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1-MCP AND MELON AFTER HARVEST: OPTIMAL APPLICATION AND THE INFLUENCE ON DIFFERENT CULTIVARS

SUMMARY

The 'Galia'-type melon (*Cucumis melo* L., *reticulatus*) is the most important melon produced in Israel. It is characterized by a fine, uniform and thin reticulated rind, a round shape, and green flesh. The fruit is aromatic, with a delicate taste. However, this type of melon has a relatively short shelf-life due to rapid physiological and pathological deterioration, which cause considerable economic loss. Treating 'Galia'-type melons with 300 nl l⁻¹ 1-MCP (1-methylcyclopropene) results in a delay of ripening during storage, and in an extended maintenance of quality during shelf-life. The effect of temperature and duration of exposure to 1-MCP during storage was evaluated for four netted melon cultivars with different climacteric characteristics. Sea transport and marketing from Israel to Europe was simulated by storing the fruit for 15 days at 5°C + 3 days at 20°C. Weight loss, firmness, sugar content (TSS), decay incidence and chilling injuries were evaluated. Applying 1-MCP at 20°C for 24 h was more effective in inhibiting ripening and preserving overall fruit quality and sensory attributes, than application at 10°C or 5°C for 24 h. 1-MCP was also more effective before fruit waxing. The effectiveness of 1-MCP on melon depends upon the climacteric characteristics of the cultivar. 1-MCP was more effective on melon cultivars with typical climacteric response such as 'Trooper', 'Melika' and Gal-96 than on 'Ori' which had a less pronounced response. We conclude that 1-MCP is most effective if applied at 20°C for 24 h before waxing.

Keywords: 1-MCP, melons, postharvest, shelf life

INTRODUCTION

The 'Galia'-type melon (*Cucumis melo* L., *reticulatus*) is an economically important melon grown in Israel. It is characterized by a fine, uniform and thin reticulated rind, a round shape, and green-ivory flesh (Karchi and Govers, 1977). The fruit is aromatic, with a delicate taste (Fallik *et al.*, 2001). However, this type of melon has a relatively short shelf-life (less than 2 weeks) due to rapid physiological (Aharoni *et al.*, 1992) and pathological deterioration (Fallik *et al.*, 2000), both of which cause considerable economic loss. The inhibitor of the hormone ethylene's ripening actions is 1-methylcyclopropene (1-MCP), a cyclic olefinic compound, which is effective at low concentrations since it remains

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bound to ethylene receptors much longer than ethylene (Sisler and Serek, 1997). It is therefore an important tool in prolonging storage and shelf-life by delaying the physiological deterioration of rapidly ripening fruits such as 'Galia' -type melon. A melon's 'taste' quality can be described by texture, aroma, and flavor attributes, and can be evaluated by a trained sensory panel (Meilgaard *et al.*, 1999). Physical appearance of melons can be described by size, color and shape (Baldwin, 2002; Li *et al.*, 2006b). A previous study found that 'Galia'-type melons responded to 300 nl l⁻¹ 1-MCP treatments by delaying ripening during storage, and maintaining physical appearance during their shelf-life (Gal *et al.*, 2006). Similar results have been reported for many other fruits and vegetables (Blankenship and Dole, 2003). 1-MCP, however, was also reported to inhibit the production of aroma compounds in climacteric fruits, which can impact eating quality (Dong *et al.* 2002; Lurie *et al.*, 2002; Balbontin *et al.*, 2007).

To maintain quality during prolonged storage, 'Galia'-type melon fruit must be waxed with polyethylene-based wax (Aharoni *et al.*, 1992). On the other hand, inappropriate wax material can significantly affect the sensory quality of 'Galia' -type melon by adding a severe 'off-flavor' during a prolonged period of storage and marketing (Fallik *et al.*, 2005).

Little is known about the influence of 1-MCP on the sensory quality of 'Galia'-type melon. Rizzolo *et al.* (2005) and Moya-Leon *et al.* (2006) reported that 1-MCP preserved the fresh flavor of 'Conference' pear after prolonged storage, while the quality of untreated fruit declined. Similar results were reported in apples (Pre-Aymard *et al.*, 2005).

The goal of the present study was to maintain the quality during prolong storage and shelf life of 'Galia'-type melons by 1-MCP treatment. The quality of the fruits was evaluated by objective measurements such as firmness, total sugars, water loss, and by hedonic measurement such as taste and aroma using a taste panel. The 1-MCP treated fruit were compared with 6 untreated and commercially waxed fruit.

MATERIAL AND METHODS

'Galia'-type melon fruit (*C. melo* var. *reticulatus* cv. "Trooper") were harvested at the green/yellow color stage [hue angle (h°) = 102 ± 4], and an initial flesh firmness of 80 N. Uniform fruit, fully netted, weighing approx. 1.2 kg each were harvested by hand from a commercial field in the desert region of Israel.

Treatments Melon fruit were divided at random into three groups, with 24 individual fruits in each group. Fruits of the control group were washed in hot water at 59°C for 20 s while brushing, and dried as described by Fallik *et al.* (2000). Fruit treated according to accepted commercial practice were washed in hot water rinsing and brushing and waxed with 'Zivdar' (water-based polyethylene wax, used commercially on melon, and contains 18% solid matter plus shellac – Safe-Pack Products, Kfar Sava, Israel) as described by Fallik *et al.* (2005). 1-MCP-treated fruit were washed and rinsed in hot water as described

above prior to the 1-MCP treatment, and exposed to 300 nl l⁻¹ 1-MCP for 24 h at 20°C, as described by Gal *et al.* (2006).

Evaluation of fruit quality The percentage of weight loss was calculated from the average weights of ten fruit before and after storage and shelf-life simulation. Fruit quality was also evaluated on the same ten fruit immediately after harvest and prior to 1-MCP treatment ($t = 0$), and after 15 d at 5°C + 3 d at 20°C. The epidermal color of fruit was evaluated using a color index of 1-6 where 1 = very green; 2 = light green; 3 = green with yellow; 4 = yellow with green; 5 = light yellow; 6 = yellow-orange (overripe). The firmness (in N) of ten unpeeled fruit was measured in C-peak mode with a Chatillon penetrometer equipped with a 6-mm conic plunger (John Chatillon & Sons, Inc., New Gardens, NY, USA). Total soluble solids (TSS) contents were measured by removing and squeezing a segment of flesh (from the peel to the seedbed), onto a digital refractometer (Atago, Co. Ltd., Tokyo, Japan). Decay was expressed as the percentage of fruit with fungal mycelia appearing on the peel.

Hedonics The flesh of five fruit from each treatment was cut into cubes (2 cm x 2 cm x 2 cm) and placed on a brown glass plate, 30 min before taste analysis began. Forty employees of the Agricultural Research Organization were asked to assess the overall taste of the treated fruit using a structured scale from 1 to 5, where 1 = very bad and 5 = excellent. 'Off-flavor' was assessed on a structured scale from 0 to 3, where 0 = no "off-flavor", and 3 = very strong "off-flavor" and inedible. Fruit texture was assessed on a structured scale from 1 to 3, where 1 = a very soft and watery texture, and 3 = a very firm and crispy texture. Each member of the panel was also asked to indicate the sample he/she liked most. The sample presentation was randomized. The tasters were 55% women and 45% men with ages ranging from 25 to 60, and 80% of the tasters being over 30 (Pre-Aymard *et al.*, 2005).

Statistical analysis Four experiments were conducted during the August – December 'Galia' -type melon export season. Each treatment consisted of six fruit packed in four export cartons (24 fruit per treatment). Angular transformation (arcsine) was applied before the analysis of the incidence of decay. Internal volatiles and sensory evaluations by both the trained and untrained panels were conducted and analyzed three times.

All data were subjected to one-way statistical analysis at $P = 0.05$ using JMP Statistical Analysis Software Programme (SAS Institute Inc., Cary, NC, USA) and the mean values for all data are presented.

RESULTS AND DISCUSSION

Quality evaluation At harvest, fruit had a color index of 3.5/6, were firm (80 N) and had a TSS of 11.2%. After 15 days in storage at 5°C, and an additional 3 days at 20°C, fruit from the 1-MCP treatments were light-yellow to greenish (5.3–4.6) compared with the yellow control fruit 5.6. Control fruit lost significantly more weight (7.8%) than fruit treated with 1-MCP (Table I). The 1-MCP treated fruit were significantly firmer (49-71 N) than the control fruit (45

N). In general, TSS contents declined during prolonged storage and shelf-life but no significant differences were observed with TSS among the treatments (data not shown).

Table I. The influence of 1-MCP¹ applied at 3 different temperatures on 'Trooper' melon (means of 3 experiments, each treatment consist of 4 cartons).

Treatment	Color ² (1-6)	Weight loss (%)	Firmness (N)	CI (%)	Decay (%)
Immediately after harvest	3.5	-	80	0	0
After 15 d at 5°C + 3 d at 20°C					
Control	5.6 a ³	7.8 a	45 d	3.5 a	5.2 a
1-MCP/5°C	5.3 ab	7.1 b	49 c	1.5 b	3.4 b
1-MCP/10°C	5.0 b	6.6 c	55 b	1.0 c	1.9 c
1-MCP/20°C	4.6 c	5.8 d	71 a	0.8 c	1.1 d

¹300 nl L⁻¹ applied for 24 h at 20, 10 and 5°C, ²Color: 1 = very green; 2 = light green; 3 = green with yellow; 4 = yellow with green; 5 = light yellow; 6 = yellow-orange (overripe).

³Values followed by the same letter do not significantly differ according to the Duncan's multiple range test, (p=0.05).

Table II. The influence of 1-MCP¹ on waxed and non-waxed 'Trooper' melon (means of 3 experiments, each treatment consist of 4 cartons).

Treatment	Color (1-6) ¹	Weight loss (%)	Firmness (N)	CI (%)	Decay (%)
Immediately after harvest	3.5	-	75	0	0
After 15 d at 5°C + 3 d at 20°C					
Control, no 1-MCP no waxing.	5.8 a	7.2 a	44 d	4.5 a	4 a
1-MCP, no waxing	4.8 c	5.8 cd	57 b	0.4 d	0.7 b
1-MCP before waxing	4.6 c	5.6 d	70 a	0.2 d	0.2 b
1-MCP after waxing	5.2 b	6.1 c	50 c	1.6 c	3 a
No 1-MCP, waxing	5.4 b	6.6 b	48 cd	2.1 b	4 a

¹300 nl L⁻¹ applied for 24 h at 20°C, ²Color: 1 = very green; 2 = light green; 3 = green with yellow; 4 = yellow with green; 5 = light yellow; 6 = yellow-orange (overripe).

³Values followed by the same letter do not significantly differ according to the Duncan's multiple range test, (p=0.05).

Exposing melon fruit to 1-MCP for 24 h inhibited the development of chilling injury (i.e., brown spots) and decay incidence in comparison with non-

treated fruit. The application of 1-MCP at 20°C was the most effective in reducing chilling injury as well as the incidence of decay (Table I).

Fruit treated according to accepted commercial practice are waxed with 'Zivdar', table II shows the response of waxed melon fruit to 1-MCP applied before or after waxing. The commercial waxing treatment reduced weight loss and chilling injury but didn't affect firmness and decay incidence after storage (Table II). The effect of 1-MCP on non waxed melon fruit was similar in this experiment to the experiment described in table I, the 1-MCP treatment inhibited weight loss and color development, decreased chilling injury and decay incidence and remained firmer after 15 days cold storage + 3 days shelf life.

The maximal effect of 1-MCP was when applied before waxing (Table II).

Hedonics Immediately after harvest, fruit were tasty with no "off-flavors" with firm flesh (Table III). After 15 d at 5°C, plus 3 d at 20°C, the tasting panel preferred the

1-MCP-treated fruit (43%), and the untreated non-waxed control fruit were scored favorably (Table III). Commercially-waxed fruit received the lowest score, mainly due to significant 'off-flavor'. The tasting panel gave the lowest score for 'off-flavor' (very little) to the 1-MCP-treated fruit in comparison with the other two treatments. Control fruit were perceived to have a soft texture, while washed and waxed fruit, and 1-MCP-treated fruit were perceived to have a firm texture (Table III).

Table III. The influence of 1-MCP treatment on the Hedonic rating of 'Trooper' melons.

Treatment	Taste ¹ (1-5)	Off-Flavor ² (0-3)	Sweetness (0-4)	Texture (1-3)
Immediately after harvest	4.2	0	3.5	3
After 15 d at 5°C + 3 d at 20°C				
Commercial treatment(Waxed)	3.0 b ³	1.8 a	2.5 b	2.1 ab
Washed	3.5 a	1.0 b	2.9 a	1.8 b
Washed + 1-MCP	3.4 a	0.4 c	2.6 b	2.5 a

¹Taste: 1 = very bad taste associated with severe 'off-flavor' and/or very soft flesh;

5 = excellent taste, very sweet, firm flesh and no 'off-flavor'.

² 'Off-flavor': 0 = no 'off-flavor'; 2 = moderate; 3 = very high 'off-flavor' (acetone/ethanol-like odor).

³Values followed by the same letter do not significantly differ according to the Duncan's multiple range test, (p=0.05).

The response of different cultivars Treatment with 1-MCP affected all the four cultivars that were tested (Table IV). The treatment reduced weight loss, maintained firmness, decreased chilling injury and decay incidence. Color development was inhibited significantly in 'Trooper', Gal-96 and 'Malika' fruit but not in the 'Ori'. In general, the 1-MCP treatment had a weaker effect on the cultivar 'Ori' than the other three cultivars. The 'Ori' untreated fruits were firmer

and less sensitive to chilling and decay than the 'Trooper', Gal-96 and the 'Malika'.

Table IV. The effect of 1-MCP applied immediately after harvest on different melon cultivars. Fruit were evaluated after 15 d at 5°C plus an additional 3 d at 20°C. The fruits were harvested according to color at the stage of 3.5 (green-yellow), and measured firmness of 70-80 N for the 'Trooper' 'Gal-96' and 'Malika' and 110 N for the 'Ori'.

Cultivar / Treatment	Color (1-6) ¹	Weight loss (%)	Firmness (N)	CI (%)	Decay (%)
'Trooper' / Control	5.2 Ab ¹	7.8 Ab	45 Bc	3.5 Aa	5.0 Ab
'Trooper' / 1-MCP	4.2 Bb	5.8 Bb	71 Ab	0.8 Bb	1.2 Bb
Gal-96 / Control	4.8 Ac	7.8 Ab	56 Bb	3.2 Aa	5.0 Ab
Gal-96 / 1-MCP	4.3 Bb	6.2 Ba	71 Ab	0.7 Bb	1.0 Bb
'Malika' / Control	5.8 Aa	8.7 Aa	33 Bd	3.5 Aa	5.7 Aa
'Malika' / 1-MCP	5.0 Ba	6.1 Ba	44 Ac	0.5 Bb	1.0 Bb
Ori / Control	5.2 Ab	6.8 Ac	83 Ba	2.0 Ab	3.3 Ac
Ori / 1-MCP	5.0 Aa	6.1 Ba	90 Aa	1.4 Ba	2.0 Ba

¹Values followed by the same **upper-case** letter do not significantly differ between the treatments, values followed by the same **lower-case** letter, do not significantly differ between cultivars according to the Duncan's multiple range test, (p=0.05).

Melon is a popular fruit that nutritionally provides a source of pro-vitamins A (β -carotene) C, and E and folic acid. Melon fruit quality traits are, a combination of many biochemical and developmental processes, and can result in either favorable or unfavorable changes in color, texture, flavor, aroma, or other aspects of the fruit. The organoleptic quality of 'Galia'-type melon fruit is mainly attributed to its aroma volatiles, sugar and acid content and texture characteristics (Hoberg *et al.*, 2003; Lester, 2006).

Storage and shelf-life of 'Galia'-type melon are limited, since a long storage period leads to a decrease in flavor and firmness, in addition to a moldy smell and 'off-flavor' (Hoberg *et al.*, 2003; Fallik *et al.*, 2005). The beneficial effects of 1-MCP, which inhibits ripening processes while reducing physiological and pathological disorders on fruits, and vegetables, have been previously reported (Blankenship and Dole, 2003). Exposing green/yellow 'Galia'-type melons to 300 nl l⁻¹ 1-MCP significantly inhibited ripening processes during prolonged storage, while maintaining fruit quality at the end of shelf-life (Gal *et al.*, 2006).

The untrained tasting panel preferred fruit treated with 1-MCP over untreated fruit (the control). The treated fruit were given higher ratings on positive qualities such as sweet, fruity, aroma balance, and lower on the negative

quality acetone taste. Treatment with 1-MCP may contribute to a better balance in overall flavor in comparison to the commercially-treated and untreated fruit. Some classes of esters are very important in determining the desired sensory flavor, and overall quality of muskmelon fruit (Senesi *et al.*, 2005). It was also reported that ethanol, ethyl acetate, and ethyl hexanoate, which are associated with perceptions of "off- flavor" and over-ripening, are found in higher levels in commercially-treated fruit. Treating 'Galia'-type melons with 1-MCP reduced "off-flavor" caused by undesirable volatiles. Fan and Mattheis (1999) found that 1-MCP inhibited most of the alcohol and ester formation in 'Fuji' and 'Gala' apples and improved the overall sensory rating of the treated fruit. Similar results were observed with 'Anna' apples (Lurie *et al.*, 2002).

Flesh of 1-MCP-treated fruit was significantly firmer than that of untreated control fruit. This can play a crucial role in overall consumer preference, because there are indications that firm texture can mask reduced flavor (Varela *et al.*, 2005).

Among the 'Galia' -type melon cultivars that were tested, the 'Ori' seems to be least responsive to 1-MCP. The 'Ori' was comparatively firmer than other cultivars at harvest and remained relatively firm even after storage. The response to 1-MCP seems to be related to ethylene sensitivity, the 'Galia' -type melons are climacteric fruit that affected by ethylene, which plays a role in the process of ripening and aging. The 1-MCP inhibits ripening response by binding to the receptors of ethylene and inherently interfering with the activity of this hormone (Sisler and Serek, 1997).

The 'Ori' hybrid displays traits of the 'Galia' -type and the 'Solar' -type melons. The 'Solar' -type melons are less aromatic and do not have the typical climacteric response during ripening and ethylene is less involved in their ripening process thus 1-MCP is less effective.

CONCLUSIONS

The sensory quality (odor, taste, and mouth sensation) of green/yellow 'Galia'-type melon that had been treated with 1-MCP could be sustained for about 3 weeks, which is more than twice as long as the average storage life of 'Galia'-type melons in current commercial practice. The extended time-span would permit sea transport of high quality melons to distant markets, thus reducing costs of expensive air transport, and consequently benefit farmers economically.

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1-MCP I DINJA NAKON BERBE: OPTIMALNA PRIMJENA I UTICAJ NA RAZLIČITE SORTE

SAŽETAK

Sorta dinje 'Galia' (*Cucumis melo* L., *reticulatus*) je najvažnija sorta dinje koja se proizvodi u Izraelu. Odlikuje se finom, ujednačenom i tankom korom, dekorativnim okruglim oblikom i zelenim mesom. Plod je aromatičan, izuzetnog ukusa. Međutim, ova vrsta dinje ima relativno kratak rok trajanja nakon branja, zbog naglih fizioloških i patoloških promjena, što prouzrokuje znatne ekonomske gubitke. Tretiranje sorte dinje 'Galia' sa 300 nl 1-1 1-MCP (1-metilciklopropan) dovodi do odlaganja zrenja tokom skladištenja i produžava održavanje kvaliteta. Izračunat je uticaj temperature i trajanje izloženosti 1-MCP tokom skladištenja kod četiri sorte dinja sa različitim klimakterijskim karakteristikama. Pomorski transport i plasman robe iz Izraela u Evropu je simuliran čuvanjem voća 15 dana, na temperaturi od 5°C i 3 dana na temperaturi od 20°C. Izračunat je gubitak težine, čvrstina, sadržaj šećera (TSS), kvarenje i oštećenja hladnoćom. Primjena 1-MCP na 20°C tokom 24 sata je bila mnogo efikasnija za inhibiciju zrenja i očuvanje opšteg kvaliteta plodova i senzorne attribute, nego pri primjeni na 10°C ili 5°C tokom 24 sata. 1-MCP je takođe bio efikasniji prije nastanka voštane prevlake na voću. Efikasnost uticaja 1-MCP na dinje zavisi od klimakterijskih karakteristika sorte. 1-MCP je efikasniji na sorte sa tipičnim klimakterijskim reakcijama, kao što su "Trooper", "Melika" i Gal-96 nego na "Ori" koja je slabije reagovala. Zaključujemo da je 1-MCP najefikasniji ako se primjeni na 20°C tokom 24 sata prije nastanka voštane opne.

Ključne riječi: 1-MCP, dinje, obrada nakon berbe, rok trajanja