INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 3, No. 4, p. 75-83, 2013

RESEARCH PAPER OPEN ACCESS

Effect of some essential oils on post harvest quality of grapevine (*Vitis vinifera* cv Rasha (Siah-e-Sardasht)) during cold storage

Loghman Salimi[1], Mousa Arshad[2], Abdol Rahman Rahimi[3*], Asad Rokhzadi[3], Sheno Amini[4], Majid Azizi[5]

[1]*Mahabad Branch, Islamic Azad University, Mahabad, Iran*

[2]*Department of Horticulture science, Mahabad Branch, Islamic Azad University, Mahabad, Iran*

[3]*Department of Agronomy and Plant Breeding, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran*

[4]*Young Researchers and Elites Club, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran*

[5]*Department of Horticulture science, Ferdowsi University of Mashhad, Mashhad, Iran*

Key words: Essential oils, grapevine, postharvest, quality parameters.

doi: http://dx.doi.org/10.12692/ijb/3.4.75-83 Article published on April 22, 2013

Abstract

This experiment was carried out in order to study the influence of some essential oils on post harvest quality of grapevine (*Vitis vinifera*) cv. Rasha (Siah-e-Sardasht). The treatments included control (distilled water) and concentrations 250 and 500 ppm of basil (*Ocimum basilicum*), wild mint (*Mentha longifolia*) and ajowan (*Carum copticum*) essential oils at two periods of 30 and 60 days storage. Results showed that essential oils decreased the decay and weight loss percentage at both storage periods. In the final stage of experiment all essential oils improved total soluble solids (TSS), maturity index and vitamin C content, while decreased titratable acidity (TA) compared with control. Decay rate, vitamin C loss and weight loss were increased by increasing storage period, whereas the application of essential oils declined these traits. The concentrations of 500ppm of basil essential oil and 250ppm of ajowan essential oil were more effective on controlling decay and weight loss, respectively. Also, the highest contents of vitamin C were obtained by concentrations of 250 and 500ppm of basil essential oil at the first and the second periods of storage, respectively.

* **Corresponding Author:** Abdol Rahman Rahimi ✉ abdolrahmanrahimi60@gmail.com

Introduction

Grapevine (*Vitis vinifera*) cv. Rasha (Siah-e-Sardasht) is one of the most important grape cultivars in Azarbayjan-e-Gharbi and Kurdistan that is cultivated as rainfed widely. Also it is important economically due to the high quality of the fruit and high storage capacity (Doulati Baneh *et al.*, 2011). Generally, the quality and shelf life of grape limited by many factors such as weight loss, firmness loss, berry shattering, stem browning and decay (Perkins-Veazie *et al.*, 1992; Crisoto *et al.*, 2001; Zutahy *et al.*, 2008). Fungal decay is the major problem in reducing the quality and the postharvest longevity of grape and the fungus *Botrytis cinerea* has an important role in this respect (Lichter *et al.*, 2005). In addition, *Aspergillus niger* Tiegh, *Rhizopus stolonifer* (Ehrenb: Fr.) Vuill, *Penicillium* spp. and *Mucor* sp. have been known as the most common pathogens of grape crop (Nelson, 1985; Snowdon 1990). Fumigation the storage by sulfur dioxide (SO2) is the common method to control grape decay (Luvisi *et al.*, 1992; Kou *et al.*, 2009). However, the use of SO2 is associated with many problems such as cracking, discoloration, bleaching and hairline in berry and browning of the rachis of grape (Zoffoli *et al.*, 2008; Kou *et al.*, 2009; Jalili Marandi *et al.*, 2010). In addition, sulfite residues can cause allergy in consumers and it is harmful to health. Therefore, Use of sulfites has been restricted in many countries (Lurie *et al.*, 2006).

In spite of consumer demand, the use of natural compounds has not been increased (Lanciotti *et al.*, 2004). Thus, seeking to obtain suitable natural compounds as a safe alternative source with chemical compounds is essential for improvement post-harvest life of horticultural products and for circumvention of the bio-environmental problems induced by these compounds. Essential oils which are one of the natural compounds in most of plants are used as medicinal, antimicrobial, antioxidantal substances, etc. (Omidbaigi, 2005). Also, the essential oils are biodegradable and eco-friendly and have been considered by scientists' worldwide (Asghari Marjanlo *et al.*, 2009). Recent experiments show that plant essential oils are effective for quality maintenance and improvement of post-harvest longevity in fruits and vegetables (Martínez-Romero *et al.*, 2004; Serrano *et al.*, 2005; Alikhani *et al.*, 2009; Abdolahi *et al.*, 2010; Mousavizadeh *et al.*, 2011). Because of possible application of essential oils as natural antimicrobial and antioxidant agents in fresh horticultural crops, they may be considered as valuable alternatives for preserving physical and chemical properties of food plants. Therefore, the purpose of this experiment was to prolong the postharvest life and maintaining the quality parameters in grapevine (*Vitis vinifera* cv Rasha: Siah-e-Sardasht) with application of basil (*Ocimum basilicum*), wild mint (*Mentha Longifolia*) and ajowan (*Carum copticum*) essential oils during cold storage.

Material and methods

Plant material

A laboratory experiment was conducted at Islamic Azad University, Sanandaj Branch,
Kurdistan, Iran. Fresh Grapevine (Vitis vinifera) cv. Rasha (Siah-e-Sardasht) was obtained from a local garden in Baneh, Kurdistan, Iran. The grapes were harvested at a stage preceding the commercial distribution in October 2011. Immediately the grapes were transferred to laboratory and selected based on homogeneous colour, size and absence of visual defects and any infection. The essential oil of basil, wild mint and ajowan were extracted by hydrodistillation using the clevenger and were obtained from Ferdowsi University of Mashhad.

Treatment setting

The treatments included control (distilled water) and concentrations 250 and 500 ppm of basil, wild mint and ajowan essential oils. One kg of the grapes was sprayed by different concentrations of essential oil using a hand-sprayer. Then the grape berries were distributed in plastic boxes and placed in cold storage at 1±1°C and the relative humidity of 55-65% for two periods of 30 and 60 days.

Decay evaluation

For evaluation of decay, the total of berries showing any visible decay in each replicate was counted and expressed as decay percentage at each period of storage (Kou *et al.*, 2009).

Quality evaluations

Quality evaluation was performed at 30 and 60 days after storage. At each evaluation time, the fruit were recorded for weight loss, titratable acidity (TA), total soluble solids (TSS), maturity index (MI) and vitamin C.

The content of weight loss was determined by difference between weights of fruit at evaluation time and initial weight and then expressed as percentage loss of initial weight.

Twenty berries from each replicate were sampled randomly for juice extraction with a hand-press juicer. The juice was filtered and used for traits evaluation.

Titratable acidity content was determined by titrating 10 ml of berry flesh juice with 0.1 N NaOH using fenolftaleine-indicator and to an endpoint of pH 8.1 and then expressed as percentage of tartaric acid. Total soluble solids was determined with a digital refractometer and expressed in °Brix (Jalili Marandi *et al.*, 2010). Maturity index was calculated with TSS/TA ratio (Abdolahi *et al.*, 2010). Ascorbic acid content was determined by the iodine titration method, then expressed as percentage (mg vitamin c per 100gr juice) (Suntornsuk *et al.*, 2002).

Statistical analysis

The experiment was established in a factorial lay out based on completely randomized design with four replications. Data were analyzed using SAS software (2001) and the mean values were compared using the LSD test at $P \leq 0.05$.

Results and discussion

Decay

Analysis of variance showed that the grape decay at 1% probability was significantly influenced by applied treatments (Table 1). After both storage periods, all essential oils reduced decay than control significantly and the lowest rate of decay was obtained by 500ppm basil essential oil. At 30 days after storage none of essential oils and different concentrations had not significant difference from one another. While, after 60 days grape decay was significantly decreased with increasing of wild mint essential oil concentration. Decay content was increased significantly in control and 250ppm concentration of wild mint and ajowan essential oils with increasing of storage period (Table 2).

Table 1. ANOA of essential oils (EO) and storage period (SP) on decay, weight loss, vitamin C, total soluble solids (TSS), maturity index (MI), and titratable acidity (TA) in grapevine cv. Rasha during storage.

	df	Decay	Weight loss	Vitamin C	TA	TSS	MI
EO	6	73.03 **	6.36 **	51.97 **	0.03 **	1.58 **	88.98 **
SP	1	129.02 **	122.37 **	546.32 **	0.00 ns	2.49 ns	0.24 ns
EO * SP	6	19.90 **	1.53 *	24.16 *	0.03 **	11.11 **	1244.88 **
CV (%)	-	22.31	12.34	14.84	2.56	3.07	4.68

** ($P<0.01$), * ($P<0.05$), ns ($P>0.05$), df (degree of freedom)

The results revealed that the essential oils decreased the decay and increased life storage grape effectively. Similarly, fungal decay in table grape was reduced by essential oils of *Thymus kotschyanus* and *Carum copticum* after 40 days storage (Jalili Marandi *et al.*, 2010). Abdolahi *et al* (2010) reported that application of *Foeniculum vulgare*, *Thymus vulgaris*, *Satureja hortensis* and *Ocimum basilicum* essential oils decreased the decay in tabarzeh table grape. In previous studies, have been showed the positive effect of essential oils and volatile compounds on reducing of fruit decay in several fruits including table grapes (Martínez-Romero *et al.*, 2004; Valero *et al.*, 2006; Abdolahi *et al.*, 2010), apricots and plums (Liu *et al.*, 2002), sweet cherry (Serrano *et al.*, 2005) strawberry (Tzortzakis, 2007) apple (Shahi *et al.*, 2003), and pear (Alikhani *et al.*, 2009). Also inhibitory effect of essential oils against fungus growth such as *Botrytis cinerea*, *Rhizopus stolonifer* (Reddy *et al.*, 1998; Asghari Marjanlo *et al.*, 2009; Abdolahi *et al.*, 2010) *Aspergillus flavus* (Bouchra *et al.*, 2003) indicated the antifungal activity of essential oils in controlling of fruit decay. The mechanisms of the antimicrobial activity of essential oils are poorly understood for us, but according to previous reports, it seems that damage to cell walls and membrane structure and function is as antimicrobial action of essential oils (Cox *et al.*, 2000; Rattanapitigorn *et al.*, 2006).

Table 2. Mean values of the effects of basil, wild mint and ajowan essential oils (BEO, MEO and AEO respectively) on decay, weight loss, and vitamin C in grapevine cv. Rasha during 30 days and 60 days after storage.

Treatments	Decay (%)		Weight loss (%)		Vitamin C (%)	
	30 days	60 days	30 days	60 days	30 days	60 days
BEO*250 ppm	5.00 ef	6.88 def	3.73 g	6.37 cd	27.03 ab	17.92 d
BEO*500 ppm	4.38 f	5.63 ef	4.25 fg	7.51 b	22.97 bc	17.45 d
MEO*250 ppm	6.25 def	9.38 b	4.10 fg	7.63 b	29.73 a	18.87 cd
MEO*500 ppm	5.00 ef	6.25 def	4.33 fg	7.61 b	27.03 ab	22.17 cd
AEO*250 ppm	5.62 ef	8.13 bcd	3.95 fg	5.47 de	21.62 cd	20.28 cd
AEO*500 ppm	5.00 ef	6.25 def	4.98 ef	7.27 bc	22.97 bc	19.81 cd
Control	8.75 bc	18.75 a	5.42 de	9.59 a	21.62 cd	12.74 e
Average	5.71 b	8.75 a	4.39 b	7.35 a	24.71 a	18.46 b

Means with the same letters in each trait do not significantly differ by LSD tests ($p < 0.05$).

Weight loss

The results of variance analysis in our study demonstrated that the effect of different essential oils and storage time on fruit weight loss percentage is significant (Table 1). In this case the results showed that all essential oils except the 500ppm ajowan essential oil significantly controlled the weight loss of grape compared to the control after 30 days of storage.

After 60 days of storage, all essential oils significantly decreased the weight loss of grape especially by 250ppm of ajowan essential oil (Table 2). In wild mint essential, there was no significant difference between the two concentrations used, while in basil and ajowan essential oils with increasing the concentration of essential oil, the weight loss of grapes were increased significantly. Also, the increasing of storage time from 30 days to 60 days significantly increased the weight loss of grapes in all treatments (Table 2).

Corresponding results were reported by, Abdolahi *et al* (2010) and Martínez-Romero *et al.*, 2004 in table grapes, Serrano *et al* (2005) in sweet cherry, Mohammadi and Aminifard (2012) in Peach. They revealed that usage of essential oils or volatile compounds reduced the weight loss in fruits.

Water loss is the overriding factor influencing postharvest longevity, and it can affect weight loss directly or several other factors such as losses in appearance, textural quality, and nutritional quality (Kader and Rolle., 2004). Water losses are as a result of transpiration from the surface of fruits (wu, 2010) or fruit respiration (Lownds *et al.*, 1994). Also, mechanical and decay damage leading to loss of water and ultimately fruit weight loss. So, according to above statement, the reducing of water and weight loss by essential oils can be attributed to controlling of decay and its damages or by decreasing of respiration rates.

Maturity index, TA, TSS

Based on ANOVA (Table 1), the results revealed that there were a significant difference ($P<0.01$) in the effects of essential oils and the two-lateral interaction of experimental factors (essential oils × storage period) on TA, TSS and maturity index in the grape. While, there were no significant difference between two storage periods.

Table 3. Mean values of the effects of basil, wild mint and ajowan essential oils (BEO, MEO and AEO respectively) on total soluble solids (TSS), maturity index (MI), and titratable acidity (TA) in grapevine cv. Rasha during 30 days and 60 days after storage.

Treatments	TA (%)		TSS (°Brix)		MI (TSS/TA)	
	30 days	60 days	30 days	60 days	30 days	60 days
BEO*250 ppm	0.68 b	0.58 c	20.20 cdef	20.75 abc	29.58 e	35.69 bcd
BEO*500 ppm	0.70 b	0.58 c	19.83 def	20.63 abcd	28.29 e	35.72 bcd
MEO*250 ppm	0.54 de	0.57 c	20.38 bcde	19.63 ef	38.03 b	34.43 d
MEO*500 ppm	0.50 f	0.55 d	21.00 abc	20.23 cdef	41.88 a	36.88 bc
AEO*250 ppm	0.54 de	0.49 f	18.58 g	21.38 a	34.73 cd	43.61 a
AEO*500 ppm	0.53 e	0.51 f	19.35 fg	21.13 ab	36.66 bcd	41.64 a
Control	0.50 f	0.73 a	21.50 a	17.00 h	43.03 a	23.31 f
Average	0.57 a	0.57 a	20.12 a	20.10 a	36.03 a	35.90 a

Means with the same letters in each trait do not significantly differ by LSD tests ($p < 0.05$).

From the results (Table 3), at 30 days after storage all used essential oils except the 500ppm of wild mint, decreased the maturity index and TSS; they also increased the titratable acidity. Basil essential oil led to the highest value and the lowest value of maturity index and titratable acidity, respectively, and in this case significant differences were observed with the other treatments.

According to table 3, our results showed that unlike the results in the first period, all essential oils decreased the titratable acidity, while improved the maturity index and TSS compared with control at 60 days after storage. Ajowan essential oil, especially at concentration of 500ppm was the most effective in improving the mentioned traits. Maturity index as TSS/TA with the increase the storage period from 30 days to 60 days were decreased in the wild mint essential oil and control, while it was increased by both concentrations of ajowan and basil essential oils. Abdolahi *et al* (2010) reported that usage of sweet basil, fennel, summer savory and thyme essential oils on table grape reduced the TSS and maturity index, which is in agreement with our results at 30 days after storage and opposite with results for the second period storage. On the other hand, Jalili Marandi *et al* (2010) reported that *Thymus kotschyanus* and *Carum copticum* essential oils had no significant effect on TSS, titrable acidity and maturity index in table grape. Mohammadi and Aminifard (2012) concluded that the peach fruits treated with anis, ammi, ziziphora and Cinnamon essential oils had a greater TSS and titratable acidity than control.

Our results demonstrated that the TSS and maturity index in the grapes treated with essential oils were lower than control (untreated fruit) at 30 days after storage. While, titratable acidity was below in untreated fruit. Probably it could be related to delay or decreases in metabolic activity, respiration and senescence in due essential oils (Mahajan *et al.*, 2010), whereas it will be done more quickly in control treatment. Also, in this case Mahajan *et al* (2010) suggested that organic acids were used in respiratory process or other biodegradable metabolic reactions. On the contrary, after 60 days of storage the grapes treated with all essential oils had a higher maturity index (high TSS and low TA) than untreated fruit. It seem, due to the evaporation of essential oil during the storage after 60 days, metabolic activity and respiration were increased gradually and lead to increase in maturity index and decrease in titratable acidity in treated fruits. Moreover, in control fruits the increase of microbial spoilage, degradation of fruits and over senescence led to decrees in TSS and maturity index.

Vitamin C

Based on variance analysis (Table 1), the results showed that the effects of essential oils, storage period and essential oils × storage period on vitamin C content in grape are significant (P<0.01).

As shown in table 2 the application 250 ppm of basil essential oil and wild mint essential oil at both concentrations led to an increase content of vitamin C compared to control at 30 days after storage. In this case the highest content of vitamin C was obtained by 250 ppm basil essential oil; in all essential oils there is no significant difference between the two applied concentrations. Also in all treatments except ajowan essential, with the increasing of storage time from 30 days to 60 days, the amount of vitamin C was significantly decreased. Vitamin C content in all treatments was higher than the control at 60 days after storage (Table 2). These results are in agreement with those obtained by Asghari Marjanlo *et al* (2010), who reported that the application of basil essential oil in low concentration increased the vitamin C content in strawberry. Low-impact ajowan essential oil in the maintaining of vitamin C after 30 days of storage, May be related to stress caused by it. Because, in accordance with the results of weight loss, concentration 500 ppm of ajowan essential oil were a similar weakening effect on the trait mentioned. It seemed with the evaporation of the essential oils with increasing storage time, the stress is reduced; also with emphasis on the control of the weight loss and decay, vitamin C was maintained by essential oils. whereas in the control treatment probably due to decay, loss of fruit juice, weight loss and stress and damage from this cases, vitamin C was declined to the lowest level of possible sharply. In addition, degradation of vitamin C increases by many factors such as water loss, chilling injury, mechanical injuries and the increase of storage time (Lee and Kader, 2000).

Conclusion

In the present study, it was found that exogenous application of essential oils as well as maintained the quality parameters, decreased the decay and increased life storage of grapevine cv. Rasha (Siah-e-Sardasht), effectively. So the essential oil as safe and eco-friendly compound could be potentially used to increase the postharvest life of fruit and vegetable as an alternative with chemical compounds.

References

Abdolahi A, Hassani A, Ghosta Y, Bernousi I, Meshkatalsadat M. 2010. Study on the potential use of essential oils for decay control and quality preservation of 'Tabarzeh' table grape. Journal of Plant Protection Research **50**, 45-52. http://dx.doi.org/10.2478/v10045-010-0008-2

Alikhani M, Sharifani M, Azizi M, Hemmati K, Mousavizadeh SJ. 2009. The effect of some natural compounds in shelf-life and quality of Pear fruit (Esfahan Shah mive cultivar) (In Persian). Journal of Agricultural Science and Natural Resources **16**, 158-171.

Asghari Marjanlo A, Mostofi Y, Shoeibi Sh, Fattahi M. 2009. Effect of cumin essential oil on postharvest decay and some quality factors of strawberry. Journal of Medicinal Plants **8**, 25-43.

Asghari Marjanlo A, Mostofi Y, Shoeibi Sh, Maghomi *M*. 2010. Effect of basil essential oil on postharvest decay and some quality factors of strawberry ('Selva') (In Persian). Journal of Medicinal Plants **8**, 131-139.

Bouchra C, Achouri M, Idrissi Hassani LM, Hmamouchi M. 2003. Chemical composition and antifungal activity of essential oils of seven Moroccan Labiatae against *Botrytis cinerea* Pers: Fr. Journal of Ethnopharmacology **89**, 165-169. http://dx.doi.org/10.1016/S0378-8741(03)00275-7

Cox SD, Mann CMl, Markham JL, Bell HC, Gustafson JE, Warmington JR, Wylie SG. 2000. The mode of antimicrobial action of the essential oil of *Melaleuca alternifolia* (tea tree oil). Journal of Applied Microbiology **88**, 170-175. http://dx.doi.org/10.1046/j.1365-2672.2000.00943.x

Crisoto CH, Smilanick JL, Dokoozlian NK. 2001. Table grapes suffer water loss, stem browning during cooling delays. California Agriculture **55**, 39-http://dx.doi.org/42. 10.3733/ca.v055n01p39

Doulati Baneh H, Jalili R, Samet Kh, Amani A. 2011. Effect of polyethylene cover and sulfer pad on storage life of grapvine (*Vitis vinifera*) cv. Rasha (Siah-e-Sardasht) (In Persian). Journal of Seed and Plant Production **26**, 457-471.

Jalili Marandi R, Hassani A, Ghosta Y, Abdollahi A, Pirzad A, Sefidkon F. 2010. *Thymus kotschyanus* and *Carum copticum* essential oils as botanical preservatives for table grape. Journal of Medicinal Plants Research **4**, http://dx.doi.org/2424-2430. 10.5897/JMPR10.421

Kou L, Luo Y, Ding W, Liu X, W Conway. 2009. Hot water treatment in combination with rachis removal and modified atmosphere packaging maintains quality of table grapes. HortScience **44**, 1947-1952.

Kader AA, Rolle RS. 2004. The role of postharvest management in assuring the quality and safety of horticultural produce. Rome, FAO Agricultural Services Bulletin **152**, p. 51.

Lanciotti R, Gianotti A, Patrignani F, Belletti N, Gverzoni ME, Gardini F. 2004. Use of natural aroma compound to improve shelf life and safety of minimally processed fruit. Trends in Food Science and Technology **15**, 201-208. http://dx.doi.org/10.1016/j.tifs.2003.10.004

Lee SK, Kader AA. 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology **20**, 207–220. http://dx.doi.org/10.1016/S0925-5214(00)00133-2

Lichter A, Zutahy Y, Kaplunov T, Aharoni N, Lurie S. 2005. The Effect of ethanol dip and modified atmosphere on prevention of *Botrytis* rot of table grape. Hort Technology **15**, 284- 291.

Liu WT, Chu CL, Zhou T. 2002. Thymol and acetic acid vapors reduced postharvest brown rot of apricots and plums. HortScience **37**, 151–156.

Lownds NK, Banaras M, Bosland PW. 1994. Postharvest water loss and storage quality of nine pepper (capsicum) cultivars. HortScience **29**, 191-193.

LurieS, Pesis E, Gadiyeva O, Feygenberg O, Ben-Arie R, Kaplunov T, Zutahy Y, Lichter A. 2006. Modified ethanol atmosphere to control decay of table grapes during storage. Postharvest Biology and Technology **42**, 222–227. http://dx.doi.org/10.1016/j.postharvbio.2006.06.011

Luvisi DA, Shorey H, Smilanick JL, Thompson J, Gump B, Knutson J. 1992. Sulfur dioxide fumigation of table grapes. University of California, Division of Agriculture and Natural Resources, Bulletin 1932, DANR Publications, Oakland CA, 21 p.

Mahajan BVC, Arora NK, Gill MIS, Ghuman BS. 2010. Studies on extending storage life of 'Flame Seedless' Grapes. Journal of Horticulture Science and Ornamental Plants **2**, 88-92.

Martínez-Romero D, Castillo S, Serrano M, Valverde JM, Guillén F, Valero D. 2004. The use of natural aromatic essential oils helps to maintain postharvest quality of 'Crimson' table grapes. Proceedings of the 5th International Postharvest Symposium. 6-11 June 2004, Verona, Italy. p, 1723-1727.

Mohammadi S, Aminifard MH. 2012. Effect of essential oils on postharvest decay and some quality factors of peach (*Prunus persica* var. Redhaven). Journal of Biological and Environmental Sciences **6**, 147-153.

Mousavizadeh SJ, Sedaghathoor S, Khorami H. 2011. Essential oils as reducing agents of cabbage peroxidase. Scientia Horticulturae **128**, 388-392. 10.1016/j.scienta.2011.01.027

Nelson KE. 1985. Harvesting and handling California table grapes for market. University of California, Division of Agriculture and Natural Resources, Bulletin 1913, DANR Publications, Oakland CA, p. 72.

Omidbaigi R. 2005. Production and processing of medicinal plants. Vol 2.Tehran. Astan Quds. In Persian.

Perkins-Veazie PM, Collins JK, Lloid J, Striegler RK. 1992. Influence of package on postharvest quality of oklahoma and arkansas table grapes. American Journal of Enology and Viticulture **43**, 79-82.

Rattanapitigorn P, Arakawa M, Tsuro M. 2006. Vanillin enhances the antifungal effect of plant essential oils against *Botrytis cinerea*. International Journal of Aromatherapy **16**,193-198. http://dx.doi.org/10.1016/j.ijat.2006.09.003

Reddy MVB, Angers P, Gosselin A, Arul J. 1998. Characterization and use of essential oil from *Thymus vulgaris* against *Botrytis cinerea* and *Rhizopus stolonifer* in strawberry fruits. Phytochemistry **47**, 1515-1520. http://dx.doi.org/10.1016/S0031-9422(97)00795-4

SAS Institute. 2001. SAS/StaTUserˇıs Guide.Version9. SAS Institute, Cary, NC.

Serrano M, Martínez-Romero D, Castillo S, Guillén F, Valero D. 2005. The use of natural antifungal compounds improves the beneficial effect of MAP in sweet cherry storage. Innovative Food Science and Emerging Technologies **6**, 115-123. http://dx.doi.org/10.1016/j.ifset.2004.09.001

Shahi SK, Patra M, Shukla AC, Dikshit A. 2003. Use of essential oil as botanical- pesticide against postharvest spoilage in *Malus pumilo* fruits. Biocontrol **48**, 223-232. http://dx.doi.org/10.1023/A:1022662130614

Snowdon AL. 1990. A color atlas of post-harvest diseases and disorders of fruits and vegetables, vol 1: general introduction and fruits. Boca Raton, FL: CRC Press, p. 302.

Suntornsuk L, Gritsanapun W, Nilkamhank S, Paochom A. 2002. Quantitation of vitamin C content in herbal juice using direct titration. Journal of pharmaceutical and Biomedical Analysis **28,** 849-855. http://dx.doi.org/10.1016/S0731-7085(01)00661-6

Tzortzakis NG. 2007. Maintaining postharvest quality of fresh produce with volatile compounds. Innovative Food Science and Emerging Technologies **8**, 111-116. http://dx.doi.org/10.1016/j.ifset.2006.08.001

Valero D, Valverde JM, Martínez-Romero D, Guillén F, Castillo S, Serrano M. 2006. The combination of modified atmosphere packaging with eugenol or thymol to maintain quality, safety and functional properties of table grapes. Postharvest Biology and Technology **41**, 317-327. http://dx.doi.org/10.1016/j.postharvbio.2006.04.011

Wu CT. 2010. An overview of postharvest biology and technology of fruits and vegetables. Technology on Reducing Post-harvest Losses and Maintaining Quality of Fruits and Vegetables. Proceedings of 2010 AARDO Workshop. Held at Taiwan Agricultural Research Institute, Council of Agriculture, Taiwan, ROS. 3-9 October 2010. p, 2-11.

Zoffoli JP, Latorre BA, Naranjo P. 2008. Hairline, a postharvest cracking disorder in table grapes induced by sulfur dioxide. Postharvest Biology and Technology **47**, 90–97. http://dx.doi.org/10.1016/j.postharvbio.2007.06.013

Zutahy Y, Lichter A, Kaplunov T, Lurie S. 2008. Extended storage of `Red Globe' grapes in modified SO2 generating pads. Postharvest Biology and Technolology **50,** 12-17. http://dx.doi.org/10.1016/j.postharvbio.2008.03.006