevertheless, different date cultivars exhibit their own color on ripening. Color parameters of the surfaces of the four samples are shown in Tables 7–10. Lightness (L^* value of the Hunter color system) values of the samples are compared in Table 7. Both storage time and treatment type had significant effects on the L^* values. The color lightness of all samples (control and the treated samples) decreased with storage time.

Treatment samples were significantly more effective than control (i.e. no treatment) in decreasing the lightness at every

Table 6 Weight loss of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$0^{A}{}_{a}$	$0.35 \pm 0.03^{A}{}_{a}$	$0.68 \pm 0.04^{A}{}_{a}$	$0.73 \pm 0.05^{A}{}_{a}$
0.5	$0.59 \pm 0.04^{A}{}_{a}$	$1.47 \pm 0.09^{Ab}{}_{a}$	$2.89 \pm 0.19^{AB}{}_{b}$	$3.91 \pm 0.38^{AB}{}_{b}$
1	$1.91 \pm 0.13^{A}{}_{a}$	$3.64 \pm 0.35^{B}{}_{b}$	$5.2 \pm 0.61^{BC}{}_{b}$	$7.17 \pm 0.82^{BC}{}_{c}$
3	$3.25 \pm 0.32^{A}{}_{a}$	$6.81 \pm 0.65^{C}{}_{b}$	$7.75 \pm 0.69^{C}{}_{b}$	$10.29 \pm 1.05^{C}{}_{c}$
6	$4.73 \pm 0.45^{A}{}_{a}$	$10.08 \pm 0.95^{D}{}_{b}$	$11.89 \pm 1.17^{D}{}_{c}$	$14.1 \pm 1.21^{D}{}_{d}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

Table 7 The lightness (L^* value of Hunter color system) of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$28.2 \pm 1.92^{E}{}_{d}$	$27 \pm 1.73^{D}{}_{c}$	$26.66 \pm 1.57^{E}{}_{b}$	$25.3 \pm 1.49^{D}{}_{a}$
0.5	$27.85 \pm 1.82^{D}{}_{d}$	$26.87 \pm 1.67^{D}{}_{c}$	$26.29 \pm 1.52^{D}{}_{b}$	$25.15 \pm 1.43^{D}{}_{a}$
1	$27.35 \pm 1.74^{C}{}_{c}$	$26.13 \pm 1.59^{C}{}_{b}$	$25.99 \pm 1.45^{C}{}_{b}$	$24.6 \pm 1.37^{C}{}_{b}$
3	$26.54 \pm 1.61^{B}{}_{c}$	$25.35 \pm 1.48^{B}{}_{b}$	$25.2 \pm 1.36^{B}{}_{b}$	$24.1 \pm 1.35^{B}{}_{a}$
6	$25.43 \pm 1.53^{A}{}_{c}$	$23.5 \pm 1.43^{A}{}_{a}$	$23.22 \pm 1.38^{A}{}_{ab}$	$22.91 \pm 1.31^{A}{}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

Table 8 Hunter color parameter of a^* value of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$7.3 \pm 0.82^{A}{}_{c}$	$7.23 \pm 0.84^{D}{}_{c}$	$6.7 \pm 0.75^{C}{}_{b}$	$6.28 \pm 0.69^{D}{}_{a}$
0.5	$6.94 \pm 0.78^{D}{}_{c}$	$6.64 \pm 0.81^{C}{}_{c}$	$6.08 \pm 0.72^{B}{}_{b}$	$5.78 \pm 0.66^{C}{}_{a}$
1	$6.57 \pm 0.74^{C}{}_{c}$	$6.3 \pm 0.76^{B}{}_{c}$	$5.77 \pm 0.68^{AB}{}_{b}$	$5.28 \pm 0.61^{B}{}_{a}$
3	$6.2 \pm 0.71^{B}{}_{c}$	$6.06 \pm 0.72^{B}{}_{c}$	$5.55 \pm 0.65^{A}{}_{b}$	$4.99 \pm 0.57^{AB}{}_{a}$
6	$5.7 \pm 0.68^{A}{}_{b}$	$5.69 \pm 0.69^{A}{}_{b}$	$5.35 \pm 0.63^{A}{}_{b}$	$4.71 \pm 0.54^{A}{}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

Table 9 The b^* value of the Hunter color system of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$10.5 \pm 1.12^{E}{}_{d}$	$9.9 \pm 0.96^{D}{}_{c}$	$8.9 \pm 0.83^{E}{}_{b}$	$8.11 \pm 0.81^{D}{}_{a}$
0.5	$9.64 \pm 1.05^{D}{}_{d}$	$9 \pm 0.91^{C}{}_{c}$	$8 \pm 0.79^{D}{}_{b}$	$7.43 \pm 0.79^{C}{}_{a}$
1	$8.96 \pm 0.98^{C}{}_{b}$	$8.41 \pm 0.88^{BC}{}_{b}$	$7.5 \pm 0.78^{C}{}_{a}$	$6.76 \pm 0.74^{B}{}_{a}$
3	$8.31 \pm 0.91^{B}{}_{c}$	$7.94 \pm 0.84^{B}{}_{c}$	$7.1 \pm 0.75^{B}{}_{b}$	$6.33 \pm 0.71^{AB}{}_{a}$
6	$7.51 \pm 0.85^{A}{}_{c}$	$7.26 \pm 0.81^{A}{}_{c}$	$6.75 \pm 0.72^{A}{}_{b}$	$5.84 \pm 0.62^{A}{}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

Table 10 Hue angle value of date fruits during storage at 25 °C for different treatments.

Storage time (month)	Treatment			
	Control	HWR-50	HWR-60	HWR-70
0	$55.2 \pm 1.69^{B}{}_{c}$	$53.9 \pm 1.55^{A}{}_{b}$	$53 \pm 1.47^{A}{}_{ab}$	$52.3 \pm 1.39^{A}{}_{a}$
0.5	$54.2 \pm 1.61^{AB}{}_{c}$	$53.6 \pm 1.51^{A}{}_{bc}$	$52.8 \pm 1.42^{A}{}_{ab}$	$52.1 \pm 1.34^{A}{}_{a}$
1	$53.7 \pm 1.57^{AB}{}_{a}$	$53.1 \pm 1.48^{A}{}_{a}$	$52.5 \pm 1.36^{A}{}_{a}$	$52 \pm 1.28^{A}{}_{a}$
3	$53.3 \pm 1.55^{A}{}_{a}$	$52.6 \pm 1.43^{A}{}_{a}$	$52 \pm 1.31^{A}{}_{a}$	$51.8 \pm 1.25^{A}{}_{a}$
6	$52.8 \pm 1.52^{A}{}_{a}$	$51.9 \pm 1.39^{A}{}_{a}$	$51.6 \pm 1.29^{A}{}_{a}$	$51.1 \pm 1.21^{A}{}_{a}$

In each row (small letters) and column (capital letters), means (±SD) supplemented by different letters differed by Duncan's multiple range test at level of 5%.

time of storage. The L^* values of the samples after 6 months of storage was in the order of: control > HWR-50 = HWR-60 = HWR-70. It seems that HWR-70 sample was more effective than other samples reducing the lightness (Table 7). Statistical analysis showed that the effect of storage time was more than the treatment in reducing the lightness of the treated samples.

Table 8 shows the a^* values of Hunter color system of date fruits during storing (0–6 months), after being treated with hot water and different dry temperatures. After 6 months of storage, there was a significant difference between the a^* values of the treated samples with HWR-70 compared to the control and other treatments. The a^* values of date palm decreased as the storage time increased. For all treatments, the a^* value of fruit stored at 25 °C was decreased significantly ($P < 0.05$) as the storage period increased. The reduction of the a^* values shows that the greenness of all samples decreases during storage.

Table 9, which shows the b^* values of the samples, indicates that the treatment and storage time both had significant impacts on the b^* value. During storage the b^* value decreased for all treatments. There were differences between the samples treated with different dry temperatures. After 6 months of storage, the order of the b^* value of the samples was: control > HWR-50 > HWR-60 > HWR-70. Normally, the Stamaran dates bear the color changes during ripening from light yellow at Khalal to darken brown at Tamr stage. The results obtained in this research indicated that the color of date fruits being stored under the influence of chemicals changed much earlier and quicker compared to the control sample. Vandercook et al. (1979) reported that oxidative browning of phenolic compounds and sugar browning are the main factors responsible for darkening at elevated temperatures. Maier and Schiller (1961a,b)reported that the darkening at 49 °C was caused primarily by non-oxidative and non-enzymic reactions. However, they reported both oxidative and non-oxidative deteriorative reactions responsible for date fruit darkening of the Deglet Noor variety at 38 °C.

Date palm stored at 25 °C had a slight decrease with 4.35% reduction from 55.2° to 52.8° in hue angle value (Table 10), which indicates a change from yellow–orange to orange–red and was most pronounced during the first month. Table 10 indicates that the treatment (after 1 month) and storage time (except the control) both had no significant impacts on the hue value. For all treatments, hue angle of fruit stored at 25 °C was not changed significantly ($P > 0.05$) as the storage period increased. Statistical analysis showed that the effect of treatment was greater than the storage time in reducing the hue value of the treated samples. These results are in agreement with those reported by Porat et al., 2000.

Conclusions

The findings of this study indicated that harvesting Stamaran dates at the Tamr stage followed by a short-time rinsing of the fruits in hot water, drying and storing of 6 months at 25 °C is a promising method for maintaining date palm fruit storage quality. As a result, this treatment of date at Tamr stage, involves; precipitating out of tannins, increasing small sugars causing sweetness, texture softening and introducing changes in fruit color and other ripening-associated quality parameters. There is a significant different between the treatments on the quality of date palm fruits. The interaction of hot water and dry temperature treatment and storage duration was affected the weight loss, pH, TSS, moisture content, color, and firmness of the treated date palm fruits significantly ($P < 0.05$). Finally, the HWR-70 was the best treatment to maintain and improve the date palm quality and was better in appearance.

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