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SZENT ISTVÁN UNIVERSITY

Department of Postharvest Science and Sensory Evaluation

EXTENDING THE STORABILITY OF MELON

Thesis book

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Budapest

2017

PhD School/ Program

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1. INTRODUCTION

Cantaloupe is a delicious fruit with its crispy, juicy texture, flavor and high nutritional value, particularly ‘Lillo’, ‘Centro’, ‘Celestial’ and ‘Donatello’ are the main melon cultivars in Hungary. However, after harvest the ripening process of melons are so quick that the softening of these fruit increases dramatically during several days of storage. In addition, melon is a ground crop and thus microorganisms are available on the melon surface easily developing during transport and storage. Therefore, maintaining the quality of melons meeting the market demand is the main target of postharvest management.

1-methylcyclopropene (1-MCP) successfully controls the ripening of fruits and vegetables during storage and transport by warding off negative ethylene effects. Almost primary publications were conducted the 1-MCP treatment within a day after harvest at ambient temperature. Rapid application of 1-MCP to melon is necessary because melon has a short shelf-life. Nevertheless, in commercial practice it is not easy to carry out the 1-MCP treatment at the harvest day due to transport or occasional lack of the air tight storage room. This is the gap in the majority of previous researches. Therefore, a question was raised: “what if the 1-MCP treatment is delayed by several days after harvest ?”.

This study is different from previous researches in the following main areas:

- Firstly, application of 1-MCP on melon at different days after harvest was tested;
- Secondly, 1-MCP microbubbles treatment as an innovative postharvest technique for the shelf-life extension of melon was tested;
- Thirdly, the combination of 1-MCP and ethylene absorber or ozone treatment was tested;
- Fourthly, comparison between traditional washing methods and microbubbles treatment in reducing microbial populations on melon skin was conducted.

2. RESEARCH OBJECTIVE

2.1 Research objective

The objective of this study was to find the possible postharvest management including 1-MCP application, storage condition and washing treatment for extending the storability of melon. Accordingly, three main practical tasks have been conducted to comply with the objective:

i. Investigating the effect of 1-MCP application on four melon cultivars at different temperatures and days after harvest.
ii. Evaluating the innovative technique such as 1-MCP microbubbles for postharvest treatment and ozone microbubbles for washing melon.
iii. Examining the effect of the ethylene absorber as well as gaseous ozone treatment during storage.

2.2 Research questions

In order to reach the research objective, some relevant questions have been deliberated:

i. Do different treatment temperatures of 1-MCP have effect on four melon cultivars?
ii. Does delayed application of 1-MCP have impact on four melon cultivars?
iii. Are there any effects of 1-MCP microbubbles treatment on melon?
iv. Does storage condition such as ethylene absorber or ozone treatment maintain the quality of melon during storage?
v. Does the combination of 1-MCP and ethylene absorber or 1-MCP and ozone have efficacy on melon during storage?
vi. Do hot water, chlorine, hot water and microbubbles, chlorine and microbubbles, and ozone microbubbles reduce microbial counts on melon skin?

2.3 Research scope

This study has conducted on four melon cultivars in Hungary.

3. MATERIALS AND METHODS

3.1 Materials and methods

Melons (*Cucumis melo* L. var. *reticulates* Naud.) were bought from an experienced grower in Hungary. Fruits were harvested from June to September 2014 and 2015 at the ½ - ¾ slip stage. Four melon cultivars comprising Lillo, Centro, Celestial, and Donatello were examined. Fruits were selected for uniformity of size, shape and freedom from external damage. The average weight of each piece was 1.0 ± 0.2 kg, the average small diameter and large diameter are 12.0 ± 0.3 cm, and 14.0 ± 0.2 cm, respectively. The sample size would be described in each experiment detail.

3.2 Measurements

The changes of melon quality during storage and shelf-life were measured by nondestructive methods: acoustic firmness, skin surface color and chlorophyll fluorescence measurement. Besides, ethylene and CO_2 production, disease incidence, chilling injury, mesophilic aerobes, and disease severity were also determined.

3.2.1 Ethylene production

Ethylene production was determined by an ICA-56 hand-held ethylene analyzer (International Controlled Atmosphere Ltd., United Kingdom) upon the measured ethylene production of the samples being held for a given time in a hermetically closed plastic container. The measurement was carried out as following: one kilogram of melon was put in a plastic box, then the box was closed. After 1h, the ethylene production of fruits was measured in ppm. Results were expressed in microliter of ethylene produced per kilogram of fruit in 1 h ($\mu l \cdot kg^{-1} \cdot h^{-1}$).

3.2.2 CO_2 production

Respiratory intensity as carbon dioxide production was measured for an hour in a closed respiratory system containing several hermetically closed plexi glass containers 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 ($ml \cdot kg^{-1} \cdot h^{-1}$)

3.2.3 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). The acoustic firmness measurement was carried out as follows: melons

were placed on sample holder, firstly AWETA table top measured the weight of the product, followed by a gentle tap at the melon. Then, the microphone recorded the signal and the system automatically selected the highest peak in the frequency spectra. The acoustic signal of sample was analyzed and together with the weight, the acoustic firmness was determined. The acoustic firmness was calculated:

$$S = f^2 * m^{2/3} \quad [1].$$

3.2.4 Chlorophyll fluorescence analysis

Chlorophyll fluorescence parameters were determined at three equidistant points on the external circumference of each fruit by a PAM WinControl-3 controlled MONI-PAM multi-channel chlorophyll fluorometer (Heinz Walz GmbH, Germany). The measurement was conducted as following: melons were placed on sample holder, Moni-PAM head flashed blue light (measuring light) at three different points of each sample. Obtained data were minimal, maximal, variable chlorophyll fluorescence (F_0, F_m, F_v) and potential quantum yield of photosystem II (F_v/F_m).

3.2.5 Surface color measurement

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).

3.2.6 Chilling injury (CI) evaluation

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 %

3.2.7 Decay percentage evaluation

Decay was evaluated by sensory evaluation as fungal mycelia appeared on stem or melon surface and calculated as the number of decayed samples divided by initial number of samples multiplied by 100.

3.2.8 Disease severity evaluation

Mould growth on melon rind or stem were tested during the storage period, and assessed by scale of 1-3, where 1 = good, fruit without decay (without mould on the rind or stem), 2 = fair, fruit with moderate decay (one or two fungal spots on melon rind or stem with 0.5 – 1 cm diameter); 3 = bad, fruit with severe decay (one or more fungal spots on melon rind or stem with more than 1.0 cm diameter). Disease severity was calculated as average score of all melon within a group.

3.2.9 Mesophilic aerobes analysis

Gauze balls were humidified by sterile distilled water before sampling. Sampling was taken at sides without decay on melon rinds with metallic ring and gauze balls (d=36.5 mm, A=10.41 cm^2). After sampling, gauze balls were packed in sterile polyethylene bags kept at -10 °C for analysis later on. Three sides on each melon surface were sampled and three fruits were used to evaluate the survival of microorganisms for each treatment. Gauze balls were put in 0.1 % peptone water, then 1 milliliter of dilutions (peptone water) 10^{-1}, 10^{-2} and 10^{-3} were plated in Plate Count Agar. Mesophilic aerobes were determined after 48 h incubation Plate Count Agar at 35 °C

3.3 1-Methylcyclopropene (1-MCP)

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

3.3.1 Application of 1-MCP gaseous form (conventional 1-MCP)

Fruits were treated with 1-MCP gas released from 1-MCP tablet in 15 ml activator solution for 24 h in an air-tight plastic box (Fig. 1). Small fan was used to mix the air in the box. The initial 1-MCP concentration in the box was 1.2 ppm.

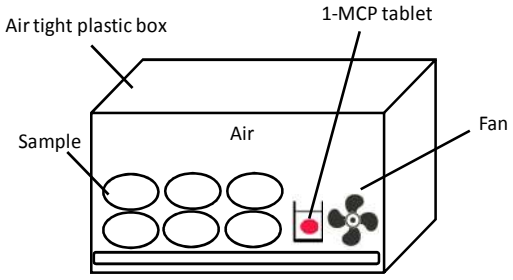

Figure 1. Schematic diagram of conventional 1-MCP application

3.3.2 Application of 1-MCP microbubbles (1-MCP MBs)

1-MCP MBs generation system was built up for postharvest treatment in this work as shown in Fig. 2. 1-MCP gas was prepared in 5 L closed glass for 45 min before application. Gaseous 1-MCP was released from 1-MCP tablet with 15 ml activator solution. Seventy liters of water (pH = 7-8) were poured into a 250 L plastic box and melons were added. Then, 1-MCP gas was pumped into circulating water at flow rate 100 liters/min by opening valve 1. 1-MCP MBs were produced by gas liquid mixing pump adjusted by valve 2, pressure 5-6 bar (Gas liquid mixing pump Type: YL8022, model: 25GO-2SS, 1.1 KW, Guangzhou Ozone Environmental Technology Co., Ltd, China). 1-MCP MBs turned water in the box

from transparent to milky appearance. Treatment time was 15, 30 and 45 min. Treatment conditions: water temperature 16 - 20 °C, pH= 7-8.

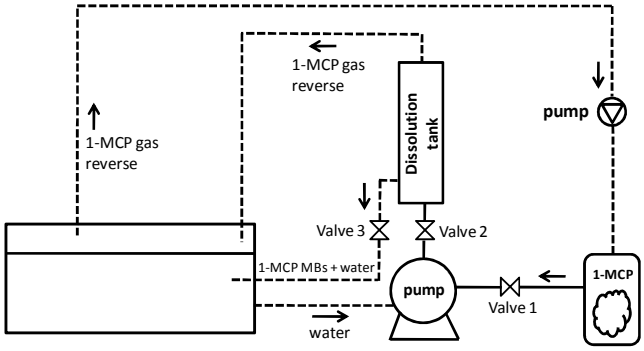

Figure 2. Schematic diagram of 1-MCP MBs generation system

3.4 Ethylene absorber (EA)

Sachets of Ethyl Stopper containing $KMnO_4$ were provided by Bioconservacion S.A., Spain. These sachets were used as ethylene absorber during storage. Recommendation of supplier is one sachet of ethylene absorber for 3-10 kg fruits. Sachets of Ethyl Stoppers were placed along with produce throughout cold storage.

Potassium permanganate removes ethylene as the following reaction ([2]):

$$3C_2H_4 + 2KMnO_4 + 4H_2O \rightarrow 3C_2H_4(OH)_2 + 2KOH + 2MnO_2 \quad [2]$$

Purple Brown

Experiment 2 would introduce ethylene absorber treatment in detail.

3.5 Chlorine

Chlorine as a sanitizing agent was provided by The Fishmarket Kft. (Budaörs, Hungary). Free chlorine concentration was measured with chlorine test kit (Hanna Instrument, free chlorine reagent HI93701-0, Romania). The initial concentration of chlorine in the chlorinated water was 280 ppm. Chlorine solution was diluted to 150 ppm for treatments.

Experiment 3 would introduce chlorine treatment in detail.

3.6 Ozone (used in experiment 2)

Ozone was generated by commercially ozone generator (Neo.Tec XJ-100, China) designed for the household use in refrigerators.

In this work, gaseous ozone 0.1ppm/h in storage experiment was used for two purposes: ethylene removal and sanitizing during cold storage.

Ozone eliminates ethylene as the following reaction ([3]):

$$O_3 + C_2H_4 \rightarrow CH_3CHO + O_2 \quad [3]$$

Experiment 2 would introduce ozone treatment in detail.

3.7 Microbubbles generation system for washing treatment

3.7.1 Ozone microbubbles generation system

Ozone microbubbles (ozone MBs) generation system was built up for washing melon in this work as shown in Fig. 3. Seventy liters tap water (pH = 7-8, t = 16 °C) was poured into a 250 L plastic box and melons were added. Gaseous ozone at the concentration of 150 ppm was produced by ozone generator (GO-R 5G, Guangzhou Ozone Environmental Technology Co., Ltd, China). Then, the mixture of ozone and air was pumped into circulating water at flow rate 100 liters/min by opening valve 1. Ozone MBs were produced by gas liquid mixing pump adjusted by valve 2. Ozone MBs turned water in the box from transparent to milky appearance. Treatment time was 2, and 5 min. Treatment conditions: water temperature 16 °C, pH = 7 – 8.

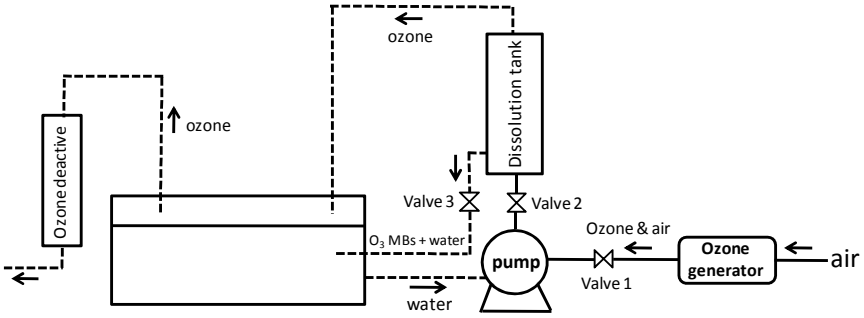

Figure 3. Schematic diagram of ozone microbubbles generation system

3.7.2 Hot water and microbubbles

The system was built up for the combination hot water and microbubbles washing treatment as shown in Fig. 4. Air was pumped into circulating water at flow rate 100 liters/min by pump. The flow rate was adjusted by valve 1. Air MBs were produced by gas liquid mixing pump adjusted by valve 2. Microbubbles turned water in the box from transparent to milky appearance. Treatment time was 2, and 5 min. Treatment conditions: water temperature 55 °C, pH = 7 – 8.

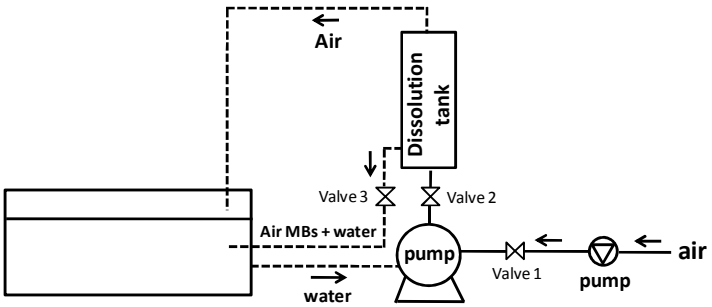

Figure 4. Schematic diagram of hot water and microbubbles generation system

3.7.3 Chlorinated water and microbubbles

The system built up for the combination of chlorine and microbubbles washing treatment was similar to that of the combination of hot water and microbubbles, but in this case hot water was replaced by chlorinated water.

3.8 Experimental design

Experiments of this research are schematically summarized in the flow chart as shown in Fig.5.

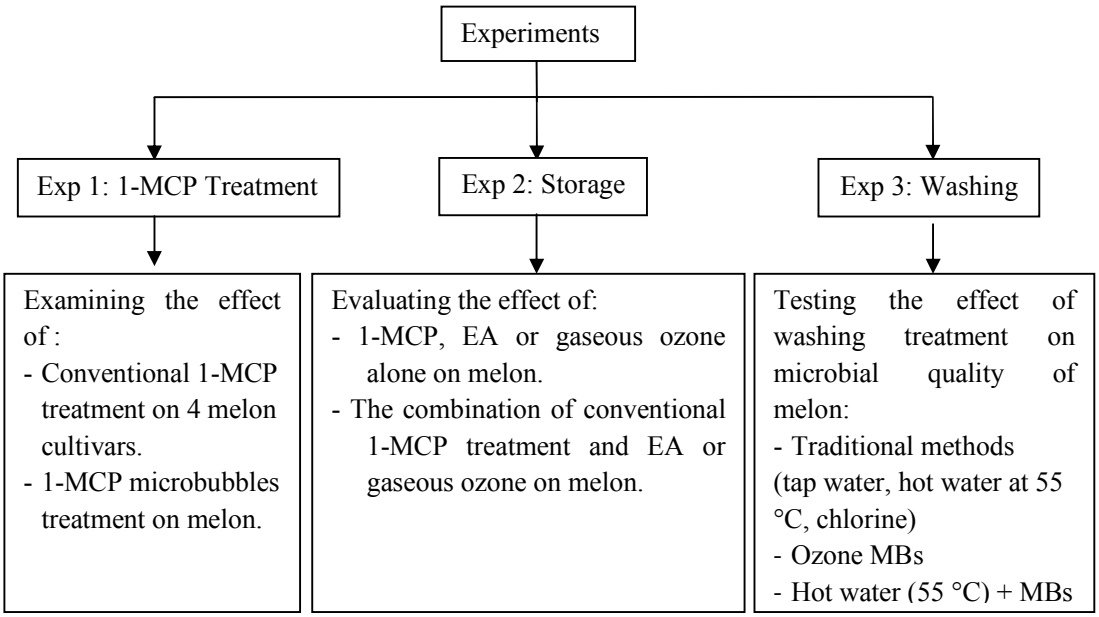

Figure 5. Experimental design

There were three experiments carried out as below:

Experiment 1: Efficacy of 1-MCP application including conventional 1-MCP (1-MCP gaseous form) and 1-MCP microbubbles on melon was tested.

Experiment 2: Effect of conventional 1-MCP treatment, ethylene absorber and ozone treatment on melon was evaluated.

Experiment 3: Different washing methods: tap water, hot water (at 55 °C), chlorine, ozone microbubbles, the combination of hot water and microbubbles or chlorinated water and microbubbles were investigated.

The procedure of each experiment would be detailed as below.

3.8.1 Experiment 1: Evaluating the effect of 1-MCP treatment on melon

3.8.1.1 Experiment 1.1: Application of conventional 1-MCP at different temperatures

Experiment 1.1 could answer the questions:

- Whether or not 1-MCP has effect on melon ?
- Are there any differences among different treatment temperatures: 5 °C, 10 °C, and 20 °C on 4 melon cultivars during shelf-life ?

1-MCP application at different temperatures

Samples of each cultivar were selected randomly into 4 groups: 3 treated groups and 1 untreated group (control). Each group contained 15 fruits. Fruits were treated with 1-MCP gas in an air-tight plastic box for 24 h (as shown in Fig. 1).

Three groups were kept for 24 h at 5, 10 and 20 °C before treatment. These groups were treated with 1-MCP at 5, 10 and 20 °C, respectively on the 1st day after harvest, whereas control melons were kept at 5 °C till the application was completed. After 1-MCP treatment, three treated groups and control were stored at room temperature (20 °C, RH 55 %) for 9 days (Table 1).

Table 1. Application of 1-MCP at different temperatures

Day / Sample	0 (Harvest)	1	2	3	4	5	6	7	8	9
1-MCP$_{5°C}$	M, C$_{5°C}$	T$_{5°C}$	SL	SL	SL	SL	SL, M	SL	SL	M
1-MCP$_{10°C}$	M, C$_{10°C}$	T$_{10°C}$	SL	SL	SL	SL	SL, M	SL	SL	M
1-MCP$_{20°C}$	M, C$_{20°C}$	T$_{20°C}$	SL	SL	SL	SL	SL, M	SL	SL	M
Control	M, C$_{5°C}$	C$_{5°C}$	SL	SL	SL	SL	SL, M	SL	SL	M

1-MCP$_{5, 10, 20 °C}$: 1-MCP application was carried out at 5, 10 and 20 °C, respectively.
C$_{5, 10, 20 °C}$: Cooling at 5, 10 and 20 °C, respectively.
T: Treated with 1-MCP for 24 h
SL: Shelf-life at 20 °C; M: measurement at 20 °C

3.8.1.2 Experiment 1.2: Application of conventional 1-MCP at different days

Experiment 1.2 could answer the following two questions:

- Whether or not the delay of 1-MCP has effect on 4 melon cultivars ?
- After harvest, how many days 1-MCP treatment can be delayed ?

1-MCP application at different days after harvest

Samples of each cultivar were selected randomly into 4 groups: 3 treated groups and 1 untreated group (control). Each group contained 15 fruits. Fruits were stored at 10 °C before treatment. Three groups were treated with 1-MCP gas on the 1st, 3rd and 5th day after harvest, respectively in an air-tight plastic box at 10 °C for 24 h (as shown in Fig. 1). During treatment period, control group (untreated) was kept at 10 °C. After 1-MCP application, 4 groups were kept at 10 °C, RH 90 - 95 % till the 7th day and then transferred to 20 °C for 3 days of shelf-life (Table 2).

Table 2. Application of 1-MCP at different days after harvest

Day / Sample	0 (Harvest)	1	2	3	4	5	6	7	8	9	10
1-MCP$_{1st}$	M, C	T	C	C	C	C	C	SL,M	SL	SL	M
1-MCP$_{3rd}$	M, C	C	C	T	C	C	C	SL,M	SL	SL	M
1-MCP$_{5th}$	M, C	C	C	C	C	T	C	SL,M	SL	SL	M
Control	M, C	C	C	C	C	C	C	SL,M	SL	SL	M

1-MCP$_{1st, 3rd, 5th}$: 1-MCP application was carried out at day 1, 3 and 5 after harvest, respectively.
C: Cooling at 10 °C; T: Treated with 1-MCP, 24 h at 10 °C
SL: Shelf-life at 20 °C; M: measurement at 20 °C

3.8.1.3 Experiment 1.3: Application of 1-MCP microbubbles (1-MCP MBs)

Experiment 1.3 could answer the question:

- Whether or not 1-MCP microbubbles have effect on 'Donatello' melon ? In addition, the efficacy of conventional 1-MCP and 1-MCP microbubbles treatment were compared.

Application of conventional 1-MCP and 1-MCP MBs

'Donatello' melons were selected randomly into 5 groups: 1 untreated group (control) and 4 treated groups comprising 1 group treated with 1-MCP gaseous form and 3 groups treated with 1-MCP MBs (Table 3). Each group contained 15 fruits. Melons were kept at 10 °C before treatment.

Application of conventional 1-MCP (gaseous form)

One group was treated with 1-MCP gas in an air-tight plastic box at 10 °C for 24 h (as shown in Fig. 1). Control group was still kept at 10 °C during 24 h long treatment of gaseous 1-MCP.

Application of 1-MCP MBs

Three groups were dipped in tap water containing 1-MCP MBs for 15, 30 and 45 min, respectively (detailed in 3.3.2). Then, three groups treated with 1-MCP MBs were kept at 10 °C for 24 h.

Shelf-life

On the second day after harvest, all samples were stored at 20 °C, RH 55 % for 9 days of shelf-life.

Table 3. Application of 1-MCP on 'Donatello' melon

Day / Sample	0 (Harvest)	1	2	3	4	5	6	7	8	9
1-MCP$_{24h}$	M, C	T	SL	SL	SL	SL	SL, M	SL	SL	M
1-MCPMBs$_{15min}$	M, C	T,C	SL	SL	SL	SL	SL, M	SL	SL	M
1-MCP MBs$_{30min}$	M, C	T,C	SL	SL	SL	SL	SL, M	SL	SL	M
1-MCP MBs$_{45min}$	M, C	T,C	SL	SL	SL	SL	SL, M	SL	SL	M
Control	M, C	C	SL	SL	SL	SL	SL, M	SL	SL	M

1-MCP MBs$_{15, 30, 45 min}$: 1-MCP MBs application was carried out for 15, 30 and 45 min, respectively.
1-MCP$_{24 h}$: conventional 1-MCP application was conducted at 10 °C for 24 h

C: Cooling at 10 °C; T: Treated with 1-MCP; SL: Shelf-life at 20 °C; M: measurement at 20 °C

3.8.2 Experiment 2: Evaluating the effect of 1-MCP, ethylene absorber and ozone

In the experiment 2, the following questions would be answered:

- Whether or not the ethylene absorber or gaseous ozone treatment have effect on 'Donatello' melon?
- Whether or not the combination of 1-MCP and ethylene absorber or gaseous ozone treatment have effect on 'Donatello' melon?

Application of 1-MCP gaseous form

'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 at 5 °C on the 1st after harvest for 24 h (as shown in Fig. 1).

Storage conditions

During 24 h long treatment, three non 1-MCP treated groups were stored separately at 3 different storage conditions:

Storage condition 1: cold storage at 5 °C + ozone 0.1 ppm/h.

Storage condition 2: cold storage at 5 °C + 6 sachets of Ethyl Stopper.

Storage condition 3: only cold storage at 5 °C.

After 1-MCP application, three 1-MCP treated groups were put into 3 different storage conditions above (Table 4). Thus, each storage condition had 2 groups: one 1-MCP treated group and one non 1-MCP treated group. All six groups were stored during 10 days at 5 °C, and then transferred to 20 °C for 4 days of shelf-life.

Table 4. Storage and shelf-life condition

Storage condition		Sample
Cold storage at 5 °C for 10 days	Gaseous ozone 0.1ppm/h	1-MCP treated group
		Non 1-MCP treated group
	Ethyl Stopper	1-MCP treated group
		Non 1-MCP treated group
	Cold storage at 5 °C	1-MCP treated group
		Non 1-MCP treated group
Shelf-life for 4 days	at 20 °C	6 groups

4.8.3 Experiment 3: Evaluating the efficacy of washing treatments

Experiment 3 would answer the question:

- Whether or not washing treatments decrease the microbial populations on melon rind ?

'Donatello' melons were randomly divided into 12 groups: 11 treated groups and 1 untreated group. Each group contained 10 fruits. Treatments were carried out in detail as following (Fig. 6).

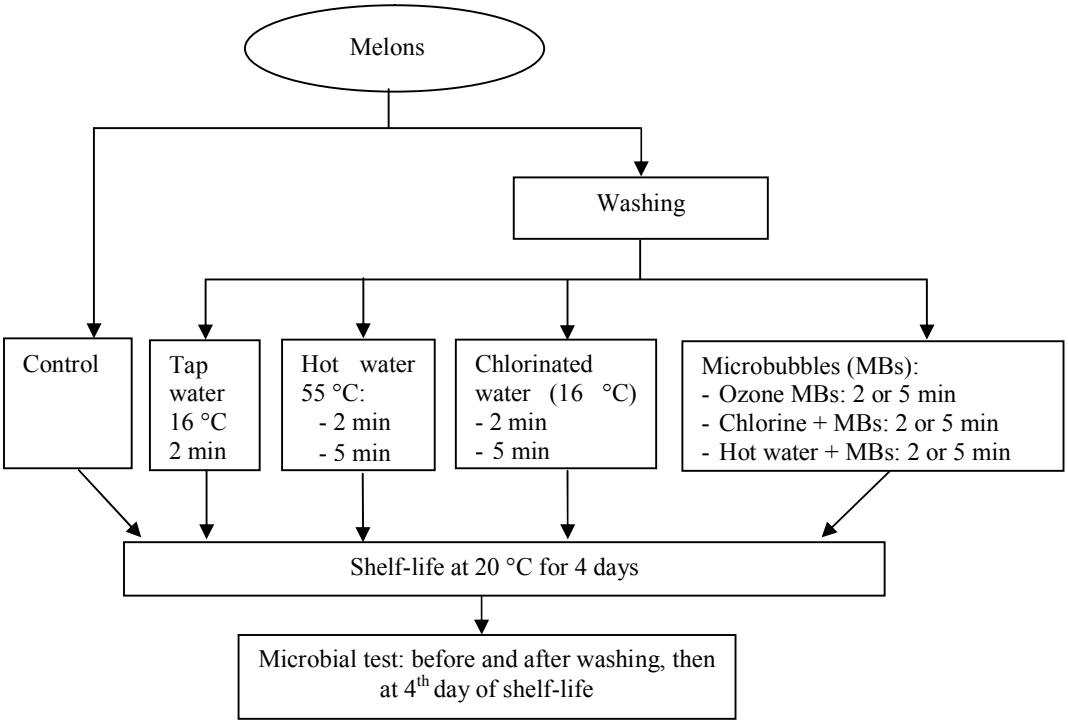

Figure 6. Washing treatment design

Measurement

Mesophilic aerobes analysis, disease incidence and disease severity were evaluated before treatment, after treatment and at 4th day of shelf-life.

3.9 Statistical analysis

All data were processed by SPSS (SPSS Inc, USA) using analysis of variance (ANOVA), followed by Tukey's method with significance level of $p < 0.05$. The results were reported with mean and standard deviation.

4. RESULTS

4.1 Effect of 1-MCP treatment on melon during storage

4.1.1 Effect of different treatment temperatures

There was no significant difference in quality indices among different treatment temperatures of conventional 1-MCP on the 1st day after harvest. The results also showed that after 9 days of shelf-life, treated 'Centro' melons had lower ethylene and CO_2 production around 48 % and 24 %, respectively, compared to control. Application of gaseous 1-MCP on the 1st day after harvest was able to extend the shelf-life of melon till 9 days at 20 °C. In addition, 1-MCP application could slow significantly the softening as well as the color change of melon during postharvest life. However, 1-MCP did not have effect on disease severity of the four melon cultivars during shelf-life. Four melon cultivars had the similar patterns of quality changes.

4.1.2 Effect of different treatment days

1-MCP application time can be delayed till the 3rd day after harvest when melons were kept at 10 °C before treatment. The efficacy of conventional 1-MCP treatment at different days after harvest on four melon cultivars (Lillo, Centro, Celestial and Donatello) was evaluated. Response of four melon cultivars during storage indicated that the effectiveness of 1-MCP decreased significantly with late treatment (5th day after harvest). The significant difference between fruits treated on the 1st day and 5th day after harvest was detected. Four melon cultivars had the similar patterns of quality changes.

4.1.3 Effect of 1-MCP microbubbles treatment

1-MCP microbubbles treatment for 30 min or 45 min delayed the ripening of 'Donatello' melon during 9 days of shelf-life. The ethylene and carbon dioxide production of 'Donatello' melon treated 1-MCP MBs for 30 min were about 11 % and 12 % lower, respectively, compared to control. 1-MCP microbubbles proved to be effective in postharvest treatment for melon.

4.2 Effect of 1-MCP, ethylene absorber and ozone treatment

Storing 1-MCP treated melons with ethylene absorber at 5 °C for 10 days did not show any additional advantages during whole storage period compared to 1-MCP alone. Moreover, there was no significant difference between samples treated with ethylene absorber or ozone and control.

Ozone treatment at 0.1 ppm/h proved to be effective in inhibiting microbial development on 'Donatello' melon during storage at 5 °C for 10 days, but fungal growth was much more serious after the removal of the fruits for shelf-life.

4.3 Effect of washing treatments on mesophilic aerobes

Population of mesophilic aerobes after treatment

These results indicated that ozone MBs 5 min and hot water MBs were the most effective in reducing microbial loads. Washing with ozone MBs for 5 min and hot water MBs for 2 or 5 min decreased approximately 2.3, 2 and 1.7 log cfu/cm^2, respectively, compared to control. Hot water and chlorine alone or chlorine MBs could decrease the microbial load with about 1 log cfu/cm^2. Tap water had no effect compared to control. No sign of damage on melon rind surface was detected after treatments.

Population of mesophilic aerobes after 4 days of shelf-life

Melons treated with ozone MBs for 5 min or hot water MBs had the lowest microbial loads, followed by that of ozone MBs 2 min, chlorine alone or chlorine MBs, and hot water. The number of microorganisms on melon washed with tap water was close to that of control samples. Chlorine was more effective in controlling microbial loads on melon surface than hot water treatment on the 4th day of shelf-life at 20 °C.

5. NEW SCIENTIFIC RESULTS

This study was carried out in order to evaluate the impact of 1-MCP treatment, storage condition and washing methods on postharvest life of melon. Data were collected during two seasons from 2014 to 2015 in, Hungary. The results indicated some important findings as follows.

1) It was concluded, that 1-MCP application time could be delayed till the 3rd day after harvest, when melons were kept at 10 °C before treatment. Response of four melon cultivars (Lillo, Centro, Celestial and Donatello) during shelf-life indicated that the effectiveness of 1-MCP decreased significantly with late treatment (5th day after harvest). Significant difference was observed between fruits treated at 1st and 5th day after harvest ($p<0.05$).
2) Application of gaseous 1-MCP on the 1st day after harvest was able to extend the shelf-life of melon till 9 days at storage temperature of 20 °C. Ethylene and CO_2 production of Centro cultivar after 9 days shelf-life decreased to 48 % and 24 %, respectively, compared to control. Four investigated melon cultivars had similar patterns of quality changes.
3) It was concluded, that 1-MCP microbubbles treatment for at least 30 min was able to delay ripening of 'Donatello' melon during 9 days of shelf-life. Ethylene and CO_2 production of 'Donatello' melon, treated for 30 min, obtained approximately 11% and 12% lower values, respectively, compared to control.
4) Ozone treatment at 0.1 ppm/h proved to be effective in inhibiting microbial development on 'Donatello' melon during storage at 5 °C for 10 days, but fungal growth became serious after removal of fruits for shelf-life at 20 °C.
5) Ozone microbubbles treatment for 5 min, with the concentration of 150 ppm, had benefit in disinfection melon rind. The ozone microbubbles treatment using water of 16 °C and pH =7-8 for 5 min reached significant reduction in the mesophilic aerobes of 2.3 $\log_{10}$ cfu.
6) Hot water microbubbles treatment was proved to be efficient in control microorganisms. The microbubbles treatment using water of 55 °C and pH =7-8 for 2 and 5 min reduced mesophilic aerobes on melon rind surface by 2 and 1.7 $\log_{10}$ cfu, respectively.

6. CONCLUSIONS AND SUGGESTIONS

6.1 Conclusions

On the ground of empirical findings in this work, some applications are drawn.

- This work provided basic information concerning different treatment temperatures and different treatment days after harvest of 1-MCP on four melon cultivars that could be useful in commercial practice.
- 1-MCP MBs proved to be an alternative technique in postharvest treatment for melon and other produces as well, particularly, when there is a lack of air tight storage room for conventional 1-MCP application.
- Microbubbles proved to be an alternative washing technique that could be applied in washing treatment.

6.2 Further researches

Further researches about storability of melon in order to meet the market requirement are highly recommended. The topic surrounding postharvest management of melon is vast. The interesting topic nowadays is quality of melon comprising a set of standard about nutrition, safety and sensory characteristics of produce. Therefore, sanitizing, treatment and proper handling should be together in order to solve postharvest problems of melon.

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