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Accelerated Ripening of Kabkab Dates Using Sodium Chloride and Acetic Acid Solutions

A. FARAHNAKY[1], H. ASKARI[1*], M. BAKHTIYARI[1*] AND M. MAJZOOBI[1*]**

[1]Department of Food Science and Technology, College of Agriculture, Shiraz University, Shiraz, I.R. Iran

ABSTRACT-In this research, the accelerated ripening of the Kabkab dates from Khalal to Tamr using NaCl and acetic acid solutions was studied. Fruits at Khalal stage were harvested and washed with distilled water before being treated with ripening inducers: 1. NaCl solutions, 2. acetic acid solutions and 3. Aqueous solution of NaCl (1%) and acetic acid. moisture, pH, colour, brix and textural firmness of the samples were monitored. Results indicated that during ripening the moisture content and colour changed significantly. The major change was observed for firmness where a maximum force for puncture test varied from about 1000 to 50 g force for all samples after 72 hours of incubation at 40 °C. Harvesting at Khalal stage followed by treating the fruits with NaCl and/or acetic acid solutions and an incubation stage at 40 °C showed to be a promising method for accelerated ripening.

Keywords: Accelerated ripening, Acetic acid, Kabkab dates, NaCl,

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 (5).

Kabkab is considered one of the main date cultivars of Iran, particularly in the southern provinces of e.g. Booshehr and Fars. Kabkab date is classified as a soft and invert type (non-sucrose) date due to its sugars and texture (9). Many investigations have studied changes occurring in the chemical composition of different date cultivars during maturation. As dates mature, their texture becomes soft which is associated with progressive changes in the fruit fiber. Mustafa *et al.* (18) reported

* Assistant Professor, Graduate Students and Assistant Professor, respectively
** Corresponding author

that the pectin content of dates increased on a fresh weight basis during maturation. Dates contain tannins which are mostly made of polyphenols. The tannins are responsible for the astringency of dates and tannin content of dates decreases as maturity progresses. There is a relationship between date sweetness and the amount of sugars which increases gradually during maturation (20).

In a study on the composition of commercial date varieties, Zia-ur-Rehman *et al.* (1999) found that flesh portion contained 3.32 % ash, 3.39 % crude fiber, 2.18 % fat, 49.87% soluble solids, 46.23% reducing sugars and 3.88 % pentosans, on a dry weight basis (28). Inayatullah et al. (12) and Abdul jabber et al. (2) reported that fresh dates with 20% moisture contained 60-65% sugars, 2.5% fiber, 2% protein, less than 2% fat and some minerals and pectin substances (12, 2). Date fruit development has been divided into four stages of kimri, Khalal, rutab and Tamr, each stage having its own physicochemical characteristics. In kimri, the fruit is green and inedible which develops into Khalal, rutab and finally Tamr. At Khalal stage the moisture of date fruits starts to decrease while sugar increases. At rutab stage the moisture of the fruit decreases rapidly, sugar increases and texture softens. The fruit at Tamr stage reaches its best consumer acceptability with the lowest moisture level, highest sugar content and a soft and palatable texture. From the kimiri to Tamr stages, moisture, acidity and tannins (the main cause of fruit astringency) decrease having their minimum level at the Tamr stage (4, 7, 10 and 19).

Enzymes play an important role in the conversion processes that take place during formation and maturation of the date fruit. Enzyme activity normally takes place in solution or moist atmospheres, the optimum temperature usually falls between 30 and 40 ˚C, over and below which the activity will decrease. Invertases are used to improve the texture and appearance of sugar wall dates (25). Similarly pectic enzymes and cellulase are employed for the quality improvement of mixed green dates (24), and for upgrading substandard Deglet Noor dates, cellulase is used. A positive correlation between the degree of darkening and increased moisture content, storage temperature and time has been reported and clearly demonstrated in experimental works (21).

Activities of cell wall degrading enzymes, pectinesterase, polygalacturonase and cellulase, were investigated during the ripening of white- and pink-fleshed guava fruit types. Pectinesterase activity increased in both guava types up to the climacteric peak of respiration and subsequently decreased. Activities of polygalacturonase and cellulase increased progressively during the ripening of both guava fruit types with a high correlation between the increase of the activity of the two enzymes and the decline of fruit flesh firmness (3).

Date fruits do not ripen evenly, even in the same bunch, and consequently several harvests are required during the harvest season (early August to late November). In some varieties only 30 to 40% of the total fruit might normally ripen on the tree, the remaining fruit fail to ripen, causing economic loss. Thus, hastening fruit ripening on or even off the tree is a critical process (7).

Natural ripening of Kabkab date fruits on palm trees causes a number of physical changes and problems in the final harvested fruits such as separation of the outer skin from the internal main date flesh (know as blistering), sticking unwanted impurities to the fruits, and increasing its microbial load. These cause technological problems for further processing of this date variety including washing, sorting, packaging, storage and marketing. Despite good acceptability of Kakbab dates in term of taste, texture and sweetness, naturally ripened Kabkab date fruits are not worthy of being processed, packed and marketed by the processors, and most are

consumed locally. Therefore, a large quantity is sold with low prices to be used only for its sugars, such as ethanol manufacturing. Compared to natural ripening, the accelerated or controlled ripening can be considered as a way forward to overcome the above mentioned problems, by shortening the time the fruits are on the palm trees. Controlled ripening also has the potential of modifying the physiological pathway from Khalal to Tamr, which may result in a lower loss of the internal flesh mass during ripening, thus, reducing the chance of separation of the outer skin from the inner flesh. Using adequate processing plans to accelerate the ripening of date fruits can be scheduled and performed in date processing factories by controlling the incoming raw material each day (7, 9 and 22).

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.* (22). They treated Pakistani Dkhaki date fruits individually and/or in 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 combined form, tended to induce ripening by causing changes in the selected quality parameters. The results of the controlled ripening of date fruits was reported to be satisfactory.

Kalra and Jawanda (13) 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% to 2% alone and in combination. They packed the dates in wooden boxes lined with paper and stored at room temperature for 18-24 hours, 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 (13). Shamshiri and Rahemi (23) 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 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 (23).

The main aim of this work was to study accelerated ripening of Kabkab date fruits from Khalal to Tamr stage using dilute solutions of NaCl and acetic acid and compare some of the physicochemical properties of the ripened samples with a control sample.

MATERIALS AND METHODS

Materials

In the current research project date fruits (variety, Kabkab) were collected from a commercial date farm in Booshehr (southern Iran) at the Khalal stage with light yellow colour in August 2007. Healthy and uniform date fruits were selected and transferred to the Department of Food Science and Technology of Shiraz University (southern Iran) to be kept at 4 ˚C before other treatments. The fruits were cleaned and washed using distilled water (at 20 ˚C) before being treated with the following ripening inducer solutions; 1. NaCl solutions at three levels (1, 2, and 3%), 2. acetic acid at four levels (0.5, 1, 1.5 and 2) and 3. a mixture solution of NaCl (1%) and acetic acid (2%) at room temperature (25 ˚C) for a period of 5 min. After the immersion of the fruits in each solution, the samples were allowed to drain for 20

min at room temperature. 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 72 h in an aerated incubator set at 40 ˚C. The samples were collected at 0, 3, 6, 9, 12, 24, 48 and 72 hours of incubation times and further experiments were carried out. All chemicals used in this research were of analytical grade and purchased from Sigma Co. (USA), unless otherwise mentioned.

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

Sample code	Treatment solution
T_0	Water
T_1	1 % NaCl
T_2	2 % NaCl
T_3	3 % NaCl
T_4	0.5 % Acetic acid
T_5	1 % Acetic acid
T_6	1.5 % Acetic acid
T_7	2 % Acetic acid
T_8	1 % NaCl & 2 % Acetic acid

Methods

Moisture content, pH, Brix, Hunter colour parameters (L, a, and b values) and fruit firmness (texture) were monitored at 0, 3, 6, 9, 12, 24, 48 and 72 h of incubation at 40 °C.

Chemical analysis of date samples

Moisture content, pH and total soluble solids (brix) were quantitatively determined according to AOAC methods (1) in triplicate.

Colour measurement of Date samples

The colour of date samples was evaluated using a modified method of Yam *et al.* (27). In a completely closed white cardboard box (dimension 60×60×90 cm) using a digital camera (Sony Cyber-Shot, 8.1 Mega pixel) with an observer angle of 0/45° between the light source and the camera, digital pictures of date samples were taken and transferred to a PC for further processing. The flash option was kept off during photography. The distance between the camera and the bottom of the box was 30 cm. The relative position of the camera and the sample was kept the same for all samples. The pictures taken were saved in the JPEG format and analysed quantitatively using the Adobe Photoshop 8 software (Adobe Systems Incorporated, USA) and colour was determined in the "Lab" mode of the software. The colour measurement tests were performed in triplicate.

Textural analysis

Using a Texture Analyser (Stevens-Lfra, England) the texture of all date samples were evaluated with a cylindrical puncture probe with the diameter of 10 mm at room temperature (about 25 ˚C). To minimise variations, it was tried to use samples with almost similar thickness. The travelling speed of the probe and the puncture distance of all tests were 0.2 mm/s and 2 mm, respectively. Maximum forces (g)

recorded during the punching process were reported as indications of the firmness of the dates texture.

Statistical analysis

The treatments were performed using a completely randomised 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 (developer, 13) program was used for all statistical analysis.

RESULTS AND DISCUSSION

In this research project date fruits of the Kabkab variety at the Khalal stage of ripening were treated with aqueous solutions containing sodium chloride or acetic acid or sodium chloride and acetic acid. The treatments were performed at room temperature by dipping the date fruits in the corresponding solutions for 5 min followed by incubating at 40 °C for up to 72 hours. Totally, nine samples (see Table 1 for the sample codes) were obtained for further physicochemical and textural experiments.

The moisture changes of the samples during incubation at 40 °C are presented in Table 2. The moisture content of the samples at the onset of incubation was about 33% which decreased significantly during the incubation for all samples. After 72 hours of incubation, the moisture reduction for the control was about 11.8%, the moisture loss of the sample treated with 3% NaCl solution was about 9.5 % while this value for the 2% acetic acid sample was about 8.7%. The incubation of date fruits was done in a perforated plastic container to allow the fruits to reach a lower level of moisture during incubation at 40 °C, which is of importance for further storage. The incubation of the fruits in open containers was designed to combine the two stages of incubation and drying, both needed for accelerating ripening of the date fruits at the Khalal stage.

Table 2. The moisture content (wet basis) changes of date fruits during ripening (0 to 72 h) after being treated with different salt solutions, acetic solutions and salt/acid mixture.

	Treatment								
Incubation Time	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
0	$32.99^{f}{}_{A}$	$32.99^{e}{}_{A}$	$32.99^{d}{}_{A}$	$32.99^{g}{}_{A}$	$32.99^{e}{}_{A}$	$32.99^{d}{}_{A}$	$32.99^{de}{}_{A}$	$32.99^{f}{}_{A}$	$32.99^{f}{}_{A}$
3	$32.99^{f}{}_{A}$	$32.99^{e}{}_{A}$	$32.99^{d}{}_{A}$	$32.99^{g}{}_{A}$	$32.99^{e}{}_{A}$	$32.99^{d}{}_{A}$	$32.99^{de}{}_{N.S}$	$32.99^{f}{}_{A}$	$32.99^{ef}{}_{A}$
6	$32.50^{e}{}_{B}$	$32.66^{e}{}_{B}$	$32.73^{d}{}_{B}$	$32.59^{f}{}_{B}$	$32.56^{de}{}_{B}$	$32.62^{cd}{}_{B}$	$32.79^{e}{}_{C}$	$32.59^{f}{}_{B}$	$31.29^{de}{}_{A}$
9	$31.83^{d}{}_{B}$	$32.05^{d}{}_{B}$	$32.22^{d}{}_{B}$	$32.12^{e}{}_{B}$	$32.20^{de}{}_{B}$	$31.98^{cd}{}_{B}$	$32.36^{de}{}_{B}$	$32.00^{e}{}_{B}$	$30.84^{d}{}_{A}$
12	$31.57^{d}{}_{A}$	$31.77^{d}{}_{A}$	$32.05^{d}{}_{A}$	$31.60^{d}{}_{A}$	$31.74^{d}{}_{A}$	$31.18^{c}{}_{A}$	$31.45^{d}{}_{A}$	$31.52^{d}{}_{A}$	$30.40^{d}{}_{A}$
24	$29.39^{c}{}_{A}$	$29.86^{c}{}_{A}$	$30.13^{c}{}_{A}$	29.18^{A}	$30.12^{c}{}_{A}$	$28.40^{b}{}_{A}$	$29.47^{c}{}_{A}$	$29.58^{e}{}_{A}$	$28.17^{c}{}_{A}$
48	$25.20^{b}{}_{B}$	$26.90^{b}{}_{C}$	$25.99^{b}{}_{BC}$	$25.12^{b}{}_{B}$	$26.26^{b}{}_{BC}$	$27.19^{b}{}_{C}$	$26.54^{b}{}_{BC}$	$26.46^{b}{}_{BC}$	$23.28^{b}{}_{A}$
72	$21.22^{a}{}_{B}$	$24.31^{a}{}_{E}$	$22.82^{a}{}_{CD}$	$21.78^{a}{}_{BC}$	$23.00^{a}{}_{CD}$	$23.53^{a}{}_{DE}$	$24.63^{a}{}_{E}$	$22.84^{a}{}_{CD}$	$19.23^{a}{}_{A}$

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

Practically, during incubation, the moisture content of the samples reduced considerably. 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 mixture solution of NaCl and acetic acid (moisture loss of 13.7%). Statistical analysis showed that the effect of incubation time was greater than the treatment solutions in reducing the moisture level of the treated samples.

Ali (1989) studied the effect of NaCl solutions (0.5-1.5%) on the curing of dates and concluded that the fruit undergoing ripening lost its weight through moisture evaporation and spoilage was considerably reduced in the NaCl treated sample during curing. He further observed that a significant increase occurred in reducing sugars, whereas non-reducing sugars decreased during storage in all treated samples (6).

Table 3 shows the Brix of the date samples (T_0 to T_8) treated with solutions of salt, acid or salt-acid mixture. For all treatment solutions (T_0 to T_8), the incubation of dates at 40 °C had significant effects on their Brix. The total soluble solid after 72 hours of incubation at 40 °C increased from 35.5 to 43.6 % for the sample treated with 2% acid solution and to 43.8% for the sample treated with 2% NaCl. The major reasons for the increase of Brix would be the escape of water over incubation time at 40 °C and enzymatic conversion of large polysaccharides into small sugars.

Table 3. Brix of date fruits during ripening (0 to 72 h) after being treated with NaCl solutions, acetic acid solutions or a salt/acid solution

	Treatment								
0	35.50 $^{a}{}_{A}$	35.50 $^{a}{}_{A}$	35.50 $^{a}{}_{A}$	35.50 $^{a}{}_{A}$	35.50 $^{a}{}_{A}$	35.51 $^{a}{}_{A}$	35.51 $^{a}{}_{A}$	35.51 $^{a}{}_{A}$	35.51 $^{a}{}_{A}$
3	36.97 $^{a}{}_{A}$	37.73 $^{b}{}_{BCD}$	36.50 $^{a}{}_{B}$	39.80 $^{b}{}_{E}$	38.73 $^{b}{}_{DE}$	34.50 $^{a}{}_{A}$	44.80 $^{e}{}_{F}$	37.00 $^{b}{}_{BC}$	38.20 $^{b}{}_{CD}$
6	37.80 $^{b}{}_{B}$	38.00 $^{b}{}_{B}$	36.50 $^{a}{}_{A}$	39.50 $^{b}{}_{CD}$	40.80 $^{c}{}_{DE}$	38.90 $^{b}{}_{BC}$	42.80 $^{c}{}_{F}$	39.47 $^{c}{}_{CD}$	41.20 $^{d}{}_{E}$
9	35.47 $^{a}{}_{A}$	38.23 $^{b}{}_{B}$	36.33 $^{a}{}_{A}$	40.65 $^{c}{}_{C}$	40.56 $^{c}{}_{C}$	41.13 $^{c}{}_{C}$	40.80 $^{b}{}_{C}$	39.93 $^{c}{}_{C}$	44.05 $^{f}{}_{D}$
12	42.80 $^{c}{}_{C}$	37.73 $^{b}{}_{A}$	36.53 $^{a}{}_{A}$	41.80 $^{d}{}_{B}$	43.66 $^{d}{}_{C}$	42.75 $^{d}{}_{BC}$	43.60 $^{cd}{}_{C}$	45.40 $^{f}{}_{D}$	46.90 $^{g}{}_{E}$
24	43.50 $^{c}{}_{C}$	37.20 $^{b}{}_{A}$	38.70 $^{b}{}_{B}$	43.40 $^{e}{}_{C}$	45.50 $^{e}{}_{E}$	44.70 $^{d}{}_{DE}$	44.60 $^{de}{}_{D}$	44.70 $^{ef}{}_{DE}$	39.20 $^{c}{}_{B}$
48	43.60 $^{c}{}_{C}$	46.40 $^{c}{}_{DE}$	43.13 $^{c}{}_{AB}$	44.30 $^{f}{}_{C}$	50.70 $^{f}{}_{F}$	45.60 $^{e}{}_{D}$	47.20 $^{f}{}_{E}$	44.30 $^{de}{}_{C}$	42.40 $^{e}{}_{A}$
0	51.10 $^{d}{}_{D}$	46.96 $^{c}{}_{B}$	43.80 $^{c}{}_{A}$	52.00 $^{g}{}_{F}$	49.60 $^{f}{}_{C}$	50.60 $^{f}{}_{D}$	47.66 $^{f}{}_{B}$	43.60 $^{d}{}_{A}$	51.70 $^{h}{}_{EF}$

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

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 ripening (0 to 72 h) after being treated with different salt solutions, acetic acid solutions and salt/acid mixture. It also reveals that during the accelerated ripening process each treatment resulted in a different pH compared to the control sample, e.g. the final pH of the sample treated with the 2% NaCl solution was 5.98 while this value for the date fruits treated with 2% acid was 7.21. Applying a solution containing 1% salt and 2% acetic acid resulted in the greatest pH (8.64) which could be considered as a better medium for microbial growth; hence this treatment may increase the total microbial load of the final product.

Table 4. The pH of date fruits during ripening or incubation (0 to 72 h) at 40 ˚C after being treated with NaCl solutions, acetic acid solutions or salt/acid solution

	Treatment								
Incubation Time	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
0	$6.62^{b}{}_{BC}$	$6.72^{bc}{}_{D}$	$6.67^{b}{}_{C}$	$6.66^{c}{}_{C}$	$6.75^{b}{}_{DE}$	$6.58^{b}{}_{B}$	$6.60^{b}{}_{B}$	$6.78^{a}{}_{E}$	$6.43^{a}{}_{A}$
3	$6.58^{b}{}_{ABC}$	$6.71^{bc}{}_{CD}$	$6.50^{a}{}_{AB}$	$6.42^{b}{}_{A}$	$6.58^{a}{}_{ABC}$	$6.64^{b}{}_{BCD}$	$6.81^{c}{}_{D}$	$6.77^{a}{}_{D}$	$8.74^{b}{}_{E}$
6	$6.73^{bc}{}_{D}$	$6.49^{b}{}_{A}$	$6.54^{a}{}_{AB}$	$6.62^{c}{}_{BC}$	$6.63^{a}{}_{C}$	$6.78^{b}{}_{DE}$	$6.59^{b}{}_{BC}$	$6.84^{a}{}_{E}$	$8.64^{b}{}_{F}$
9	$6.60^{b}{}_{A}$	$6.69^{bc}{}_{AB}$	$7.00^{e}{}_{E}$	$6.77^{d}{}_{BC}$	$6.88^{c}{}_{D}$	$6.73^{b}{}_{B}$	$6.85^{c}{}_{CD}$	$6.87^{a}{}_{CD}$	$8.70^{b}{}_{F}$
12	$6.86^{c}{}_{B}$	$6.91^{cd}{}_{C}$	$6.74^{c}{}_{A}$	$6.94^{e}{}_{C}$	$6.77^{b}{}_{A}$	$7.04^{c}{}_{D}$	$7.09^{d}{}_{E}$	$7.20^{b}{}_{F}$	$8.74^{b}{}_{G}$
24	$6.70^{bc}{}_{A}$	$6.70^{bc}{}_{A}$	$6.73^{c}{}_{A}$	$7.26^{f}{}_{B}$	$7.15^{d}{}_{B}$	$7.37^{d}{}_{B}$	$7.71^{e}{}_{C}$	$7.80^{d}{}_{C}$	$8.73^{b}{}_{D}$
48	$6.70^{bc}{}_{A}$	$7.19^{d}{}_{C}$	$6.87^{d}{}_{B}$	$6.76^{d}{}_{AB}$	$7.10^{d}{}_{C}$	$7.34^{d}{}_{D}$	$7.16^{d}{}_{C}$	$7.40^{c}{}_{D}$	$8.65^{b}{}_{E}$
72	$5.69^{a}{}_{B}$	$5.90^{a}{}_{C}$	$7.28^{f}{}_{E}$	$5.98^{a}{}_{C}$	$7.07^{d}{}_{D}$	$5.05^{a}{}_{A}$	$5.85^{a}{}_{BC}$	$7.21^{b}{}_{DE}$	$8.64^{b}{}_{F}$

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

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 (see Materials and methods for details). Firmness values (maximum force of puncture test) of date fruits during ripening (0 to 72 h) after being treated with different salt or acetic acid solutions or salt/acid mixture are presented in Table 5. As the table shows, during 72 hours of accelerated ripening the firmness (maximum force) of the fruits decreased for all treatments significantly. For example, the firmness of the fruits treated with the 2% NaCl solution changed from 1026 to 48.2 (g force) for the incubation times of 0 and 72 hours, respectively.

Table 5. Firmness (maximum force required for texture test, g_{force}) of date fruits during ripening or incubation (0 to 72 h) at 40 ˚C after being treated with NaCl solutions, acetic acid solutions or a salt/acid solution

	Treatment								
Incubation Time	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
0	$1026.00^{f}{}_{A}$	$1026.00^{d}{}_{A}$	$1026.00^{f}{}_{A}$	$1026.00^{d}{}_{A}$	1026.00^{A}	$1026.00^{f}{}_{A}$	$1026.00^{d}{}_{A}$	$1026.00^{e}{}_{A.}$	$1026.00^{f}{}_{A.}$
3	$941.80^{ef}{}_{C}$	$949.00^{d}{}_{C}$	$938.80^{ef}{}_{C}$	$953.60^{d}{}_{C}$	$1040.40^{d}{}_{C}$	$895.60^{e}{}_{C}$	$399.20^{c}{}_{A}$	$329.40^{d}{}_{A}$	$606.20^{e}{}_{B}$
6	$771.80^{cd}{}_{D}$	$1033.80^{d}{}_{E}$	$944.60^{e}{}_{D}$	$997.20^{d}{}_{E}$	$497.40^{c}{}_{C}$	$363.80^{c}{}_{BC}$	$451.80^{c}{}_{C}$	$299.60^{d}{}_{AB}$	$186.40^{d}{}_{A}$
9	$746.00^{cd}{}_{D}$	$751.40^{c}{}_{D}$	$922.20^{ef}{}_{E}$	$797.60^{c}{}_{DE}$	$345.60^{b}{}_{B}$	$589.60^{d}{}_{C}$	$256.40^{b}{}_{AB}$	$221.40^{c}{}_{A}$	$164.90^{cd}{}_{A}$
12	$640.80^{c}{}_{CD}$	$548.40^{b}{}_{C}$	$697.40^{d}{}_{DE}$	$785.20^{c}{}_{E}$	$319.40^{b}{}_{B}$	$168.40^{b}{}_{A}$	$184.00^{b}{}_{A}$	$136.40^{b}{}_{A}$	$143.40^{c}{}_{A}$
24	$833.80^{de}{}_{C}$	$528.20^{b}{}_{B}$	$533.20^{c}{}_{B}$	$459.20^{b}{}_{B}$	$123.00^{a}{}_{A}$	$87.20^{ab}{}_{A}$	$93.60^{a}{}_{A}$	$60.00^{a}{}_{A}$	$87.40^{b}{}_{A}$
48	$320.00^{b}{}_{D}$	$164.40^{a}{}_{B}$	$257.00^{b}{}_{C}$	$95.40^{a}{}_{A}$	$59.40^{a}{}_{A}$	$56.20^{ab}{}_{A}$	$33.80^{a}{}_{A}$	$51.80^{a}{}_{A}$	$55.80^{a}{}_{A}$
72	$37.80^{a}{}_{A.}$	$62.00^{a}{}_{A}$	$48.20^{a}{}_{A}$	$53.00^{a}{}_{A.}$	$40.40^{a}{}_{A.}$	$36.00^{a}{}_{A}$	$33.60^{a}{}_{A.}$	$37.80^{a}{}_{A}$	$43.80^{a}{}_{A}$

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

There were also significant differences between the treatments up to the incubation time of 48 hours in terms of the maximum force required for the puncture tests. Up to 24 hours of incubation, acetic acid solutions were more effective than NaCl solutions, e.g. the firmness of the 2% acetic acid solution and 3% NaCl solution were 60 and 459.2 (g force), respectively. However, after 72 hours of incubation at 40 °C, the firmness of all treated samples was almost similar. It was also noted that the fruits cured by the treatment solutions were flatter at the surface as compared to naturally ripened date fruits. However, increased firmness was noticed towards the centre of the fruits and the process of ripening initiated from the fruit surface and progressed towards the fruit core. Kalra et al. (14) also reported that salt and acetic acid produced surface ripening of the dates. (14).

The fruit colour plays a key role in the marketing value and quality index. Similarly, colour variation is closely associated with the ripening progress. Nevertheless, different date cultivars exhibit their own colour on ripening. Colour parameters of the surfaces of the nine samples (from nine treatments) are shown in Tables 6-8. Lightness (L value of the Hunter colour system) values of the samples are compared in Table 6. Both incubation time and treatment type had significant effects on the L values. The colour lightness of all samples (control and the treated samples with NaCl and acid solutions) decreased with incubation time.

Table 6. The lightness (L value of Hunter colour system) of date fruits during ripening (0 to 72 h) after being treated with different salt solutions, acetic solutions and a salt/acid mixture

	Treatment								
Incubation Time	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
0	63.33 $^{c}{}_{A}$	63.33 $^{d}{}_{A}$	63.33 $^{d}{}_{A.}$	63.33 $^{c}{}_{A.}$	63.33 $^{e}{}_{A}$	63.33 $^{e}{}_{A.}$	63.33 $^{e}{}_{A}$	63.33 $^{e}{}_{A.}$	63.33 $^{e}{}_{A.}$
3	54.00 $^{b}{}_{B}$	55.00 $^{c}{}_{B}$	54.33 $^{c}{}_{B}$	53.00 $^{b}{}_{B}$	52.67 $^{d}{}_{B}$	53.33 $^{d}{}_{B}$	45.67 $^{c}{}_{A}$	44.00 $^{d}{}_{A}$	44.00 $^{d}{}_{A}$
6	53.50 $^{b}{}_{D}$	51.00 $^{b}{}_{CD}$	54.67 $^{c}{}_{D}$	53.0 $^{b}{}_{D}$	46.00 $^{c}{}_{BC}$	46.00 $^{c}{}_{BC}$	49.67 $^{d}{}_{CD}$	43.00 $^{d}{}_{AB}$	38.67 $^{d}{}_{A}$
9	54.33 $^{b}{}_{E}$	50.00 $^{b}{}_{CD}$	52.67 $^{c}{}_{DE}$	53.33 $^{b}{}_{DE}$	47.00 $^{c}{}_{C}$	40.00 $^{b}{}_{AB}$	41.00 $^{b}{}_{B}$	42.67 $^{d}{}_{B}$	37.25 $^{d}{}_{A}$
12	52.00 $^{b}{}_{E}$	50.67 $^{b}{}_{E}$	53.67 $^{c}{}_{E}$	52.00 $^{b}{}_{E}$	46.67 $^{c}{}_{D}$	39.00 $^{b}{}_{BC}$	40.00 $^{b}{}_{C}$	36.00 $^{c}{}_{B}$	29.67 $^{c}{}_{A}$
24	62.67 $^{c}{}_{F}$	61.00 $^{d}{}_{F}$	52.00 $^{c}{}_{E}$	53.33 $^{b}{}_{E}$	43.00 $^{c}{}_{CD}$	47.00 $^{c}{}_{D}$	42.33 $^{bc}{}_{C}$	30.00 $^{b}{}_{B}$	24.67 $^{bc}{}_{A}$
48	52.33 $^{b}{}_{E}$	34.00 $^{a}{}_{C}$	43.33 $^{b}{}_{D}$	35.33 $^{a}{}_{C}$	35.66 $^{b}{}_{C}$	34.00 $^{b}{}_{C}$	28.00 $^{a}{}_{B}$	26.33 $^{ab}{}_{AB}$	22.00 $^{ab}{}_{A}$
72	40.00 $^{a}{}_{F}$	36.00 $^{a}{}_{EF}$	33.67 $^{a}{}_{DEF}$	34.67 $^{a}{}_{EF}$	26.33 $^{a}{}_{BC}$	27.66 $^{a}{}_{BCD}$	30.33 $^{a}{}_{CDE}$	21.33 $^{a}{}_{AB}$	15.33 $^{a}{}_{A}$

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

NaCl and acid solutions were more effective than water (i.e. control) in decreasing the lightness. The L values of the samples after 72 h of incubation indicate that the lightness of the samples was in the order of: $T_0>T_1>T_3>T_2>T_6>T_5>T_4>T_7>T_8$. It seems that acetic acid solutions were more effective than the salt solutions in reducing the lightness (Fig.1). Table 7 shows the **a** values of Hunter colour system of date fruits during ripening (0 to 72 h), after being treated with different salt solutions or acetic acid solutions and a salt/acid mixture. After 72 hours of incubation, there was a significant

difference between the **a** values of the treated samples with NaCl and acetic acid as compared to the control. The **a** values of T_2 to T_8 samples were lower than the control while T_1 was the same as the control. The order of the **a** value of the samples was: T_0 and T_1>T_2>T_3>T_6>T_4 and T_5>T_7>T_8. The reduction of the **a** values is shows that the greenness of all samples decreases during ripening.

Table 7. Hunter colour parameter of a value of date fruits during ripening (0 to 72 h) after being treated with different salt solutions, acetic solutions and a salt/acid mixture

Incubation Time	Treatment								
	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
0	40.00 ^{a} $_{A.}$	40.00 ^{b} $_{A.}$	40.00 ^{a} $_{A.}$	40.00 ^{a} $_{A}$	40.00 ^{c} $_{A.}$	40.00 ^{bc} $_{A.}$	40.00 ^{b} $_{A.}$	40.00 ^{b} $_{A.}$	40.00 ^{e} $_{A.}$
3	41.00 ^{ab} $_{B}$	43.00 ^{c} $_{B}$	41.00 ^{a} $_{B}$	43.00 ^{a} $_{B}$	42.33 ^{cd} $_{B}$	40.67 ^{bc} $_{B}$	48.67 ^{d} $_{C}$	46.67 ^{c} $_{C}$	32.33 ^{cd} $_{A}$
6	41.50 ^{ab} $_{D}$	29.00 ^{a} $_{A}$	42.33 ^{a} $_{D}$	42.33 ^{a} $_{D}$	31.33 ^{a} $_{AB}$	32.33 ^{a} $_{AB}$	31.33 ^{a} $_{AB}$	36.33 ^{ab} $_{D}$	34.66 ^{d} $_{BC}$
9	42.00 ^{ab} $_{BC}$	44.33 ^{c} $_{CD}$	42.33 ^{a} $_{C}$	42.67 ^{a} $_{C}$	44.33 ^{de} $_{CD}$	40.00 ^{bc} $_{B}$	46.00 ^{cd} $_{D}$	45.67 ^{c} $_{A}$	35.00 ^{d} $_{A}$
12	42.66 ^{abc} $_{B}$	43.33 ^{c} $_{B}$	42.00 ^{a} $_{B}$	43.67 ^{a} $_{B}$	44.00 ^{de} $_{B}$	43.33 ^{cd} $_{B}$	45.00 ^{c} $_{B}$	34.00 ^{a} $_{B}$	34.00 ^{d} $_{A}$
24	40.67 ^{ab} $_{B}$	42.67 ^{c} $_{B}$	41.00 ^{a} $_{B}$	42.00 ^{a} $_{B}$	46.67 ^{e} $_{C}$	47.00 ^{d} $_{C}$	46.67 ^{cd} $_{C}$	40.00 ^{b} $_{B}$	30.00 ^{bc} $_{A}$
48	43.00 ^{bc} $_{C}$	43.50 ^{c} $_{C}$	43.67 ^{a} $_{C}$	44.00 ^{a} $_{C}$	44.67 ^{de} $_{C}$	41.67 ^{abc} $_{BC}$	40.33 ^{b} $_{BC}$	38.00 ^{ab} $_{B}$	27.66 ^{b} $_{A}$
72	45.00 ^{c} $_{D}$	45.00 ^{c} $_{D}$	44.00 ^{a} $_{D}$	42.00 ^{a} $_{D}$	36.67 ^{b} $_{BC}$	36.67 ^{ab} $_{BC}$	41.00 ^{b} $_{CD}$	33.67 ^{a} $_{B}$	19.33 ^{a} $_{A}$

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

Table 8, which shows the **b** values of the samples, indicates that the treatment solution and incubation time both had significant impacts on the **b** value. During incubation the **b** value decreased for all treatments (T_0-T_8). There were differences between the samples treated with different solutions. After 72 h of incubation, the order of the **b** value of the samples was: T_0>T_3>T_1 and T_2>T_6>T_5 > T_4>T_7>T_8.

Normally, the Kabkab dates undergo colour changes during ripening from light yellow at Khalal to golden brown at Rutab stage. The results obtained in this research indicated that the colour of date fruits being ripened 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 (26). Maier and Schiller (1960) reported that the darkening at 49 ˚C was caused primarily by non-oxidative and non-enzymic reactions (15). However, Maier and Schiller (1961, a, b) reported both oxidative and non-oxidative deteriorative reactions responsible for date fruit darkening of the Deglet Noor variety at 38 ˚C (16,17).

Although the ripened date samples were not studied over storage period, no considerable textural or colour changes were observed upon keeping the samples in a cold room (4 ˚C) for up to one month. Study of microbiological attributes and storage

stability of the treated samples seem necessary to determine the shelf life of the samples.

Table 8. The b value of the Hunter colour system of date fruits during ripening (0 to 72 h) after being treated with different salt solutions or acetic solutions and salt/acid mixture

	Treatment								
Incubation Time	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**
0	$69.33^{c}{}_{A.}$	$69.33^{d}{}_{A.}$	$69.33^{d}{}_{A.}$	$69.33^{c}{}_{A.}$	$69.33^{e}{}_{A.}$	$69.33^{e}{}_{A.}$	$69.33^{d}{}_{A.}$	$69.33^{e}{}_{A.}$	$69.33^{e}{}_{A.}$
3	$60.66^{b}{}_{CD}$	$63.67^{c}{}_{D}$	$61.67^{c}{}_{D}$	$61.67^{b}{}_{D}$	$61.33^{d}{}_{D}$	$62.00^{d}{}_{D}$	$57.00^{c}{}_{BC}$	$55.00^{d}{}_{B}$	$50.67^{d}{}_{A}$
6	$61.25^{b}{}_{DE}$	$58.00^{b}{}_{CD}$	$63.00^{c}{}_{E}$	$61.33^{b}{}_{DE}$	$53.67^{c}{}_{BC}$	$54.33^{c}{}_{CD}$	$58.00^{c}{}_{BC}$	$53.00^{d}{}_{B}$	$47.00^{d}{}_{A}$
9	$62.33^{b}{}_{D}$	$59.33^{b}{}_{D}$	$60.67^{c}{}_{D}$	$61.33^{b}{}_{D}$	$56.00^{c}{}_{C}$	$52.67^{c}{}_{B}$	$52.00^{b}{}_{B}$	$54.00^{d}{}_{BC}$	$46.00^{d}{}_{A}$
12	$60.33^{b}{}_{E}$	$60.00^{b}{}_{E}$	$62.33^{c}{}_{E}$	$61.00^{b}{}_{E}$	$56.67^{c}{}_{D}$	$50.67^{c}{}_{C}$	$51.00^{b}{}_{C}$	$46.67^{c}{}_{B}$	$39.00^{c}{}_{A}$
24	$68.00^{c}{}_{E}$	$68.00^{d}{}_{E}$	$61.00^{c}{}_{D}$	$61.67^{b}{}_{D}$	$53.67^{c}{}_{C}$	$56.00^{c}{}_{C}$	$52.67^{b}{}_{C}$	$41.00^{b}{}_{B}$	$32.67^{b}{}_{A}$
48	$61.00^{b}{}_{E}$	$46.00^{a}{}_{C}$	$53.00^{b}{}_{D}$	$47.00^{a}{}_{C}$	$47.33^{b}{}_{C}$	$44.00^{b}{}_{C}$	$38.00^{a}{}_{B}$	$38.33^{b}{}_{B}$	$28.00^{b}{}_{A}$
72	$51.00^{a}{}_{E}$	$44.67^{a}{}_{DE}$	$44.67^{a}{}_{DE}$	$45.67^{a}{}_{DE}$	$35.33^{a}{}_{BC}$	$36.67^{a}{}_{C}$	$40.67^{a}{}_{CD}$	$28.67^{a}{}_{B}$	$18.00^{a}{}_{A}$

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

CONCLUSIONS

Naturally, date fruits go through all stages of their ripening from Kimari, Khalal, Rutab to Tamr on the palm tree (8, 10 and 11). The natural ripening of Kabkab date fruits on its tree has proved to be problematic for further stages of packaging, storage and marketing due to specific processing conditions and low consumer acceptance of this valuable agricultural commodity.

The findings of this study indicated that harvesting Kabkab dates at the Khalal stage followed by a short-time dipping of the fruits in NaCl or acetic acid solutions and an incubation stage of about 48-72 hours at 40 °C is a promising method for controlled ripening of date fruits. This specific procedure accelerates ripening of the date fruits from Khalal to Tamr stages to over three days instead of weeks of natural ripening process on the tree.

The results of this study were in agreement with the findings of Saleem *et al.* (2005) who used dilute solutions of NaCl and acetic acid for the accelerated ripening of Pakistani Dkhaki date fruits (22). Ripening of immature Medjool dates using solar energy in shrink covered pallets has been reported as a practical solution for controlled ripening of Medjool dates by Navarro (20). This method has also been effective in disinfecting the fruits by exposing the fruits to heat of up to 50 ˚C. Awad (2007) reported that postharvest dipping of date fruits (Helali variety) at the *Bisir* stage in ethrel at 4.2 $mL.L^{-1}$ and abscisic acid at 1.0 mM, significantly enhanced ripening, compared to the controls (7). However, ABG-3168 (an ethylene blocker) application at 3.33 $g.l^{-1}$ significantly inhibited ripening, suggesting a role of ethylene in the ripening process. Ethanol vapor significantly hastened the ripening of *Bisir* fruit over 10 days at ambient conditions in desiccators. The response of immature fruit to ethanol vapor was much greater than mature ones. Also, the immersion of

fruit in water for 10 h significantly increased fruit ripening as compared to the controls.

The ripening agents possibly disrupt the epidermal cells and the protoplasms, thereby releasing and activating the enzymes. Ripening by involvement of enzymes like invertase, polygalacturonase, cellulase, pectin esterase and polyphenol oxidases, causes the structural parts e.g. pectin and cellulose that hold cells together, to become soluble, and the tannins to precipitate. As a result, this facilitates the ripening process of fruits from Khalal to Tamr, which involve; precipitating out of tannins, increasing small sugars causing sweetness, texture softening and introducing changes in fruit color and other ripening-associated quality parameters. The extent of modification varies in rate depending on the stage of fruit maturity and the environmental factors responsible for the ripening/curing of the fruits (23).

On the other hand, when date fruits are naturally ripened, large quantities of date fruits are transferred to the processing plants in a relatively short period of time, while the processing capacity is limited. The accelerated ripening reported in this paper can help solve this problem as date fruits at the Khalal stage can be harvested according to a timetable dictated by a processing schedule.

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رساندن مصنوعی خرمای کبکاب با استفاده از محلول های کلرید سدیم و اسید استیک

عسگر فرحناکی[۱]، **حامد عسگری[۱]***، **مریم بختیاری[۱]*** **و مهسا مجذوبی[۱]***

[۱]بخش علوم صنایع غذایی، دانشکده کشاورزی، دانشگاه شیراز، شیراز، جمهوری اسلامی ایران

چکیده–در این پژوهش رساندن مصنوعی خرمای رقم کبکاب از مرحله خلال تا تمر با استفاده از محلول کلرید سدیم و اسید استیک مورد بررسی قرار گرفت. پس از برداشت میوه های خرما در مرحله خلال و انجام عملیات شستشو، میوه ها با محلول های حاوی کلرید سدیم، اسید استیک و یا مخلوط هر دو تیمار شدند و پارامترهای تغییرات رطوبت، pH، پارامترهای رنگ سنجی، بریکس و سفتی بافت نمونه ها اندازه گیری شدند. نتایج نشان داد که در طی رساندن مصنوعی، میزان رطوبت و پارامترهای رنگ سنجی a, L و b کاهش معنی داری داشتند. درمورد کلیه نمونه ها بعد از ۷۲ ساعت گرمخانه گذاری در ۴۰°C نیروی پیشینه لازم برای ارزیابی بافت از حدود ۱۰۰۰ به ۵۰ گرم کاهش یافت که نشان دهنده تغییرات شدید بافت و نرم شدن آن است. ارزیابی کلی نتایج نشان داد که از رساندن مصنوعی میوه خرمای برداشت شده درمرحله خلال با استفاده از محلول کلرید سدیم و اسید استیک و گرمخانه گذاری در ۴۰ °C می تواند به عنوان روش مناسبی برای رساندن خرمای واریته کبکاب استفاده شود.

واژه های کلیدی: اسید استیک، تسریع رساندن، خرمای کبکاب، کلرید سدیم.

*به ترتیب استادیار، دانشجوی کارشناسی ارشد، دانشجوی کارشناسی ارشد و استادیار
**مکاتبه کننده