EFFECT OF 1-MCP, ETHYLENE ABSORBER AND OZONE ON MELON QUALITY DURING STORAGE

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This work was aimed to investigate the effect of 1-methylcyclopropene (1-MCP), ethylene absorber (EA), ozone alone or in combination on ethylene production, respiration rates, acoustic firmness, surface color, chlorophyll fluorescence parameters, and disease severity of melon. Melons treated with 1-MCP at 5 °C were stored with sachets of Ethyl Stopper containing $KMnO_4$ (Bioconservacion S.A., Spain) or ozone at 0.1 ppm/h during 10 days at 5 °C and subsequent 4 days of shelf-life at 20 °C. Samples treated with 1-MCP were firmer than the rest of the samples during storage. In addition, 1-MCP could slow the postharvest yellowing of melon rind compared to other treatments. The combination of 1-MCP and EA did not offer any additional effect in comparison with 1-MCP alone. Ozone treatment during cold storage decreased disease severity, however, fruits exposed to ozone had more serious decay throughout shelf-life, probably due to the poor quality of air in the chamber. Thus, the utilization of ozone in postharvest management and market environment should be considered for potential benefit.

Keywords: 1-MCP, ethylene absorber, ozone, melon, storage

Introduction

Cantaloupe is a delicious dessert fruit with its crispy, juicy texture, flavor and high nutritional value. Nonetheless, this fruit is perishable. In order to extend postharvest life of melon, the two main problems such as rapid postharvest ripening and microbial quality should be considered together (AHARONI et al., 1993; UKUKU, 2006).

The aim of this study was to evaluate the effectiveness of 1-MCP, ethylene absorber (EA), and ozone alone or in combination on melon during cold storage and shelf-life.

Materials and Methods

Materials

Fresh samples of 'Donatello' melons (*Cucumis melo.* var. *reticulates* L Naud. 'Donatello') were harvested while at ½ - ¾ slip stage from an experienced grower in July 2015, Hungary. Fruits were transported to the University in Budapest, Hungary.

1-MCP (0.14 % 1-MCP tablet, SmartFresh®, AgroFresh, Philadelphia, USA) as an application of SmartFresh® system was provided by Rohm and Haas Polska Sp.z.o.o.

Sachets of Ethyl Stopper containing $KMnO_4$ were provided by Bioconservacion S.A., Spain.

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Ozone at concentration 0.1ppm/h was generated by an ozone generator (Neo. Tec XJ-100, China).

Methods

Experimental design

Fruits were selected for uniformity of size, and free from external damage. Donatello melons were divided randomly into 6 groups. Each group contained 15 fruits. Melons were cooled down to 5 °C before treatment. Three groups were treated with gaseous 1-MCP in an air-tight plastic box at 5 °C on the 1st day after harvest for 24 h. During 24-h long treatment, three non 1-MCP treated groups were still stored at 5 °C, RH 90-95 %. After 1-MCP application, samples of 6 groups were put in three different storage conditions (Table 1).

Table 1. Storage and shelf-life condition

<table>
<tr><th colspan="2">Storage condition</th><th>Samples</th></tr>
<tr><td rowspan="3">Cold storage at 5 °C for 10 days</td><td>Ozone 0.1ppm/h</td><td>1-MCP treated group
Non 1-MCP treated group</td></tr>
<tr><td>Ethyl Stopper (EA)</td><td>1-MCP treated group
Non 1-MCP treated group</td></tr>
<tr><td>Only cold storage at 5 °C</td><td>1-MCP treated group
Non 1-MCP treated group</td></tr>
<tr><td>Shelf-life for 4 days</td><td>at 20 °C</td><td>6 groups</td></tr>
</table>

Measurements

The disease severity and chilling injury were assessed initially before storage (day 0), and at the 4th, 8th, 10th, and 14th day.

The ethylene and CO_2 production, acoustic firmness, surface color and chlorophyll fluorescence parameters were measured before storage (day 0) and at the 10th and 14th day.

Acoustic firmness. Acoustic firmness (Stiffness, $Hz^2 \cdot g^{2/3}$) of samples was determined at two opposite sides on the exterior circumference of each fruit, using an AWETA table top acoustic firmness sensor model DTF V0.0.0.105 (AWETA, Nootdorp, The Netherlands).

Ethylene production. Ethylene production was determined by an ICA-56 hand-held ethylene analyzer (International Controlled Atmosphere Ltd., UK) upon the measured ethylene production of the samples being held for a given time (about an hour) in a hermetically closed plastic container. Results were expressed in microliter of ethylene produced per kilogram of fruit in 1 h ($\mu l \cdot kg^{-1} \cdot h^{-1}$).

Respiration rate. Respiratory intensity as carbon dioxide production was measured for an hour in a closed respiratory system equipped with FY A600-CO2H carbon dioxide sensors connected to an Almemo 3290-8 data logger (Ahlborn Mess-und Regelungstechnik GmbH, Germany). Results were expressed in milliliter of CO_2 produced per kilogram of fruit in 1 h ($ml \cdot kg^{-1} \cdot h^{-1}$).

Surface color. Melon peel color was measured with a portable Minolta Chroma Meter CR-400 (Minolta Corporation, Osaka, Japan). CIE L*, a* and b* color characteristics were determined at three equidistant points on the external circumference of each fruit. Hue angle (H^o) value was calculated as arctangent (b/a).

Chilling injury (CI). CI symptom was determined as brownish pitting and water-soaked areas on melon rind surface and evaluated by the scale of 1-5, where: (1) no CI; (2) CI area ≤ 10 %; (3) CI area from 11 to 25 %; (4) CI area from 26 to 50 %; (5) CI area ≥ 50 % (Yang et al., 2003).

Disease severity. Melons were tested for mould growth on melon rind or stem during storage period, and assessed by scale of 1-3, where 1 means good, fruit without decay (without mould on the rind or stem), 2 means fair, fruit with moderate decay; 3 means bad, fruit with severe decay. Disease severity was calculated as average score of all melons within a group (YANG et al., 2003).

Statistical analysis

All data were processed by SPSS (SPSS Inc, USA) using analysis of variance (ANOVA) with the following factors: treatment type (1-MCP, non 1-MCP); storage condition (ozone, ethylene absorber) and storage period (0, 10, and 14 days), followed by Tukey's method with a significance level of $P < 0.05$. The results were reported with mean and standard deviation (95 % confidence interval).

Results and Discussion

Ethylene and CO_2 production

As shown in Fig. 1, the ethylene production of fruits treated with 1-MCP was significantly lower than others. Samples treated without 1-MCP had high ethylene production persisting during whole storage. EA or ozone alone did not show benefit in declining ethylene production compared to control (Fig. 1). In addition, the combination of 1-MCP and EA or ozone did not have any additional advantages in comparison with 1-MCP. Similarly, 1-MCP application also more strongly influenced CO_2 production than other treatments (Fig. 1). No difference was detected in respiration rates between control, and fruits treated with EA or ozone.

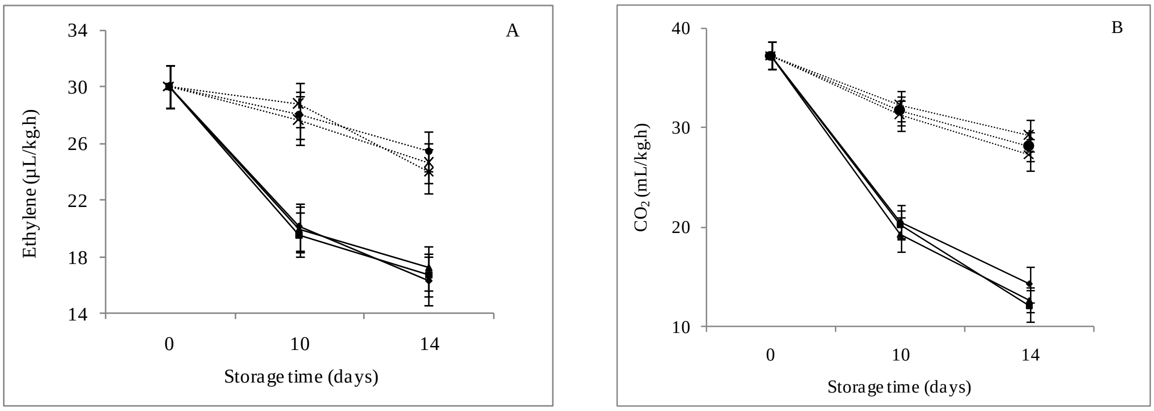

Fig. 1. Ethylene (A) and CO_2 production (B) of melon during storage and shelf-life. Values are the mean ± SD (—▲— 1-MCP and Ozone; —■—1-MCP and EA; —♦—1-MCP; ···●···Ozone; ···×···Control; ···✳···EA)

Acoustic firmness and hue angle value

The firmness and hue angle values of all samples declined with increasing storage period, but at different rates (Fig. 2). Firmness of all samples exhibited a sharp decrease throughout shelf-life due to higher temperature. Another reason could be that fruits were close to advanced ripening. According to these differences, there were two distinct groups: 1-MCP treated samples retained firmness and surface color rather than control, EA or ozone treated fruits. Application of 1-MCP dramatically inhibited ethylene action induced by the ripening of melon. Consequently, fruits derived from 1-MCP treatment had higher firmness and hue angle values compared to others during experiment (Fig. 2). In contrast, the presence of EA or ozone did not affect significantly firmness and hue angle values vs. control during cold storage and shelf-life. Accordingly, fruits treated with EA or ozone were firmer than control, but only slightly. Also, the chlorophyll fluorescence parameters didn’t show difference between control and EA or ozone treated fruits (data not shown). In addition, fruits previously stored in EA or ozone still continued normal ripening during shelf-life, similarly to control. On the contrary, 1-MCP still delayed the ripening throughout shelf-life.

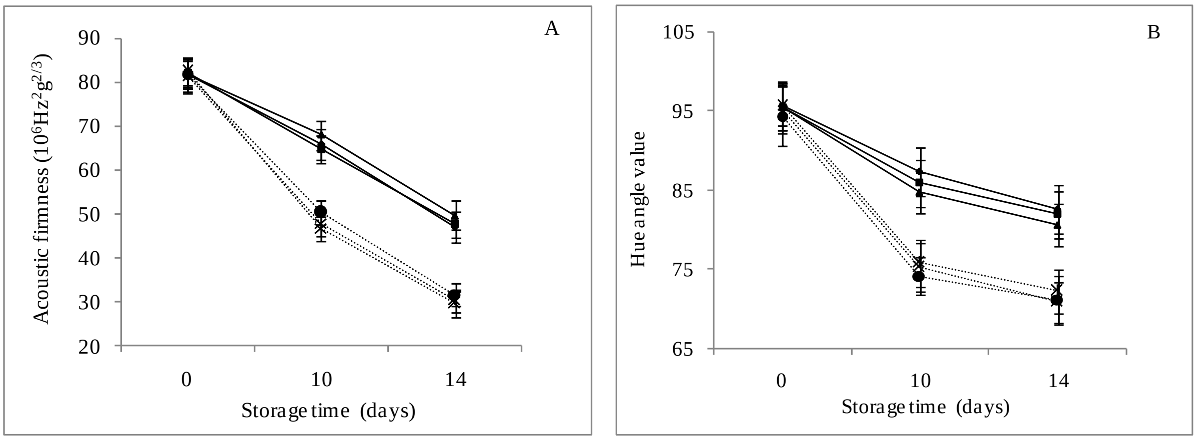

Fig. 2. Acoustic firmness (A) and hue angle value (B) of melon during storage and shelf-life. Values are the mean ± SD (—▲— 1-MCP and Ozone; —■— 1-MCP and EA; —♦—1-MCP; ···●···Ozone;···×···Control; ···✳···EA)

1-MCP markedly delayed the ripening of melon, could maintain melon quality during 10 days at cold storage and 4 days of shelf-life compared to other treatments. This was coincident with previously reported results (ERGUN et al., 2005; GAL et al., 2006; SHI et al., 2014). Ethylene absorber decreased fruit softening, but not significantly compared to control. Ethylene absorber and 1-MCP have been used widely to control ethylene action, in order to delay ripening during the transport and storage, however, each of them has its different impact. In case of 1-MCP treatment, perception of ethylene was blocked, while ethylene removal decreased ethylene level in the storage environment, particularly in sealed environment such as controlled atmosphere and packaging (TERRY et al., 2007; WATKINS, 2006). It is assumed that 1-MCP binds irreversibly to the ethylene receptors (MEYER and TERRY, 2010). Therefore, 1-MCP could maintain the effect during the whole storage. While ethylene absorber could not have effect when samples were removed from chamber. Fruits resume normal ripening when removed from ethylene absorber (MEYER and TERRY, 2010; SILVA et al., 2009). In this work, melon treated with 1-MCP did not fully ripen, in agreement with an earlier report for avocado (MEYER and TERRY, 2010). The combination of 1-MCP and ethylene absorber did not have any additional effect in comparison to 1-MCP alone.

The results showed that ozone treatment had no effect in maintaining the quality compared to control. Number of studies reported that ozone treatment had effectiveness in extending shelf-life of persimmon (SALVADOR et al., 2006), papaya (ALI et al., 2014), broccoli and cucumber (SKOG and CHU, 2001). However, there was no effect of ozone treatment on apple and pear (SKOG and CHU, 2001). Thus, ozone efficacy might depend on produce (LIEW and PRANGE, 1994). In this work, samples treated with ozone or ethylene absorber alone did not maintain the quality because melons producing ethylene have a high level of ethylene inside these fruits. It could be explained that ozone or EA is effective in oxidizing the surrounding ethylene environment rather than a decline in ethylene production.

Chilling injury

There was a minor difference in sensitivity to CI between treatments during storage (Table 2). Storing at 5 °C induced CI on melon skin. CI developed on approximately 10 % of the melon surface area at the 4th day of cold storage and increased scores were found with extending cold storage duration. Samples stored with ozone were more sensitive to CI than other samples, however, the significant difference was only observed at 10th day of storage and shelf-life.

Table 2. Chilling injury rating of melon during storage and shelf-life

Treatments \ Day	0	4	8	10	14
1-MCP	1.0	1.8 a	2.1 a	2.1 a	2.1 a
1-MCP + EA	1.0	1.9 a	2.1 a	2.1 a	2.1 a
1-MCP + ozone	1.0	1.9 a	2.4 a	2.5 b	2.5 b
EA	1.0	1.9 a	2.1 a	2.1 a	2.1 a
Ozone	1.0	2.1 a	2.4 a	2.5 b	2.5 b
Control	1.0	1.9 a	2.1 a	2.1 a	2.1 a

Means followed by the same letters are not significantly different at the same measurement time (Tukey's, $p < 0.05$).

Ozone treatment had higher CI rates perhaps due to cuticle damage caused by the oxidizing activity of ozone (ALI et al., 2014; SALVADOR et al., 2006). Therefore, skin was more susceptible to low temperature.

Disease severity

The early sign of microbial decay occurred at the 8th day of storage and developed rapidly during shelf-life (Table 3). Low temperature could slow the microbial growth. Ozone was effective in inhibiting microbial development throughout cold storage, however, fruits previously stored with ozone had serious decay during shelf-life. 1-MCP treated samples had less decay than others except the combination of 1-MCP and ozone. There was no significant difference in decay between fruits treated with EA, ozone or control.

Table 3. Disease severity of melon during storage and shelf-life

Treatments \ Day	0	4	8	10	12	14
1-MCP	1.0	1.0	1.1 a	1.1 a	1.3 a	1.7 a
1-MCP + EA	1.0	1.0	1.1 a	1.1 a	1.4 a	1.9 a
1-MCP + ozone	1.0	1.0	1.0 a	1.0 a	1.7 ab	2.5 b
EA	1.0	1.0	1.1 a	1.3 ab	1.5 ab	2.5 b
Ozone	1.0	1.0	1.0 a	1.0 a	1.7 ab	2.7 b
Control	1.0	1.0	1.3 a	1.5 b	1.7 ab	2.5 b

Means followed by the same letters are not significantly different at the same measurement time (Tukey's, $p < 0.05$).

The results also showed that disease severity was high in fruits treated with EA and control at the 10^{th} day and shelf-life. It could be that control and EA treated fruits were at advanced ripening stage, thus more susceptible to decay.

Fruits stored with ozone showed less disease severity than those of other treatments during cold storage due to antimicrobial efficacy of ozone (GUZEL-SEYDIM et al., 2004). The result coincided with previous reports (PALOU et al., 2002). Nonetheless, melons exposed to ozone prior to shelf-life had more serious decay throughout shelf-life than the rest because a cleaner surface may be more susceptible to recontamination (GIL et al., 2009; UKUKU, 2006).

Conclusion

The results of this work indicated a benefit of 1-MCP in delaying the ripening of melon. Ozone had an effect on inhibiting microbial development during storage, however fungal growth was much more serious when fruits removed for shelf-life. Ethylene absorber did not show any advantages throughout storage period. Application of 1-MCP and ozone could control two main problems causing postharvest loss of melon.

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