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Determination of the Optimum Harvest Date for 'Magenta' Charentais Melon (*Cucumis melo* L.) Fruit in Jordan

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ABSTRACT

The aim of this study was to determine the optimum harvest date for Charentais melon (*Cucumis melo* L.) cv. 'Magenta' ensuring export to destination markets in Europe. Fruits were harvested at three stages of development: immature, early ripening and ripe corresponding to 70 (H1), 75 (H2) and 80 (H3) days after sowing the seeds (DAS), respectively. Fruits from each harvest were tested for quality immediately after harvest and after storage periods of 5, 10 or 15 days, which is the expected marketing period, at 7°C. External and internal color, firmness, soluble solids content (SSC), titratable acidity (TA), weight and total aroma were the quality parameters investigated. Date of harvest markedly impacted most of the quality parameters, while storage affected firmness and aroma. H1 fruits had higher firmness, lower SSC, lower total aroma volatiles' concentration and smaller size, whereas H3 fruits showed exactly the opposite and H2 fruits were intermediates. Generally, storage resulted in increased total aroma volatiles, progressive weight loss, decreased firmness, slight effect on color change, but had no effect on SSC and TA. It is concluded that harvesting at 75 DAS (H2) resulted in the best fruit quality that might very well withstand handling, reaching the export markets in an excellent condition, while harvesting at 80 DAS (H3) resulted in fruit quality preferences for immediate consumption at the local market.

Keywords: *Cucumis melo*, Total aroma, Firmness, Color, Quality.

INTRODUCTION

Charentais cantaloupe melons (*Cucumis melo* L. var. *cantalupensis* Naud.) are orange-fleshed fruits with a light green striped skin that becomes creamy when the fruits are ripe. The fruit, distinguished for its fragrance, is characterized by its aroma volatiles as a major quality attribute (Flores *et al*., 2002) and by a faster ripening rate than other cantaloupes. Flavor, which is comprised of aroma and taste (Meilgaard *et al.,* 1991; Shewfelt, 1993) is considered one of the most important quality criteria of fruits and vegetables in influencing consumer preferences. Aroma is a complex mixture of a large number of volatile compounds with a composition specific to species and variety (Sanz *et al*., 1972). It is considered one of the important determinants of fruit quality as perceived by consumers and thus it has been studied in detail (Wyllie and Leach, 1990).

In general, melon fruits differ in behavior during ripening, patterns of sugar and acid accumulation and content and composition of secondary metabolites associated with color, taste and aroma (Perin *et al.,* 2002; Burger *et al.,* 2006). Fruit quality depends mostly

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on harvest maturity. Ripening after harvest can improve the quality of melons, but only if the fruits have attained the proper maturity with a high soluble solids content (SSC) (Chachin and Iwata, 1988).

The most easily observed changes during fruit ripening are those related to color, texture and taste. The internal changes and taste modification of melons are due to changes in aromatic compounds, organic acids and soluble sugars (Seymour *et al.*, 1993).

Determining the optimal harvest time for production of high quality fruits necessitates an understanding of the proper physicochemical parameters associated with consumer preference and acceptance.

Harvest of melons at the proper stage of maturity is crucial to good eating quality (Lester and Shellie, 1992; Artes *et al.,* 1993). The mature stage of the fruits at harvest is of fundamental importance, because sugar content does not increase after this moment. Therefore, if the fruits are not sufficiently mature when harvested, they will not reach an optimum level of quality when ripened and if they are harvested too ripe, their storage potential will decrease. Some melon (*Cucumis melo* L.*)* cultivars show an extremely rapid decrease in flesh firmness during ripening, limiting their transport, storage and shelf life (Nishiyama *et al.,* 2007). Hence, melon fruits from the U.S. and Central America are harvested at different stages of development to adapt to different transit times (Lester and Saftner, 2008).

Although quality parameters such as firmness, SSC, TA, SSC/TA ratio and size tested in the current study were reported elsewhere for other types of melons including cantaloupes, no correlation has been made between all these quality parameters and aroma in Charentais melon.

Hence, the objective of this work was to study the effect of harvest date and storage time on quality criteria, including aroma, of Charentais cv. 'Magenta' melon that would be acceptable by the consumers and withstand handling and shipping stresses as well.

MATERIALS AND METHODS

Plant Materials

Seeds of a commercial hybrid 'Magenta', French type Charentais melon (*Cucumis melo* L.), were sown in September 2008 in open fields at two locations (a commercial farm and the Experimental Farm of the Faculty of Agriculture) in the Jordan Valley. Identical standard cultural practices were followed in both locations. Fruits were harvested at three stages of development: immature, early ripening and ripe [70, 75 and 80 days after sowing the seeds (DAS), respectively]. 48 fruits were harvested from both locations in each harvest, selected for uniformity in size and freedom from defects to obtain homogeneous samples. The samples were immediately transported to the laboratory, pooled and divided randomly into four treatments with three replicates. Twelve fruits were assigned for immediate analysis from each harvest designated as H1, H2 and H3 for the first, second and third harvests, respectively. The remaining fruits were packed in standard cardboard melon shipping cartons and placed in a cold storage room at 7°C and 85% relative humidity for either 5, 10 or 15 days, designated as $H_{1\text{-}5}$ (storage of the first harvest for 5 days) and so on for the other treatments, for the simulation of transportation period under refrigeration.

Quality Measurements

Fruit quality was evaluated immediately after harvest and at the end of each storage period according to the following criteria:

Color: External and internal colors of each fruit were determined using a CR-400 Chroma Meter (Minolta, Osaka, Japan) and expressed in the Axiphos, GmbH 2002 L* a* b* color space (illuminant D55 , 10º view

angle, illumination area diameter 8 mm). Results were expressed as lightness (L^*), chroma ($C^*= [(a^*)^2+ (b^*)^2]^{0.5}$) and hue angle ($h_{ab}=\tan^{-1}[(b^*) (a^*)^{-1}]$. Four readings were taken for each fruit from four sides before cutting the fruit for other four readings for the internal color measurements.

Size: Size was evaluated by the fruit weight immediately after harvest and after each storage period using a Sartorius CP 16001 balance (Frankfurt, Germany).

Weight Loss: It was calculated as the difference between the initial (prior to storage) weight and the final weight (after storage).

Flesh Firmness: It was measured at three equidistant positions on the equator of each fruit using a Penetrometer (Effegi, Milan, Italy) equipped with a 6.5-mm diameter plunger tip after peeling 3x3 cm of the fruit surface and the results were expressed in "Newton".

Soluble Solids Content (SSC): SSC was measured at 20°C using a digital refractometer (Atago, U.S.A.) expressed as percentage. Two longitudinal slices (from stem end to calyx end) were taken, core and peel were removed, the remaining tissue was blended and filtered and three readings were recorded.

Titratable Acidity (TA): It was measured according to AOAC (1990), in which an amount of 10 ml of juice was titrated with 0.1 N NaOH to pH 8.2 with 1% (V/V). Phenolphthalein and the results were recorded as meq/100mL.The results were expressed as citric acid percentage.

Sugar/Acid Ratio: It was calculated as °Brix value /acid percentage.

Aroma Compounds: Two slices from each fruit sample were taken, peeled, chopped into small cubes and blended for 2 minutes. The procedure of Scalzo *et al*. (2001) was followed, in which a 10-g sample of the homogenized melon flesh was placed into a 20-ml vial, closed tightly and frozen at -30°C until used. A gas chromatograph-mass spectrometer (GC-MS; Model QP2010-Shimadzu, Japan) with automatic head space sampler (HT 250- LabHut, Italy) and software (GCM Solution V2.4- Shimadzu, Japan) was used. The GC was equipped with a TRB-WAX column (length = 30 m; diameter = 0.25 mm and film thickness = 0.25 µm), with a purge flow rate of 3.0 ml min^{-1}, a column flow rate of 1.0 ml min^{-1} and a total flow rate of 13.7 ml min^{-1} . The column temperature was programmed as follows: 45°C for 8 min, then 6°C min^{-1} up to 100°C. The split injection ratio was 1:9.7 and the injector port temperature was 200°C. The MS detector interface temperature was 250°C and the ionsource temperature was at 200°C. At the time of analysis, the vials with samples were kept at 80°C for 60 min and then 300 µl of the head-space were injected into the GC. Known concentrations of commercial standards were used to identify and quantify the chromatographic peaks. Total aroma is reported here as mg/100g f.w.

Statistical Analysis

A randomized complete block design (RCBD) with three replicates for fruit sampling, with each fruit being an experimental unit, was followed in this experiment. Analysis of variance (ANOVA) was performed using the Statistical Analysis Systems computer package (SAS Institute, 2004). Treatment means were compared by the Duncan's multiple range test at $P = 0.05$. Similar results with no consistent statistically significant differences were detected between the two locations, so means presented in this paper are combined averages of the two locations.

RESULTS AND DISCUSSION

External Color: Delaying the harvest date caused a decrease in the L* values of H3 fruits at the ripe stage of development picked 80 days after sowing the seeds (DAS) as compared to H1 and H2 fruits at the immature and early

ripening stages picked 70 and 75 DAS, respectively, with significant differences (Table 1). No significant differences were detected among the L* values as a result of storage in all treatments (Table1). Moreover, no significant differences were detected among the values of chroma and hue angle neither as a result of harvest time nor as a result of storage period (Table 1). Nevertheless, a subtle change in the skin color from dark green to yellow-green to creamy was noticed as a result of delaying the harvest time and extending the storage time. Similar changes in the external color of muskmelons stored for 10 days were previously reported (Shellie, 1999).

Internal Color: L* values decreased, while the chroma increased with delaying harvest (Table1). H3 fruits at the ripe stage of development were most affected by such a change with significant differences observed among the obtained values (Table 1). However, no significant differences were detected among the values of H1, H2 and H_3 hue angle (Table 1). Storage time was of no effect in changing the L* values and chroma except in $H_{3\text{-}10}$ and $H_{3\text{-}15}$ fruits of the ripe stage with significant differences (Table 1). Harvest date and storage showed no effect on the hue angle except in $H_{1\text{-}15}$ fruits at the immature stage with significant differences observed (Table 1). The decrease in hue angle might have been as a result of prevailing of the orange color that was mainly due to a high concentration of ß-carotene (Lester and Eischen, 1996; Robertson and Decker-Walters, 1999).

Table 1. External and internal color of Charentais 'Magenta' melons harvested on three different harvest dates (H1, H2 or H3) and stored at 7 °C for either 5, 10 or 15 days.

Treatment	External			Internal		
	L*[y]	c	h	L*	c	h
H_1	64.7ab[z]	2.1bcd	139.0abc	66.9ab	19.5cd	51.5a
$H_{1\text{-}5}$	65.7a	1.4d	154.7ab	66.7abc	18.8d	51.1ab
$H_{1\text{-}10}$	65.6a	1.8cd	112.2bc	65.6abc	18.7d	44.3bc
$H_{1\text{-}15}$	65.2a	1.8cd	147.3abc	67.5a	19.8cd	42.1c
H_2	64.3abc	3.2abc	135.5abc	65.1bc	25.5b	54.8a
$H_{2\text{-}5}$	62.8cd	2.6bcd	126.2bc	64.5bcd	25.9b	51.7ab
$H_{2\text{-}10}$	64.7ab	2.2bcd	96.0c	62.6de	24.1bc	49.8abc
$H_{2\text{-}15}$	65.0a	2.5bcd	84.4a	65.3abc	23.9bc	47.5abc
H_3	62.0d	4.2a	116.9bc	61.5e	30.6a	52.5a
$H_{3\text{-}5}$	63.3bcd	3.5ab	122.6bc	64.5bcd	28.3ab	48.6abc
$H_{3\text{-}10}$	62.9cd	3.3abc	97.6c	64.5cd	26.0b	48.7abc
$H_{3\text{-}15}$	61.77d	3.2abc	96.4c	62.4de	27.6ab	49.2abc

[y] L* = lightness; c = chroma; h = hue.

[z] Means within columns followed by the same letter are not significantly different at p =0.05 according to Duncan's multiple range test.

Firmness: Both harvest time and storage exerted a noticeable effect on firmness loss (Fig. 1). Firmness loss was inversely correlated with the progression of the developmental stage when harvest was delayed and when storage time was extended. Firmness decreased in H2 and H3 fruits as compared to H1 fruits with significant differences shown among the values (Fig. 1). A decline of 3.3 and 3.0 % in firmness values was observed between H1 and H2 fruits and between H2 and H3 fruits, respectively. A 6.2 % decline in firmness loss, however, was recorded between H1 and H3 fruits with more profound effect observed as a function of storage period, where 9.7, 7.4 and 5.3% decline percentages in firmness were noticed between H1 and $H_{1\text{-}15}$, H2 and $H_{2\text{-}15}$ and H3 and $H_{3\text{-}15}$, respectively. Similar reports were previously published indicating that firmness decreased to 50% in honeydew melons stored at 5^{o}C for 8 days (Madrid, 1993); whereas Portela and Cantwell (1998) reported a 28% decrease in firmness in cantaloupe pieces stored at 5 ^{o}C for 12 days. Saftner *et al.* (2006) reported a decrease in firmness between 20-50% in all genotypes tested.

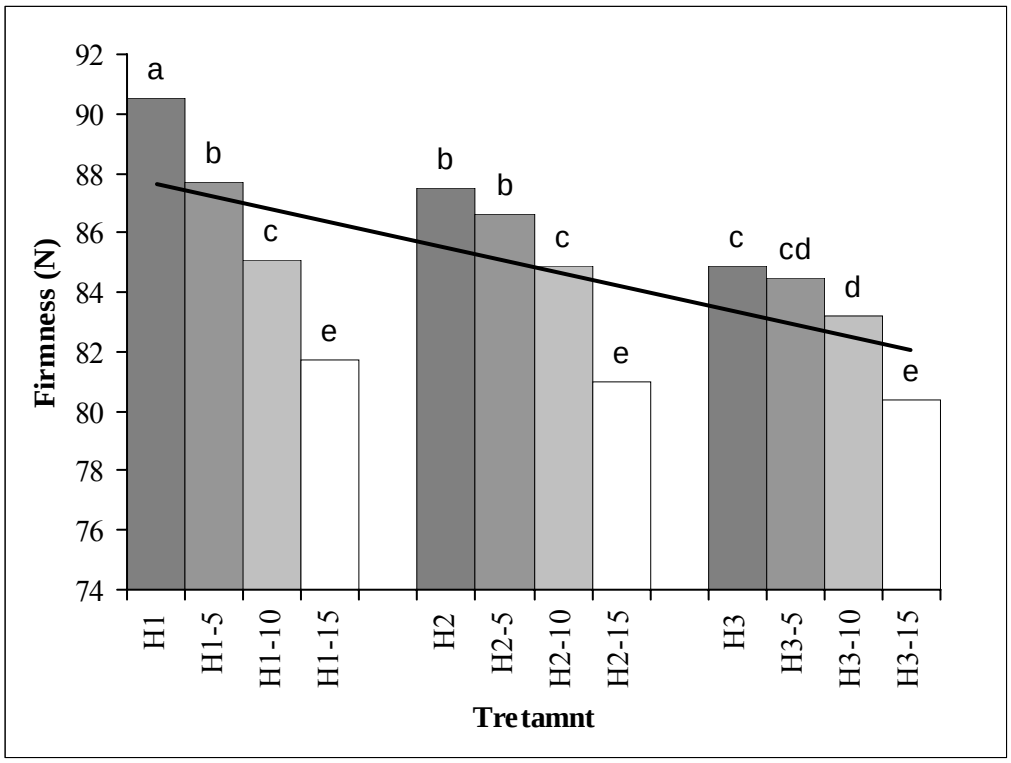

Figure1. Firmness of Charantias 'Magenta' melons harvested on three different harvest dates (H1, H2 or H3) and stored at 7 ^{o}C for either 5, 10 or 15 days. Bars with the same letter are not significantly different at *p* =0.05 according to Duncan's multiple range test.

Size: The size of the fruit, measured by its weight, increased with delaying harvest time (Fig. 2). The average weight of fruits increased 4.4% and 9.1 %, between all treatments of the first (H1) and the second (H2) harvest and between the second (H2) and third (H3) harvests, respectively (Fig. 2). Additionally, a 13.9% increase in weight in fruits of all treatments of the third (H3) harvest as compared to those of the first (H1)

harvest was observed. Significant differences exist mainly between the fruits, collectively, of the first (H1) harvest and those of the third (H3) harvest (Fig. 2). These results are in agreement with a previous work reporting a considerable increase in weight that was noticed during ripening of two cultivars of muskmelons (Villanueva *et al.,* 2004).

Weight Loss: Weight losses in the three storage periods in all harvests were: 1.61, 1.70, 1.79, 1.75, 1.81, 1.83, 0.97, 1.54 and 1.93% for $H_{1\text{-}5}$ to $H_{3\text{-}15}$, respectively. Weight loss ranged between the lowest 0.97 (in $H_{3\text{-}5}$) and the highest 1.93% (in $H_{3\text{-}15}$). The first 5 days in storage resulted in a higher rate of weight loss in all stored fruits for the three harvests. Beyond that, the weight loss rate declined. These results are in agreement with Miccolis and Saltveit (1995), where the fruit weight loss was less than 3% after three weeks of storage at 7 or 12°C, but it was around 4% for melons stored at 15°C. Placing the fruits in a cold storage without prior pre-cooling might have resulted in a higher weight loss (water loss) due to the differences in partial pressure for the first few days. Once the fruit temperature cooled down at or near the storage temperature, the partial pressure difference narrowed and the weight loss rate declined.

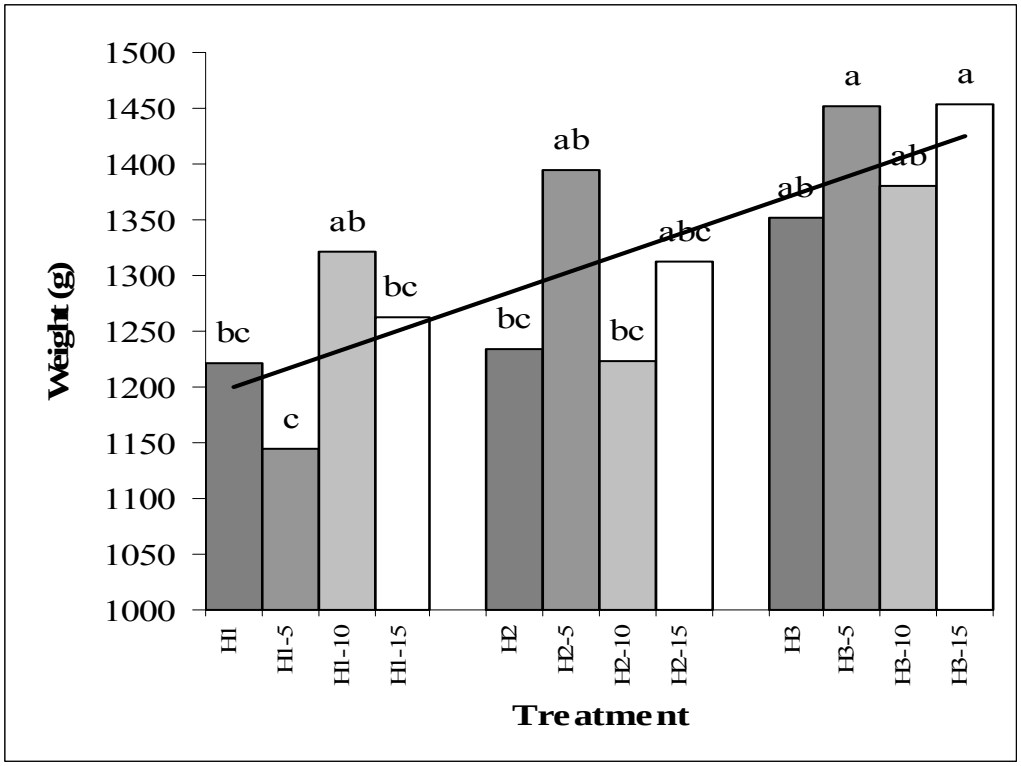

Figure 2. Weight of Charentais 'Magenta' melons harvested on three different harvest dates (H1, H2 or H3) and stored at 7 °C for either 5, 10 or 15 days. Bars with the same letter are not significantly different at *p* =0.05 according to Duncan's multiple range test.

SSC: An increase in the soluble solids content (SSC) of fruits of H2 and H3 with significant differences was recorded as compared to fruits of H1 (Table 2). It has been reported that melons harvested immature (prior to full slip) are generally not as high in SSC as those harvested at full slip (Beaulieu *et al.,* 2004; Robertson and Decker-Walters, 1999). In the current experiment, the increase was a function of harvest time, where a 31.9% and 33.0% increase was observed between H2 and H1, H3 and H1, respectively, whereas an increase of 1% only was recorded between H3 and H2 (Table 2). These figures are much higher than those in a previous work reporting an increase in SSC of 0.3-3.0% in honeydew genotypes between the first harvest and second harvest (Saftner *et al.,* 2006).

Storage for 5, 10 or 15 days resulted in no increase in the SSC. Similarly, Miccolis and Saltveit (1995) found that soluble solids content did not change significantly during three weeks of storage at 7,12 and 15 °C plus three days at 20 °C for six indoor melon cultivars.

In the present experiment, the average SSC increased by 23.0% and 4.5 % between fruits of H1 and H2, and H2 and H3 with their corresponding storage periods, respectively. Moreover, the increase in the average SSC was as high as 28.7% between fruits of H1 and H3 in a matter of 25 days (the difference between the first sampling and the last sampling).

TA: The titratable acidity showed an increase in fruits of H_2 as compared to H1 and H3 with significant differences observed (Table 2). Generally, lower TA values were recorded in fruits at the immature stage of the first (H1) harvest and the corresponding storage periods followed by an increase in the second (H2) harvest and then decreased again in fruits of the third (H3) harvest and its subsequent storage periods. It has been reported that total acidity increased in melons during development, stabilized or decreased at later stages of ripening (Villanueva *et al*., 2004). No significant differences were detected in TA values as a result of storage period in all treatments (Table 2).

SSC/TA: The ratio of SSC/TA followed the pattern of the SSC increase (Table 2). With increasing the SSC, the ratio increased from 57.8% to 62.9% to 72.0% in fruits of H1, H2 and H3, respectively, with significant differences among the values (Table 2). The increase in SSC and decline in TA in fruits at the ripe stage (H3) might be the best combination for consumer acceptance.

Table 2. Soluble solids content (SSC), titratable acidity (TA) and SSC:TA ratio of Charentais 'Magenta' melons harvested on three different harvest dates (H1, H2 or H 3) and stored at 7 ^{o}C for either 5, 10 or 15 days.

Treatment	SSC (%)	TA (%)	SSC/TA (ratio)
H1	7.2b[y]	0.120d	60.0de
H_{1-5}	7.1b	0.125bcd	57.0ef
H_{1-10}	7.2b	0.124cd	58.5def
H_{1-15}	7.4b	0132abcd	55.8f
H2	9.5a	0.148a	64.5c
H_{2-5}	8.9a	0.138abc	63.9c
H_{2-10}	8.6a	0.140abc	61.4cd

Treatment	SSC (%)	TA (%)	SSC/TA (ratio)
$H_{2\text{-}15}$	8.6a	0.141ab	61.6cd
H3	9.6a	0.129bcd	74.9a
$H_{3\text{-}5}$	9.6a	0.136abcd	70.3b
$H_{3\text{-}10}$	9.1a	0.128bcd	70.9b
$H_{3\text{-}15}$	8.9a	0.124cd	71.7b

[y] Means within columns followed by the same letter are not significantly different at p =0.05 according to Duncan's multiple range test.

Total Aroma: In general, an upward trend was observed in total aroma, increasing with harvest delay and storage period (Fig. 3). Total aroma increased by 2.3 and 2.1 folds in H2 and H3 fruits, respectively, as compared to H1 fruits as a function of harvest delay. It has been reported that aromatic volatile concentrations generally increased during melon maturation and ripening (Beaulieu *et al*., 2004). Storage period had a more profound effect on total aroma, where an increase of 2.1, 2.0 and 2.7 folds was recorded in fruits of $H_{1\text{-}15}$, $H_{2\text{-}5}$, $H_{3\text{-}15}$ as compared to H1, H2 and H3, respectively. Although the general trend was an upward one, $H_{2\text{-}15}$ showed a sharp drop in total aroma value as compared to all other treatments, with the exception of H1 (Fig. 3). Senesi *et al*. (2005) showed that the volatile composition can be affected by storage conditions. However, Kemp *et al*. (1973) did not show marked differences in volatile composition in melons kept in cold storage for 2 weeks. Our results coincide with some previous reports showing an increase in the total volatile concentration for the first 2 days in storage, remaining stable or decreasing thereafter, in fresh-cut chunks of melons (Saftner *et al*. 2006). Additionally, aroma of minimally processed honeydew melons decreased during storage at 5 ^{0}C for 12 days (Portela and Cantwell, 1998), while it increased in honeydew pieces stored for 4 days at 15 ^{0}C (Madrid, 1993). In another report, production of aroma volatiles was suppressed at 10 days after storage and then increased toward 15 days of storage (Khanom *et al*., 2003).

The correlation between aroma and other quality parameters in Charentais melons during development or storage has not been sufficiently studied to guide producers to the appropriate time for harvesting. Additionally, some contradiction exists in regard to the reliability of the maturity indices or quality parameters used. Wyllie and Leach (1990) stated that none of the parameters-sugar level, acidity, sugar: acid ratio, color, texture and aroma- tested alone or in combination can be considered reliable. However, Lester and Shellie (1992) reported that SSC is an important quality parameter that cannot stand alone, but in conjunction with flavor.

Harvest of melons at the proper stage of maturity is crucial to good eating quality (Lester and Shellie, 1992; Artes *et al.,* 1993). The mature stage of the fruit at harvest is of fundamental importance, because sugar content does not increase after this moment. Some melon (*Cucumis* melo L.*)* cultivars show an extremely rapid decrease in flesh firmness during ripening, limiting their transport, storage and shelf life (Nishiyama *et al.,* 2007).

In our experiment, an attempt was done to study the most common quality parameters with the aim of making a possible correlation among the different quality parameters tested to find the best combination possible for harvesting at an optimum maturity stage, acceptable to consumers.

The ripening stage of fruits, a function of harvest date, resulted in noticeable differences in most parameters investigated. Fruits at the immature stage (H1) picked 70 DAS were with high flesh firmness values, low total aroma compounds' concentration, low SSC, less developed internal pigmentation and small size. Fruits at early ripening stage (H2) picked 75 DAS were of intermediate firmness values, high total aroma compounds' concentration, high SSC, partially developed internal pigmentation and relatively large size. Fruits at the ripening stage (H3) picked 80 DAS were of low firmness values, high total aroma compounds' concentration, high SSC, well developed internal pigmentation and large size.

It is concluded that the most optimum harvest date for immediate consumption might be H3 fruits at the ripe stage picked 80 DAS, although they will not be tolerable of shipping and handling stresses. However, for distant markets, H2 fruits at the early ripe stage (75 DAS) would be a better choice and can withstand shipping and handling stresses for almost 10 days, while still having an acceptable quality.

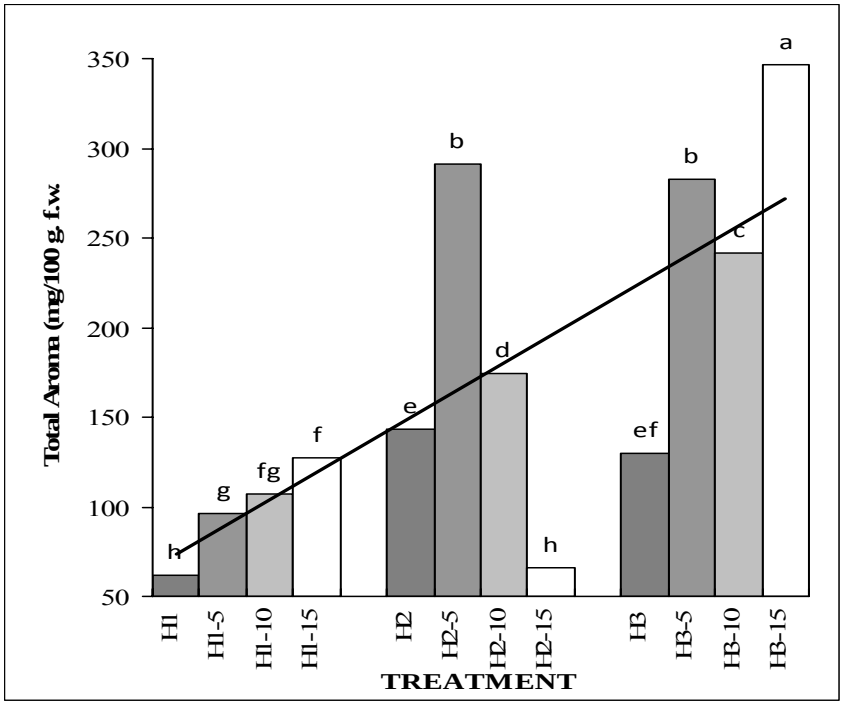

Figure 3. Total aroma of Charentais 'Magenta' melons harvested on three different harvest dates (H1, H2 or H3) and stored at 7 ^{o}C for either 5, 10 or 15 days. Bars with the same letter are not significantly different at *p* =0.05 according to Duncan's multiple range test.

Acknowledgments

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تحديد الموعد المناسب للقطاف لثمار شمام الشارانتيز من صنف "Magenta " في الأردن

نجيب العاصي و نهاد السميرات* و نذير الحديدي**

ملخـص

أجريت هذه الدراسة لتحديد موعد القطاف المناسب لثمار شمام الشارانتيز من صنف "*Magenta*" الذي يمكن المنتجين من التصدير للأسواق التصديرية الخارجية . قطفت الثمار على ثلاث مراحل من النضج تتوافق مع 70 يوماً (*H1*) و 75 يوماً (*H2*) و80 يوماً (*H3*) من تاريخ زراعة البذور (*DAS*). تم فحص الثمار بعد قطفها مباشرة وبعد تخزينها في درجة حرارة 7°س لمدة 5 أيام أو 10 أيام أو 15 يوماً (الفترة الزمنية المحتملة للتسويق). وقد تمت قراءة معايير الجودة التالية: التلون الخارجي والداخلي، الصلابة، نسبة المواد الصلبة الذائبة، الحموضة، الوزن، ومركبات النكهة الكلية. أظهرت النتائج أن لموعد القطف أثراً ملموساً على معظم معايير الجودة، في حين اقتصر الأثر المباشر للتخزين المبرد على الصلابة والنكهة. فقد أظهرت ثمار (*H1*) صلابة عالية وقراءة منخفضة لنسبة المواد الصلبة الذائبة والنكهة وحجماً صغيراً، في حين أظهرت ثمار (*H3*) عكس ذلك تماماً، بينما كانت ثمار (*H2*) في مرحلة متوسطة بينهما. و عموماً، نتج عن التخزين زيادة في مركبات النكهة، وتسارع في فقدان الوزن، وفقدان في الصلابة، وتأثير بسيط على اللون، ولم يؤثر على نسبة المواد الصلبة الذائبة أو الحموضة. ويستدل من ذلك على أن قطف الثمار بعد 75 يوماً (*H2*) سيكون الأنسب لوصول الثمار إلى الأسواق التصديرية بجودة عالية، في حين أن القطف بعد 80 يوماً (*H3*) سيكون مناسباً للاستهلاك المحلي.

الكلمات الدالة: شمام الشارانتيز، صنف ماغنتا، الموعد المناسب للقطاف، مركبات النكهة، الصلابة، اللون، الجودة.

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