EFFECTS OF SOME POSTHARVEST TREATMENTS ON QUALITY OF FRESH-CUT 'BRAEBURN' APPLE DURING COLD STORAGE

EFECTELE UNOR TRATAMENTE POST-RECOLTARE ASUPRA CALITĂȚII MERELOR 'BRAEBURN' TĂIATE PE DURATA STOCĂRII LA RECE

KOYUNCU M. A.[1], KOYUNCU Fatma[1]

e-mail: fatmaoker@gmail.com

Abstract. *The aim of this research is to determine the effects of Lovastatin, 1-MCP, and hot water treatments on quality of fresh-cut "Braeburn" apple during cold storage. Fruits picked at optimum harvest time were transported to the Postharvest Physiology Laboratory of Horticulture Department immediately. Fruits treated with Lovastatin (1.25 mmol/l), 1-MCP (1 µL L^{-1}), hot water (50°C for 60 s), and control group were sliced with an apple slicer device. Sliced apples were packaged in plastic boxes and stored at 0°C and 90±5 relative humidity during 14 days. Weight loss, fruit flesh firmness, titratable acidity, fruit flesh colour, respiration rate, ethylene production and microbial activity were determined at the beginning and after 7 and 14 days of storage. As a result, 1-MCP treated apple slices had a little higher titratable acidity and L* values than those of the other treatments. Lovastatin treated apples gave better results in terms of microbial activity compared to other applications. Fresh–cut 'Braeburn' apple could be stored at 0°C and 90±5 relative humidity for 7 days without significant quality losses.*

Key words: Lovastatin, 1-MCP, hot water, fresh-cut apple, storage

Rezumat. *Scopul acestei lucrări a fost de a determina efectele induse de tratamentul cu Lovastatin, 1-MCP, şi apă fierbinte asupra calității merelor "Braeburn" proaspăt tăiate pe durata depozitării la rece. Fructele au fost culese în perioda optimă de recoltare după care au fost imediat transportate către Laboratorul de Fiziologia plantelor din cadrul Departamentului de Horticultură. Fructele au fost tratate cu Lovastatin (1,25 mmol/l), 1-MCP (1 µL L^{-1}) şi apă fierbinte (50°C timp de 60 s), apoi lotul martor a fost tăiat cu ajutorul unui dispozitiv de feliat. Merele feliate au fost ambulate în pungi de plastic şi depozitate la 0°C şi o umiditate relativă de 90±5 pe durata a 14 zile. Pierderile în greutate, consistența feliilor de măr, aciditatea titrabilă, culoarea feliilor de măr, rata de evaporare, producția de etilenă precum şi activitatea microbiană au fost determinate la începutul perioadei de stocare cât şi după 7 respectiv 14 zile. Ca şi rezultat s-a observat că feliile de măr tratate cu 1-MCP au avut valorile pentru aciditatea titrabilă şi L* ceva mai mari decât cele obținute la folosirea altor tratamente. Merele tratate cu Lovastatin au avut rezultate mai bune în ceea ce priveşte activitatea microbiană decât în cazul*

[1]Süleyman Demirel University, Isparta, Turkey

aplicării altor metode de tratare. Merele 'Braeburn' proaspăt tăiate pot fi depozitate la o temperatură de 0°C şi o umiditate relativă de 90±5 pentru 7 zile fără pierderi calitative semnificative.

Cuvinte cheie: Lovastatin, 1-MCP, apă caldă, mere proaspăt tăiate, depozitare

INTRODUCTION

Apple, a well-known fruit, is produced and consumed in many parts of the world. Turkey is also one of the main producer countries of apples in the world with 2.890.000 tons, following China and America (FAO, 2016). Thus, the susceptibility of apple and their products to enzymatic browning during postharvest, handling, and processing operations continues to be an important topic from the food science and technology (Eissa *et al.,* 2006; Bayındır *et al.*, 2013). Consumer demand is increasing for convenient, ready-to-use and read-to-eat fruits and vegetables with a fresh-like quality (Rupasinghe *et al.*, 2005). However, little has been done to evaluate the effects of some applications (lovastatin, hot water, some natural products and their derivatives) and techniques such as modified atmosphere packaging (MAP), controlled atmosphere (CA) and dynamic controlled atmosphere (DCA) on fresh-cut produce quality in Turkey. Fresh-cut fruits undergo mechanical injuries caused by fresh-cut processing such as peeling, shredding, cutting etc. The physical injury attendant to fruit processing initiates a series of events such as increased respiration and ethylene production, and increased enzyme activities (King and Bolin, 1989). Blankenship and Dole (2003) indicated that different physical and chemical techniques have been developed to extend the shelf life of fresh-cut produce: refrigeration, disinfection, ethylene absorbers, gamma irradiation, edible coating, chemical dipping and controlled/modified atmosphere.

This study aimed to investigate the effects of lovastatin, 1-MCP and hot water treatments on quality of fresh-cut 'Braeburn' apple during cold storage.

MATERIAL AND METHOD

Apples cv. 'Braeburn' picked at the optimum harvest date in two experimental years from a commercial orchard in Isparta (Turkey) were transported to laboratory, immediately. Fruits were randomly selected and exposed to four different treatments. In the first treatment, fruits were placed in sealed plastic bags and exposed to 1-MCP (1 µL L^{-1}) for 24 h at 20 °C. In the second treatment, an oil solution of 1.25 mmol L^{-1} was prepared by dissolving lovastatin in chloroform and then diluting with commercial sunflower oil. Apples were wiped with cheese-cloth dipped in oil containing lovastatin (Ju and Curry 2000). In the third treatment, fruits were dipped into hot water at 50°C for 60 s as Kupferman (2001) reported. For fourth application, the apple of same amount in per treatment was used as control fruit. After treatments apples were sliced with an apple slicer, and packaged in plastic boxes. Packaged apple slices were stored at 0°C and 90± 5 % Rh for 14 days in normal (air) atmosphere (21% O_2+0.03 % CO_2). Weight loss (%), fruit flesh firmness (N), titratable acidity (%), fruit flesh colour (CIEL*a*b*), respiration rate (ml CO_2/kg h^{-1}), ethylene production (ppm) and microbial activity (log cfu) were determined at the beginning and after 7 and 14 days of storage.

Statistical analyses were performed with General Linear Model (GLM) using SPSS software package (v.16.0). The differences among means were analyzed by Duncan's multiple range test at a significance level of 0.05.

RESULTS AND DISCUSSIONS

The weight losses of all treated and sliced apples increased slightly at the end of 14 days storage. The effect of treatments on weight losses of stored slices in both years was not significant, but only the storage period had significant effect on fruits stored in first year. Lovastatin and 1-MCP treatments relatively limited the weight loss of fresh-cut apples compared to other treatments (tab. 1). It was thought that this positive effect of lovastatin may be due to the barrier effect of sunflower oil applied with lovastatin against moisture vapor permeable. Calderon-Lopez *et al*. (2005) reported similarly that 1-MCP treatment had positive effects on the weight loss of apple slices.

Table 1

Weight loss (%) of cold stored apple slices after different postharvest treatments

Storage period (days)						
	First Year			Second year		
Treatments	**7**	**14**	**Mean**	**7**	**14**	**Mean**
Control	0.04	0.08	0.06[2]	0.02	0.04	0.03[2]
Hot water	0.04	0.09	0.07	0.00	0.03	0.02
1-MCP	0.05	0.08	0.06	0.00	0.02	0.01
Lovastatin	0.03	0.06	0.05	0.00	0.02	0.01
Mean	0.04 b[1]	0.08 a		0.01[2]	0.03	

[1] Means followed by different letters with in the same row and column are significantly different at *P*<0.05, [2] not significant

The average flesh firmness of apple slices increased slightly (23.8 N and 22.3 N) in both years at the end of 14 days storage compared to initial (23.3 N and 21.6 N) values (tab. 2). This result may be due to difficulty of penetration of probe to elastic apple slices after 14 days storage. Otherwise, it is difficult to say that the firmness of apple slices increased with increasing storage period. In fact, Koyuncu *et al*. (2010) found that the flesh firmnesses of apple slices treated with hot water, 1-MCP and lovastatin were higher at the end of 14 days storage compared to initial values. In this research, the best result in terms of firmness was obtained from apple slices treated with 1-MCP. Fresh-cut fruit firmness is an important quality attribute that can be affected by cell softening enzymes present in the fruit tissue and by decreased turgor due to water loss (Varoquaux *et al.,* 1990).

Table 2

Flesh firmness (%) of cold stored apple slices after different postharvest treatments

Storage period (days)								
	First Year				Second year			
Treatment	**0**	**7**	**14**	**Mean**	**0**	**7**	**14**	**Mean**
Control	22.5	24.1	24.9	23.8 [2]	23.0	21.0	22.4	22.1 [2]
Hot water	23.4	24.6	23.8	23.9	21.3	21.2	21.9	21.5
1-MCP	24.1	24.0	23.5	23.9	21.1	21.9	21.9	21.6
Lovastatin	23.2	25.0	22.8	23.7	21.0	21.6	22.9	21.8
Mean	23.3b[1]	24.4a	23.8b		21.6ab[1]	21.4b	22.3a	

[1] Means followed by different letters with in the same row and column are significantly different at *P*<0.05, [2] not significant

There were not much variations in the average titratable acidity contents of apples at the end of storage period compared to initial values. However, the highest titratable acidity contents (0.68% and 0.53%) were found in apple slices treated with 1-MCP in both years (tab. 3). Koyuncu *et al.* (2010) found that 1-MCP treated apple slices showed the highest (0.57 %) titratable acidity content throughout the cold storage. Perera *et al.* (2003) also indicated that 1-MCP treatment was significant in terms of titratable acidity in fresh-cut apples.

Table 3.

Titratable acid content (%) of cold stored apple slices after different postharvest treatments

Storage period (days)								
	First Year				Second year			
Treatment	**0**	**7**	**14**	**Mean**	**0**	**7**	**14**	**Mean**
Control	0.65	0.65	0.71	0.67ab[1]	0.59	0.41	0.56	0.52[2]
Hot water	0.66	0.69	0.66	0.67 ab	0.54	0.40	0.52	0.49
1-MCP	0.66	0.71	0.67	0.68 a	0.55	0.41	0.63	0.53
Lovastatin	0.61	0.61	0.61	0.61 b	0.53	0.35	0.46	0.45
Mean	0.65[2]	0.67	0.66		0.55a[1]	0.39b	0.54a	

[1] Means followed by different letters with in the same row and column are significantly different at *P*<0.05, [2] not significant

The effects of storage period on flesh colour of apple slices were significant (data are not showed) except for first-year L^* value ($P<0.05$). Generally, L^* values of apple slices declined during the storage period. The L^* value is useful indicator of darkening during storage, either resulting from browning reactions or from increasing pigment concentrations (Rosaj-Graü *et al.*, 2006). A decrease in L^* value indicates a loss of whiteness (brightness), and a more positive a^* value indicates browning, whereas a more positive b^* indicates yellowing (Buta *et al.*, 1999). In the first year, while 1-MCP treated apples had the highest L* value (72.09), in the second year apple slices treated with hot water (73.52) and 1-MCP (73.38) had more brightness than the other groups. Fan *et. al* (2005) reported that calcium treated slices were whiter than those of non-treated. Similar results in L^* values were found by Raybaudi-Massilia *et al*. (2007). As expected, a significant increasing in b* values was observed throughout storage for all treatments. Correspondingly, Koyuncu *et al.* (2010) and Bayındır *et al*. (2013) found that the b* values of sliced apples increased clearly during cold storage.

The effects of storage period and treatments on respiration rate of apple slices were significant in first year. But, respiration rate of apple slices was not affected by storage period and treatments during storage in second year ($P<0.05$). The average respiration rate values increased after 14 days storage (6.10 and 8.57 ml CO_2/kg h^{-1}) compared to initial (5.02 and 6.50 ml CO_2/kg h^{-1}) values (tab. 4). Similar results were found by Koyuncu *et al.* (2010), Chung and Moon (2009) and Calderon-Lopez *et al.* (2005). Apple slices treated with 1-MCP and lovastatin had lower respiration rates than those of the hot water and control groups at the end of storage period (tab. 4). Likewise, Koyuncu *et al.* (2010) found that lovastatin and 1-MCP treated "Granny Smith" slices gave the lowest respiration rates towards the end of their storage life.

Table 4.

Respiration rate (ml CO_2/kg h^{-1}) of cold stored apple slices after different postharvest treatments

	Storage period (days)							
	First Year				Second year			
Treatment	**0**	**7**	**14**	**Mean**	**0**	**7**	**14**	**Mean**
Control	5.60	3.29	6.77	5.22 b[1]	7.43	11.87	10.77	10.0[2]
Hot water	4.86	4.88	9.00	6.25 a	2.64	8.56	8.48	6.56
1-MCP	5.21	5.84	5.04	5.36ab	4.26	7.76	8.46	6.83
Lovastatin	4.43	3.08	3.60	3.70 b	11.69	9.50	6.56	9.25
Mean	5.02ab[1]	4.27b	6.10a		6.50[2]	9.42	8.57	

[1] Means followed by different letters with in the same row and column are significantly different at *P*<0.05, [2] not significant

Throughout the storage, the changes in the ethylene production of the stored apple slices were shown in the Tables 5. Ethylene production decreased significantly (P<0.05) with increasing storage period. The average ethylene values were 0.75 ppm (first year) and 2.06 ppm (second year) at the beginning of the storage. These values decreased to 0.21 ppm and 0.96 ppm, respectively, after 14 days storage. Likewise, Perera *et al.* (2003) and Bayındır *et al.* (2013) reported that there was a general decline in ethylene productions of apple slices throughout storage period. The effect of treatments on ethylene production of apple slices was not significant, however, lovastatin treated apples had the lowest values (0.11 and 0.31 ppm) at the end of storage in both years. Koyuncu *et al.* (2010) indicated similar effects of lovastatin and 1-MCP.

The effects of storage period and treatments on microbial activity of apple slices were significant (data are not showed) in both years (P<0.05). The number of total bacteria on fresh cut apple slices increased with increasing storage period in all treatments. Similarly, the number of yeasts and molds increased steadily during storage period. The lowest average yeast and mold counts were determined in apple samples treated with lovastatin. While hot water was limiting application for bacteria in first year, 1-MCP gave better results in second year compared to other treatments. It can be said that storage duration was more effective than treatments in terms of microbial quality of stored apple slices. Similar results were obtained by Muthuswamy *et al.* (2008) in fresh cut apples during storage. Bett *et al.* (2001) also reported that storage duration was important factor for microbial activity of apple slices.

Table 5.

Ethylene production (ppm) of cold stored apple slices after different postharvest treatments

Storage period (days)								
	First Year				Second year			
Treatment	**0**	**7**	**14**	**Mean**	**0**	**7**	**14**	**Mean**
Control	0.69	0.10	0.17	0.32[2]	2.68	3.32	1.07	2.36[2]
Hot water	0.88	0.19	0.24	0.44	0.98	2.49	1.65	1.71
1-MCP	0.67	0.25	0.32	0.41	1.11	2.01	0.80	1.31
Lovastatin	0.76	0.13	0.11	0.33	3.46	1.95	0.31	1.91
Mean	0.75a[1]	0.17b	0.21ab		2.06a[1]	2.44a	0.96b	

[1] Means followed by different letters with in the same row and column are significantly different at *P*<0.05, [2] not significant

CONCLUSIONS

1-MCP treated apple slices had a little higher titratable acidity and L* values than those of the other treatments. Generally, lovastatin and 1-MCP treated apple slices gave better results for microbial activity than those of hot water and control applications. It can be said that fresh–cut 'Braeburn' apple could be stored at 0°C and 90±5 relative humidity for 7 days without significant quality losses.

REFERENCES

1. **Bayındır D., Dilmaçünal T., Koyuncu M.A., Onursal C. E. 2013 -** *Effects of some treatments on the quality of fresh-cut 'Pink Lady' apples during cold storage*. Acta Hort. 1012:1057-1064.
2. **Blankenship S.M., Dole J. M. 2003 -** *1-Methylcyclopropene:* a review. Postharvest Biol. Technol., 28, 1-25.
3. **Bett K.L., Ingram D.A., Grimm C.C., Lloyd S.W., Spanier A.M., Miller J.M., Gross K.C., Baldwin E.A., Vinyard B.T., 2001 -** *Flavor of fresh-cut 'Gala'apples in barrier film packaging as affects by storage time.* J. Food Safety 24, 141-156.
4. **Buta J. G., Moline H. E., Spaulding D. W., Wang C. Y., 1999 -** *Extending Storage Life of Fresh-Cut Apples Using Natural Products and Their Derivatives. J*. Agr. Food Chem., 47(1), 1-6
5. **Calderon-Lopez B., Bartsch J.A., Lee C., Watkins B.C. 2005 -** *Cultivar effects on quality of fresh cut apple slices from 1-MCP treated apple fruit.* J. Food Sci. 70 (3), 221-227.
6. **Chung H.S.,–Moon K.D. 2009 -** *Browning characteristics of fresh-cut "Tsugaru" apples as affected by pre-slicing storage atmospheres.* Food Chem. 114, 1433-1437.
7. **Eissa H.A., Fadel H., Ibrahim G. E., Hassan I. M., Elrashid A. A., 2006 -** *Thiol containing compounds as controlling agents of enzymatic browning in some apple products*. Food Res. Int. 39, 855–863.
8. **Fan X., Niemera B. A., Mattheis J. P., Zhuang H., Olson D. W. 2005 -** Quality *of fresh-cut apple slices as affected by low-dose ionizing radiation and calcium ascorbate treatment.* J. Food Sci., 70(2), 143-148.
9. **Ju Z, Curry E.A., 2000 -** *Lovastatin inhibits α-farnesene synthesis without affecting ethylene production during fruit ripening in "Golden Supreme" apples*. J. Amer. Soc. Hort. Sci. 125:105-110.
10. **King A. D., Bolin H. R., 1989 -** *Physiological and microbiological storage stability of minimally processed fruits and vegetables.* Food Technology, 43, 132–135.
11. **Koyuncu M.A., Koyuncu F., Dilmaçünal T., Kuleaşan H., Çetinbaş M., Güçlü, F., 2010 -** *Cold storage of fresh-cut "Granny Smith" apples.* Acta Hort. 876:307-319.
12. **Kupferman E., 2001 -** *Storage scald of apples.* URL: www.postharvest.tfrec.wsu.edu/EMK2000C. pff.
13. **Muthuswamy S., Rupasinghe H.P.V., Stratton G. W., 2008 -** *Antimicrobial effect of cinnamon bark extract on Escherichia coli ol 57:H7, Listeria innocua and fresh cut apple slices.* J. F. Saf., 28, 534-549.
14. **Perera C.O., Balchin E., Baldwin L., Stanley R., Tian M., 2003 -** *Effect of 1-MCP on the quality of fresh-cut apple slices.* J. Food Sci. 68 (6), 1910-1914.
15. **Raybaudi-Massilia R. M., Mosqueda-Melgar J., Sobrino-Lopez A., Soliva-Fortuny, R., Martin-Belloso O., 2007 -** *Shelf-life extension of fresh-cut "Fuji" apples at different ripeness stages using natural substances.* Postharvest Biol. Technol., 45, 265–275.

16. **Rosaj-Graü M A, Sobrino-Lopez A., Tapia S. A., Martin-Belloso O., 2006 -** *Browning inhibition in fresh-cut 'Fuji' apple slices by natural antibrowning agents.* J. Food Sci., 71(1), 59-65.
17. **Rupasinghe H.P.V., Murry D.P., DeEll J.R., Odumeru J., 2005 -** *Influence of 1-Methylcyclopropene and natureseal on the quality of fresh-cut "Empire" and "Crispin" apples.* Journal of Food Quality 28:289307.
18. **Varoquaux P., Lecendre I., Varoquaux F., Souty, M., 1990 -** *Changes in firmness of kiwifruit after slicing*. Sci. Aliment 10, 127-139.
19. *****, 2016 - FAO** http://faostat.fao.org