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Original article

Preharvest and postharvest treatments for increasing the rate of ripening of date palm fruit (*Phoenix dactylifera* L.) cv. Medjool

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Summary. Date palm (*Phoenix dactylifera* L.) is an important subsistence crop for regions having water scarcity problems, however it requires significant amount of heat for ripening of the fruits; and fruits do not ripen on the tree in some climatic regions. This study aimed to hasten the ripening process of date fruits cv. Medjool by some preharvest and postharvest applications. Three doses (500, 750 and 1,000 ppm) of Ethephon, two controls and apple vinegar (4-5% acidity) were used in the preharvest studies with or without bunch bagging (perforated black polyethylene bags). Postharvest experiments were conducted with visually mature firm (Khalal) fruits of the cv. Medjool, and are subjected to i-) dipping into distilled water; ii-) dipping into Ethephon 500 ppm; iii-) dipping into Ethephon 750 ppm; iv-) dipping into apple vinegar (4-5 % acidity); v-) dipping into grape vinegar (4-5 % acidity); and vi-) freezing at -18°C for 3 days. Results showed that bunch bagging enhances fruit ripening on the tree, increase fruits' total soluble solids (TSS) and reduce titratable acidity (TA) at both Tamr and Khalal stages. Preharvest application of 1,000 ppm Ethephon (with bunch bagging) found to have highest ratio of Tamr (37%) and Rutab (46%) fruits where preharvest apple vinegar application had slight effect on the fruit ripening (12% Tamr) as compared with control (8% Tamr). On the other hand, postharvest application of apple vinegar, freezing at -18°C and grape vinegar found to enhance fruit ripening and the percentage of Tamr fruits were determined as 100%, 100% and 92% respectively.

Key words: ethephon, bunch bagging, apple vinegar, grape vinegar, freezing

Introduction

Nearly ¾ of the earth's surface consists of water, however only less than 1% of this amount is available for drinking and irrigation (1). On the other hand, human induced climate change reported to cause impacts on ecosystems, water resources and human nutrition (2). Water scarcity is an emerging problem for the earth (3) and for Cyprus (4). Therefore, to overcome these challenges, it is crucial for considering different types of agricultural adaptation, including crops with high irrigation use efficiency (5). Date palm (*Phoenix dactylifera* L.) is a drought tolerant crop which is known as an important subsistence crop for regions having water scarcity problems (6).

Date palm fruits include certain essential minerals and vitamins; and contain carbohydrates, lipids, proteins and dietary fiber (7). On the other hand, pharmacological studies noted that date palm fruits have high antioxidant capacity (8), anti-diabetic characteristics (9), antiviral activities (10) and anti-inflammatory properties (11). Medjool is a premium variety in the international market where it was reported to have large size fruits and excellent sensory qualities (12,13). The agronomic conditions in Cyprus are ideal for growing date palms including Medjool variety. However, although it is an early-maturing variety, total heat units are not enough in Cyprus for the ripening of Medjool varieties on the tree. Date can be harvested at three different stages: mature firm (Khalal), half ripe (Rutab) and fully ripe (Tamr). At the mature firm (Khalal) stage, the fruits have high amount of soluble tannins and they are astringent. Therefore, removal of tannins is required for making the fruits edible. Dates require cross pollination

and the pollination does not occur at the same time on the different trees, even at the same bunch. Thus, several harvests are necessary (14)

Early maturing date palm trees require at least 1,800 heat summation units (HSU) on the base of 18°C, where most of them need 2,600 HSUs for ripening of the fruits on the tree (15,16). Some agro climatic conditions i.e. Northern Cyprus do not supply the required amount of heat unit for the date palm fruits for ripening on the trees. Only about 10-20% of the total date fruits cv. Medjool is reported by farmers in Northern Cyprus to be ripen on the tree, in which the remaining un-ripe fruits cause important economic loss. Date palm fruits mainly ripen in August to September in Northern Cyprus, and decrease in temperatures occurring after September cause failure in ripening. Researchers reported that bunch bagging, by increasing the accumulation of heat units at the surrounding environment of the date palm fruits, and abscisic acid (1 mM) application hasten ripening in date palm fruits (17). It was also noted that ethephon application (500-1,500 ppm) induces ripening in date palm fruits cv. Zaghloul and cv. Samani (18) and cv. Helali (17). Al-Juburi et al. (19) reported that effectiveness of ethephon sprays differ in different climatic conditions. Therefore, this study aimed to hasten the ripening process of date fruits cv. Medjool by some preharvest and postharvest applications.

Materials and Methods

Preharvest applications

Preharvest studies were conducted at the Research and Application Farm of the European University of Lefke, near Güzelyurt city (35°11'10.23" N, 32°58'22.24" E, altitude 23 m a.s.l.) during the 2018 season. Thirty-six uniform 6-years old cv. Medjool date palm trees were selected for this study. Bunches of the all trees were hand pollinated with the same male flowers of a same tree during March. Preharvest treatments were arranged in a split-plot design with two main factors (no bagging and bunch bagging with perforated black polyethylene bags) and six treatments combined with each main factors. Treatments were as follows: control-1, control-2, Ethephon 500 ppm, Ethephon 750 ppm, Ethephon 1,000 ppm and apple vinegar (4-5% acidity). Each treatment replicated three times (one tree per replication). Bunch bagging (with 48 perforations) and spraying of ethephon was performed 4 weeks after fruits entered into Khalal stage (on 3rd of September 2018). Studies were continued for 35 days and the treatments, except control-2, were finalized on 8th of October (when daily heat summation units decreased to 2 C at the base of 18°C; and rains started). During this period, the Tamr fruit in each bunch of each treatment were periodically counted, collected and weighed. The control-2 treatment was continued until 28th of October, when the heat summation unit (HSU) decreased below zero (at the base of 18°C) and heavy rains started. At the end of the experiments, all fruits were harvested and categorized as mature firm (Khalal), half ripe (Rutab: softening more than 25%) and fully ripe (Tamr). Total 20 Tamr and 20 Khalal fruits per tree (replication) were randomly selected for quality measurements. Fruit weight (g), fruit diameter (mm) and fruit length (mm) were measured independently for each fruit. A homogenous juice sample was prepared from each replication of each treatment for the determination of total soluble solids (TSS) and acidity. Hand refractometer was used to measure the total soluble solids (TSS) as % Brix and titratable acidity (TA: g/100 g of malic acid) was evaluated according to AOAC (20) by titrating juice samples with 0.01 N NaOH until the end-point of pH 8.1.

Postharvest applications

Postharvest experiments were conducted with visually mature firm (Khalal: full yellow colored) fruits of the cv. Medjool, which were collected from a single date palm tree received regular cultural practices (neither bunch bagging nor Ethephon application) at the same orchard. The harvested Khalal fruits were immersed in water and ones which settled at the bottom were referred to as mature fruit; thus the experiments were continued with those fruits (approximately 95% of the fruits settled bottom). Fruits were subjected to six different treatments. The five of the six treatments are as follows: i-) dipping into distilled water under ambient conditions for 30 minutes; ii-) dipping into ethephon 500 ppm under ambient conditions for 3 minutes; iii-) dipping into ethephon 750 ppm under ambient conditions for 3 minutes; iv-) dipping into apple vinegar (4-5 % acidity) under ambient conditions for 30 minutes; and v-) dipping into grape vinegar (4-5 % acidity) under ambient conditions for 30 minutes. The final treatment of the postharvest experiments was keep-

ing the fruits under -18°C for 3 days. Each treatment was replicated three times (12 fruit/replicate). Each fruit was sorted and numbered; and the fruit weight was noted. All the treated fruits were kept under ambient conditions (25 ±1°C and 50-65% relative humidity) for 9 days for ripening. During this period, number of half ripe (Rutab: softening more than 25%) and fully ripe (Tamr) fruits were periodically noted. Fruit weight (g), color, TSS and TA were measured at the end of the experiments, as described above.

Effects of the applications on the fruit color was determined according to the formula of Konica Minolta (21). To measure the CIE L*a*b* colors of the samples, a mini light box (width:22 cm, lenght:30 cm, height:22 cm) was modified from Kim et al. (22) to isolate ambient light effects (Figure 1). One LED light was used to provide light to the mini light box with 5 V supply through a 220 R current limiting resistor. A smartphone (Samsung Galaxy S6) was placed on top of the light box and picture of the samples, both before and after ripening experiment, were captured 22 cm above the samples. The CIE L*a*b* colors of the fruit samples were then read on Photoshop CS6. The L* indicates lightness, a* indicates the red/green coordinate, and b* refers the yellow/blue coordinate. The differences (Deltas: Δ) between the color values (ΔL*, Δa* and Δb*) were calculated according to the following formulas, developed by Konica Minolta (21):

- ΔL* (L* after - L* before) = positive result (+) means "after" is lighter, negative result (-) means "after" is darker
- Δa* (a* after - a* before) = positive result (+) means "after" is redder, negative result (-) means "after" is greener
- Δb* (b* after - b* before) = positive result (+) means "after" is yellower, negative result (-) means "after" is bluer

Afterwards, above results were used in the following formula to calculate total difference (Delta E: ΔE*), which is always positive:

$$\Delta E^* = \sqrt{\{(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2\}}$$

Data analysis

SPSS 20.0 software was used to perform analysis of variance (ANOVA) to analyze the data. Separation of the means of different treatments was then performed by Tukey's (HSD) multiple range test at $P \leq 0.05$.

Results

Preharvest studies

Heat summation units (HSUs) of the growing area during the studies were calculated on the base of 18°C and 10°C separately, and are given in Table 1. Flowering of the date palm trees began during mid-March. According to the climatic data, daily heat units were negative until the 23th of March, which was noted as the first day of flowering for this experiment. The preharvest applications of present study were performed 4 weeks after fruits entered into Khalal stage (on 3rd of September 2018). The total HSUs at the time of preharvest applications on the base of 18°C and 10°C, were calculated as 964 and 2,284, respectively. The experiments were performed with two controls, and one of the controls (control-2) was continued until the daily heat summation unit (HSU) decreased below zero (at the base of 18°C) and heavy rains started. At that time, HSU on the base of 18 and 10°C, were calculated as 1,279 and 3,039, respectively. Both HSUs are below the thresholds reported for cv. Medjool as 1,800 and 3,440 (16,23) and this result supports the findings of present study while ripening ratio of the control treatments were very low on the tree (Figure 2).

Results given in Figure 2. suggest that bunch bagging enhanced fruit ripening in both control and other treatments. It was also observed that bunch bagging increased the ratio of Rutab fruits. The lowest ratio of the Tamr fruits were obtained from control-1 without bunch bagging and followed by control-2 without bunch bagging. No statistical difference was de-

Table 1. Heat summation units of the growing area from flowering till the end of the experiments

Duration	HSU on the base of 18°C	HSU on the base of 10°C
From flowering till the preharvest applications	964	2,284
From flowering till the end of control-1 and experiments	1,209	2,809
From flowering till the end of control-2	1,279	3,039

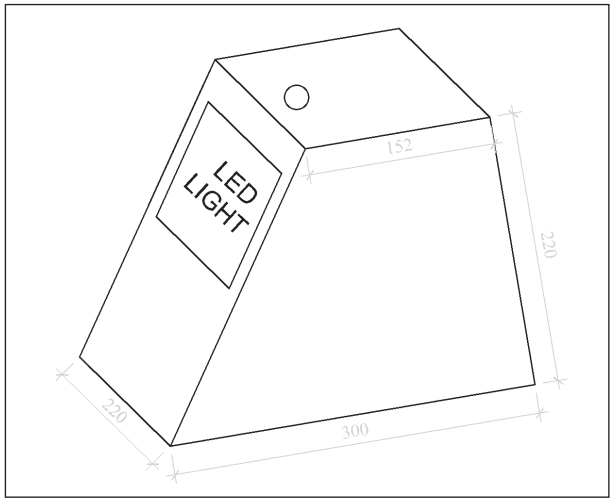

Figure 1: 3D printed drawing of mini light box.

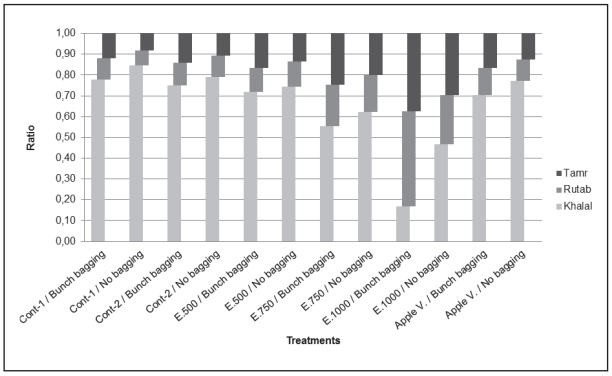

Figure 2: Effects of different preharvest treatments on the ripening of date palm fruits cv. Medjool

termined between these two treatments. The highest ratio of Tamr and Rutab fruits were obtained from the 1,000 ppm Ethephon application with bunch bagging. Other two lower doses of Ethephon (500 ppm and 750 ppm) and apple vinegar were also found to slightly increase the Rutab and Tamr ratio.

Pomological measurements showed that all applications, including bunch bagging, had significant influence on the fruit weight, fruit diameter and fruit length of Tamr and Khalal fruits (Table 2). The highest fruit of weight at Tamr fruits was obtained from 500 ppm Ethephon application without bunch bagging, while the lowest obtained from control-2 with bunch bagging. Significant differences were obtained between the bunch bagging and no bagging for all pomological measurements. Bunch bagging was found to reduce the fruit weight, fruit diameter and fruit length of Tamr fruits, while it was noted to increase these at Khalal fruits. Applications of Ethephon were also found to increase fruit weight, fruit diameter

Table 2. Effects of different preharvest treatments on the fruit weight, fruit diameter and fruit weight of date palm fruits cv. Medjool

Treatments		Fruit weight		Fruit diameter		Fruit length	
		Tamr	**Khalal**	**Tamr**	**Khalal**	**Tamr**	**Khalal**
No bagging	Control-1	11.2 ab	14.3 de	19.5 bc	23.7 d	34.3 a	39.7 bc
	Control-2	10.8 b	14.0 e	19.1 bc	23.1 d	33.5 a	39.3 c
	Ethephon 500 ppm	12.0 a	14.2 e	20.1 b	23.0 d	33.1 a	37.0 d
	Ethephon 750 ppm	11.8 ab	17.1 a	22.9 a	26.3 a	33.6 a	39.3 c
	Ethephon 1,000 ppm	10.8 b	15.5 bc	19.9 b	23.8 cd	34.0 a	43.2 a
	Apple Vinegar	8.6 c	11.0 g	18.9 bc	21.3 e	33.7 a	37.2 d
Bunch bagging	Control-1	7.5 cde	16.2 ab	15.7 e	24.8 b	31.2 bc	43.2 a
	Control-2	7.1 e	15.9 bc	15.3 e	24.4 bc	30.7 c	42.5 a
	Ethephon 500 ppm	7.3 de	16.9 a	17.3 d	24.6 b	32.9 ab	41.0 b
	Ethephon 750 ppm	8.3 cd	17.0 a	20.1 b	26.2 a	34.2 a	39.0 c
	Ethephon 1,000 ppm	7.5 cde	15.2 cd	18.4 cd	23.7 cd	32.6 ab	42.6 a
	Apple Vinegar	7.6 cde	12.8 f	20.2 cd	23.5 cd	33.4 a	36.2 d
No bagging / Average		*10.9* **	*14.4* **	*20.1* **	*23.5* **	*33.7* **	*39.3* **
Bunch bagging / Average		*7.6* **	*15.6* **	*17.8* **	*24.5* **	*32.5* **	*40.8* **

*Values followed by the same letter or letters within the same column are not significantly different at 5% level (Tukey's HSD multiple range test). Comparison of the no bagging and bunch bagging were done with independent samples t-test; and ** used to show significant differences at 99% and ns referred non-significant.*

and fruit length at both Tamr and Khalal stages. As expected, fruit weight, fruit diameter and fruit length were found to decrease from Khalal stage to Tamr stage, which represents the ripening of the fruits.

Treatments rather than bunch bagging found to have no significant effects on the total soluble solids (TSS) and titratable acidity (TA) of fruits (Table 3). Bunch bagging found to increase TSS of fruits at both Tamr and Khalal stages, however to reduce the TA contents of fruits at both Tamr and Khalal stages. Increase in TSS and decrease in TA are the signs of ripening and this result supports the other findings of present study, where bunch bagging found to enhance ripening. On the other hand, clear difference was found for the TSS and TA contents of the fruits between Khalal and Tamr stages. TSS increased from 29.5-31.9% to 65.0-68.7% during ripening and TA decreased from 1.14-1.32% to 0.14-0.23%.

Postharvest studies

Preharvest studies revealed that the date palm fruits cv. Medjool do not ripen on the tree in Northern Cyprus. Furthermore, postharvest studies were conducted to hasten ripening of the fruits. At the time of treatments, all fruits were in the Khalal stage. One day after application, all fruits which were subjected to freezing at -18°C showed ripening and entered into the Rutab stage (Figure 3). Around 15% of the fruits which were subjected to grape vinegar and 10% of the fruits which were subjected to apple vinegar also showed ripening and observed in Rutab stage. No changes observed in control and 500 ppm Ethephon applications, where only 3% of the fruits which were subjected to 750 ppm Ethephon moved into Rutab stage. At the 3rd day after application, all fruits of the freezing treatment found to be fully ripen (Tamr stage). Apart from the freezing treatment, 5% of the fruits of apple vinegar treatment showed full ripening. Ripening hastened 5 days after the applications of apple and grape vinegar and Ethephon applications. However, the effects of vinegars were much higher than the Ethephon applications. 22% of the control fruits also showed slight ripening and moved from Khalal stage to Rutab stage. However, no change observed on the control fruits after that. At the 9th day of applications, all fruits belonging to apple vinegar treatment and 92% of the fruits of grape vinegar treatment were fully ripened. Percentage of fully ripen (Tamr) fruits were found to be 33% and 50% for the applications of 500 ppm and 750 ppm Ethephon, respectively. The Khalal fruits in all treatments, including

Table 3. Effects of different preharvest treatments on the total soluble solids (TSS) content and titratable acidity (TA) of date palm fruits cv. Medjool

Treatments		TSS (% Brix)		TA (g/100g of Malic acid)	
		Tamr	Khalal	Tamr	Khalal
No bagging	Control-1	65.0 b	29.5 b	0.21 ab	1.28 b
	Control-2	65.2 b	29.7 b	0.21 ab	1.27 b
	Ethephon 500 ppm	65.2 b	29.2 b	0.21 ab	1.28 b
	Ethephon 750 ppm	65.3 b	29.5 b	0.22 ab	1.27 b
	Ethephon 1,000 ppm	65.2 b	29.7 b	0.22 ab	1.28 b
	Apple Vinegar	65.5 b	29.8 b	0.23 a	1.32 a
Bunch bagging	Control-1	68.7 a	31.8 a	0.14 cd	1.14 c
	Control-2	68.5 a	31.9 a	0.14 cd	1.15 c
	Ethephon 500 ppm	68.3 a	31.2 a	0.14 cd	1.15 c
	Ethephon 750 ppm	68.3 a	31.3 a	0.14 cd	1.18 c
	Ethephon 1,000 ppm	68.7 a	31.3 a	0.14 cd	1.15 c
	Apple Vinegar	68.5 a	31.5 a	0.16 c	1.18 c
No bagging / Average		*65.2* **	*29.6* **	*0.22* **	*1.28* **
Bunch bagging / Average		*68.5* **	*31.5* **	*0.14* **	*1.16* **

*Values followed by the same letter or letters within the same column are not significantly different at 5% level (Tukey's HSD multiple range test). Comparison of the no bagging and bunch bagging were done with independent samples t-test; and ** used to show significant differences at 99% and ns referred non-significant.*

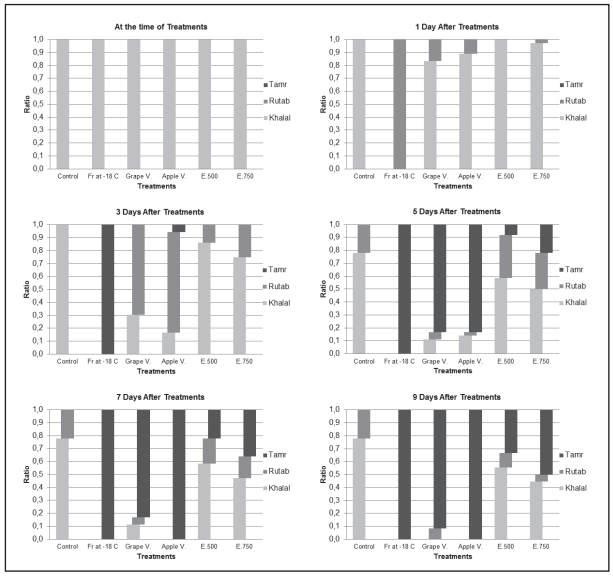

Figure 3: Effects of different postharvest treatments on the ripening of date palm fruits cv. Medjool

control, started to show drying and deterioration at the 9th day after applications.

At the time of postharvest applications to the fruits, all fruits were in Khalal stage and there were no significant differences among the weights of the fruits (Table 4). During the 9 days of storage/ripening, fruit weight in all treatments decreased. It was observed that the fruits treated with grape vinegar decreased more; and had significant difference from the other fruits. When comparing the percent (%) reductions in fruit weight, it was again observed that the highest reduction (26%) was occurred at the fruits treated with grape vinegar. It was followed by the applications of apple vinegar, control, freezing and Ethephon. These data are parallel to the results of ripening, except control treatment. Results suggest that decrease in fruit weight is not always a result of ripening, but might be a cause of deterioration.

Table 5 shows the TSS and TA of the fruits from Khalal and Tamr stages, 9 days after treated with differ-

Table 4. Effects of different postharvest treatments on fruit weight of date palm fruits cv. Medjool

Treatments	First weight	Final weight	Percent (%) Reduction in weight
Control	18.08 a	14.14 ab	21.4% bc
Freezing at -18°C	16.89 a	13.58 ab	19.4% cd
Apple Vinegar	17.58 a	13.61 ab	22.5% b
Grape Vinegar	17.94 a	13.28 b	26.0% a
Ethephon 500 ppm	16.78 a	13.56 ab	19.0% cd
Ethephon 750 ppm	17.81 a	14.44 a	18.3% d

Values followed by the same letter or letters within the same column are not significantly different at 5% level (Tukey's HSD multiple range test).

Table 5. Effects of different preharvest treatments on the total soluble solids (TSS) content and titratable acidity (TA) of date palm fruits cv. Medjool

Treatments	TSS (% Brix)		TA (g/100g of Malic acid)	
	Khalal	Tamr	Khalal	Tamr
Control	35.0 c **	53.5 d **	0.82 a **	0.39 a **
Freezing at -18°C	N/A	60.5 c **	N/A	0.28 b **
Apple Vinegar	N/A	67.3 a **	N/A **	0.25 bc **
Grape Vinegar	48.0 b **	65.5 ab **	0.45 b **	0.26 b **
Ethephon 500 ppm	53.3 a **	65.2 b **	0.38 c **	0.22 d **
Ethephon 750 ppm	53.7 a **	65.3 ab **	0.36 c **	0.23 cd **

*Values followed by the same letter or letters within the same column are not significantly different at 5% level (Tukey's HSD multiple range test). Comparison of the Khalal and Tamr fruits were done with independent samples t-test; and ** used to show significant differences at 99% and ns referred non-significant. N/A means not applicable.*

ent treatments. Results showed that there is a significant difference between the TSS of fruits at Tamr stage. Highest TSS measured from the fruits treated with grape vinegar. This treatment was also found to have the highest ripening ratio. Freezing at -18°C was also one of the best treatments for having highest percentage of fully ripened fruits, but fruits of this treatment had lower TSS than the other treatments. This might be due to the short period of ripening. Results suggest that, even the fruits are in same stage (Khalal or Tamr), the treatments highly influence TSS of the fruits. The TA of the fruits were found to decrease during ripening and significant difference was obtained among the treatments. Highest TA at the Tamr fruits were obtained from control fruits and the lowest from the Ethephon applications. The TA of the fruits treated with grape vinegar and Ethephon at Khalal stage was also found to decrease as compared to control treatments. This shows the biochemical changes in the fruit body which did not turned into pomological changes and did not resulted with ripening.

Postharvest treatments found to have different effects on the fruit color, as in fruit ripening (Figure 4). ΔL* of the fruits treated with different treatments found to have negative results which indicates the darkness. The fruits treated with grape vinegar, apple vinegar and 750 ppm Ethephon found to be darker than the others. These results are parallel to the ripening results. The fruits treated with freezing at -18°C found to be lighter than the fruits treated with apple vinegar. Results suggested that as the fruits ripen, darkness increases. Δa* values of the fruits were found to be positive and Δb* values of the fruits were noted as negative. These results showed that fruits become redder and bluer during ripening. All treatments found to have higher values than

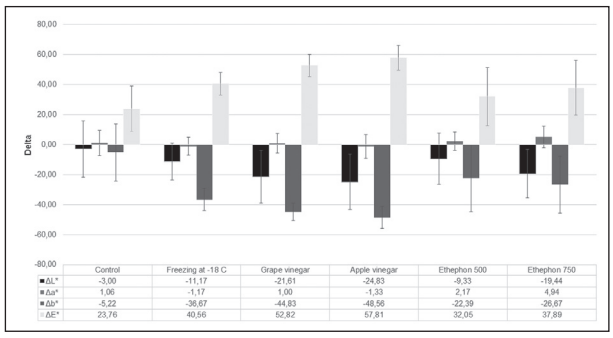

Figure 3: Effects of different postharvest treatments on the ripening of date palm fruits cv. Medjool

the control. Total color difference (ΔE*) was found to be highest at the fruits treated with apple vinegar (57.81) and followed by grape vinegar (52.82). The ΔE* of the control fruits was found to be lowest and measured as 23.76.

Discussions

Preharvest studies

It is well known phenomena that fruit trees require a certain amount of heat energy for growing, developing, flowering and/or ripening of the fruits. The mathematical expression of this energy is referred as heat summation unit (HSU) and is the sum of daily average temperature (°C) minus the base temperature of 18°C. It is calculated with the temperatures from flowering to harvesting. Swingle (15) reported that date palms require at least 1,833 HSUs (above 18°C) for maturation of the fruits. Numerous researchers noted that the HSUs are differing among the different varieties (24,25) and 1,800 HSUs are required to ripen early bearing cultivars and 2,600 HSUs are ideal for ripening many of them (16,26). There are a few studies conducted for the HSU requirements of cv. Medjool, but it is reported to be an early fruit bearing cultivar with around 1,800 HSUs (at the base of 18°C). On the other hand, Mertia and Kumawat (23) reported that cv. Medjool requires about 3,440 HSU for maturation, but the calculations were at the base of 10°C. In present study, two control treatments were tested (with two different time of harvesting) and ripening on the tree was found to be around 10% for both treatments. The HSUs for these treatments (on the base of 18°C) were calculated as 1,209 and 1,279, where both are far below the threshold reported as 1,800. The HSUs (on the base of 10°C) were measured as 2,809 and 3,039 which are also below the thresholds reported as 3,440 by Mertia and Kumawat (23) for cv. Medjool. All of these results supports the findings of present study where the ripening ratio on the tree (without any treatments) had been found to be below 10%.

Results of present study showed that bunch bagging increased the ratio of Tamr and Rutab fruits of cv. Medjool. The highest ratio of Tamr and Rutab fruits were obtained from the 1,000 ppm Ethephon appli-

cation with bunch bagging. Other two lower doses of Ethephon (500 ppm and 750 ppm) and apple vinegar were also found to slightly increase the Rutab and Tamr ratio. Results also showed that during ripening, from Khalal to Tamr, fruits lose weight and volume. The total soluble solids (TSS) and titratable acidity (TA) contents of the fruits also changed during ripening, while TSS increased and TA decreased as suggested by Ahmed et al. (27). Total soluble solid contents of Tamr fruits of present study were found to be similar with the finding of Salomon-Torres et al. (28) who reported 67.5% Brix when pollinated with itself. Muralidhara et al. (29) reported that fruits physiologically firm at Khalal stage and have its maximum weight and size; thus noted that bunch bagging improves ripening of date palms by increasing heat accumulation around the fruits. Fruits starts to soften and lose weight in Rutab stage mainly because of polygalacturonase and betagalactosidase (30). Glasner et al. (31) reported that as fruits soften and ripen, they start to lose tannins and gain sugars which increase TSS. The removal of astringency might be associated with the higher respiration due to heat accumulation; which increase CO_2 concentration around to fruits and lead acetaldehyde production (17). Higher doses of preharvest applied Ethephon was also found to improve ripening of date fruits, as agreed with Awad (17), and Al-Saif et al. (32) and disagree with the findings of Al-Juburi et al. (19). No previous studies noted for the effects of apple vinegar and/or grape vinegar on the ripening of the date palm fruits. However, previously Kader and Hussein (33) reported that acetic acid, which is the primary acid in apple and grape vinegar, is used postharvest to enhance ripening of date fruits.

Postharvest studies

Postharvest tests of present study found to be very effective in ripening of the date palm fruits cv. Medjool. Highest efficacy obtained from freezing at -18°C treatment and apple vinegar application, and followed by grape vinegar and Ethephon applications. Previously Kader and Hussein (33) reported that postharvest applied acetic acid and freezing enhance ripening, but no information was given about the required duration and their influence on the TSS and TA. Present study also showed that the application of grape vinegar significantly influences and increases the TSS. The treatments also found to influence the TSS and TA of the un-ripe Khalal fruits too. Previously Rouhani and Bassiri (34) reported that Ethephon application slightly affects fruit ripening. Awad (17) also noted that postharvest applied Ethephon and abscisic acid significantly enhance fruit ripening of cv. Helali. Matsuo and Ito (35) reported that Ethephon reacts with the tannins and form a non-astringent insoluble gel which promotes ripening. Postharvest treatments found to have different effects on the fruit color, as in fruit ripening. L* and b* values found to decrease and a* values found to increase during ripening. Similarly, Alhamdan et al. (36) reported that freezing enhances fruit ripening, decreases L* and b* values and increases a* values of cv. Barhi dates. Changes in color is closely related with the ripening stage of the fruits. Hazbavi et al. (37) also noted that storage time enhances ripening and reduce the lightness of date palm fruits.

Conclusions

Results of present study showed that heat summation unit (HSU) on the basis of 18°C was 1,279 in Northern Cyprus and is not enough for date palm fruits cv. Medjool to fully ripen on the tree. It was observed that bunch bagging enhances fruit ripening. Bunch bagging was also found to increase TSS of fruits at both Tamr and Khalal stages, however to reduce the TA contents of fruits. Preharvest application of 1,000 ppm Ethephon found to have highest ratio of Tamr and Rutab fruits where preharvest apple vinegar application had slight effect on the fruit ripening. On the other hand, postharvest application of apple vinegar, grape vinegar and freezing at -18°C were found to enhance date fruit ripening. Postharvest Ethephon application was also found to enhance ripening of the date palm fruits but the efficacy found to be less than 50%. It was also found that Tarm fruits are darker (negative ΔL^* values), redder (positive Δa^* values) and bluer (negative Δb^* values) than the Khalal fruits.

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