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Vacuum packaging optimises quality and reduces postharvest losses of pomegranate fruits

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ABSTRACT

Purpose: Pomegranate fruit is highly susceptible to water loss and chilling injuries during postharvest cold storage. Thus an experiment was conducted to evaluate the effects of modified atmosphere packaging on pomegranate shelf life and chilling resistance under cold storage. **Research method**: Treatments were vacuum packed and unpacked fruits (control) that were stored in a cold room at 5 ± 0.5 °C and 80 ± 5% RH. At the end of each storage period (30, 40, 50, 70, 90 and 130 days), packed fruits were assessed for physicochemical and quality parameters while control fruit were assessed after 90 days of storage. **Findings:** Results showed that packaging improves TSS/TA, and some color attributes, and decreased anthocyanin, total acidity, weight loss, electrolyte leakage, chilling injury index and unmarketable fruits. Evaluation of traits in different durations showed that vacuum packaging significantly reduced weight loss, electrolyte leakage, chilling injury index, and interestingly decreased the number of unmarketable fruits by 30%, compared with control. Anthocyanin contents significantly decreased since day 70 of storage. The *a** and chroma values of peel significantly increased in packaging treatments as storage period progressed, however, hue value significantly decreased, compared with control. **Research limitations:** There was no significant limitation to report. **Originality/Value:** The results suggest that bulk vacuum packaging can be used for up to 3 months to successfully alleviate chilling injury, reduce weight loss and the postharvest losses, and to extend the storage life of pomegranate fruit during cold storage.

INTRODUCTION

Pomegranate is a non-climacteric fruit that will not continue to ripen once they are picked, thus the fruits must be picked in fully mature stage (Kader et al., 1984).

Losses of horticultural produce are a major problem in the postharvest chain. Therefore, minimizing postharvest losses of horticultural products, which is estimated at about 20-50% of the total production in the world, is a very effective way of increasing food availability (Kader, 2004). Loss of quantity is more common in developing countries due to lack of the availability of basic postharvest equipment, tools, and supplies in rural areas such as packinghouses, packages, storage structures and processing equipment (Kitinoja & Gorny, 1999). Hence, various postharvest treatments are employed to improve the quality and to extend the postharvest life of fresh products. It is well known that using different pretreatments, low storage temperature and packaging are most important to reduce postharvest losses (Caleb, 2012; Pareek, 2015). Cold storage is the most reliable method available for extending the fresh condition of fruits and vegetables as it inhibits the destructive activities of decay-causing microorganisms and also slows down the normal process of deterioration. However, pomegranate which is a subtropical fruit is highly susceptible to water loss, chilling injuries, and decay caused by postharvest pathogens during cold storage as reported previously by several studies (Artés et al., 2000; Elyatem & Kader, 1984; Moradinezhad et al., 2013). For example, storage at or below 5 °C resulted in severe chilling injury symptoms on the fruit in the form of brown discoloration of the skin, surface pitting, and increased susceptibility to decay organisms (Elyatem & Kader, 1984). 'Shishe-Kab' is an Iranian cultivar with sweet, soft and red arils, and is strongly susceptible to water loss, chilling injuries and decay during storage (Moradinezhad et al., 2013; 2018). Different studies have shown that a combination of pre-storage chemical treatments and different packaging led to satisfactory results to maintain quality and reduces significant postharvest losses during prolonged cold storage in Shishe-Kab pomegranate cultivar (Moradinezhad et al., 2013; 2014; 2018; Ranjbari et al., 2016; 2018).

The ability of modified atmosphere packaging (MAP) to extend the shelf life of foods has been known for a long time. A modified atmosphere (MA) is created when fruits are sealed in polyethylene bags with a relatively low permeability to gases. The gaseous atmosphere of the package is likely to change during storage from metabolism of the product (the O_2 level decreases, and the CO_2 increases) and therefore the atmosphere becomes modified indirectly (Kader et al., 1994). The generic term also includes applications such as vacuum packaging (VP) (Yahia, 2009). The simplest most common means of modifying the internal gaseous atmosphere is a vacuum pack. Owing to microbial and product metabolism, and gas permeation, the atmosphere becomes modified.

Nowadays, vacuum packaged products are available in the markets which include fresh fruits and vegetables. This method provides a relatively low-cost alternative to controlled atmosphere storage.

Besides, lack of suitable harvest tools and trained harvesters in rural areas lead to improper harvesting and handling operations with less care and attention, which lead to damages caused by cuts and impact bruising during hand harvesting and overturning, and finally to quality deterioration and shortening of storage life. The pomegranate fruit is commonly loaded into large wooden pallet bins in the field and then are transported directly to the cold storage. However, after a few weeks of storage, they have to repack into open plastic boxes for size grading and also to separate damaged and infected fruits. To overcome with mentioned problems, we have tested a new methodology in a small-scale in which pomegranate fruit are directly harvested and vacuum packed into thick polyethylene bags in packhouse and then transferred to cold storage. The objectives of this work, therefore, were to evaluate the effect of the MAP including vacuum packaging (VP) on the physicochemical attributes and quality of pomegranate fruit cv. ‘Shishe-Kab’ during both short and long-term storage periods, as well as to determine the efficacy of a simple and low-cost postharvest technology and innovation in reducing postharvest losses and storage disorders compared to conventional handling and storage method.

MATERIALS AND METHODS

Preparing the plant material and packaging procedures

Pomegranate fruits ‘Shishe-Kab’ harvested from a commercial orchard in Ferdows, South Khorasan province, Iran during 2015 growing season. Fruits were handpicked at full maturity stage, early in November and immediately transported by a vehicle under protected conditions to the Postharvest Laboratory at University of Birjand, Iran. Fruits were then selected for uniformity in size (280-330 g), shape and color. Sunburned, bruised and injured fruits were discarded. Neither washing nor postharvest chemical treatments were applied. A total of 560 fruits were prepared and separated randomly into seven lots and used for the following treatments. Each fruit lot comprising four open top plastic boxes with dimensions of 45 cm long, 30 cm wide and 20 cm height (twenty fruits per box). One lot of the fruits allocated to control samples (fruits without any treatment and packing, were stored in open top plastic boxes for 90 days), and the six remained lots were used for vacuum packaged of fruit with various storage durations (30, 40, 50, 70, 90 and 130 days). For vacuum packing, 20 fruits (about 6 Kg) were placed in a medium Low-density Polyethylene (LDPE) bag (dimensions: 35 × 55 cm, with 50 μm thickness) and then the air in the bag was removed by a vacuum pump with a pressure of 350 mm of Hg, which made the bag completely collapsed around the fruit and sealed. Thereafter, vacuum packed and unpacked fruits (control) were placed in open plastic boxes and then stored in a cold room at 5 ± 0.5 °C and RH 80 ± 5%. At the end of each storage period (30, 40, 50, 70, 90 and 130 days), packed fruits were transferred to the lab and were assessed for physicochemical and quality parameters, decay and CI, while control fruit evaluated after 90 days of cold storage.

Physicochemical properties

Titratable acidity, pH, total soluble solids

Titratable acidity (TA) was determined by titration of 2 ml of juice with 0.1 M NaOH to an end point of pH 8.1 and results were showed as a percentage of citric acid. The pH was measured at room temperature using a pH meter. Total soluble solids (TSS) was determined with a hand-held refractometer (RF 10, °Brix 0–32, Extech Co., USA) at 25 °C, and expressed as °Brix.

Total anthocyanin content evaluation

Total anthocyanin content (TAC) was determined spectrophotometrically by the pH differential method (Lako et al., 2007). Absorbance was measured at 510 and 700 nm in buffers at pH 1.0 and 4.5 using spectrophotometer (Model Unico 2100, China), and then calculated according to the following equations (1, 2):

$$A = [(A510 - A700)\ pH_{1.0} - (A510 - A700)\ pH_{4.5}]. \quad (1)$$

Results were expressed as mg of cyanidin-3-glucoside per 100 mL of juice, using a molar absorptive coefficient (ε) of 26,900 and a molecular weight of 449.2, and then total anthocyanin content was calculated as follows (2):

$$\text{Total anthocyanin}\left(\frac{\text{mg}}{\text{l}}\right)=\frac{\text{A}\times\text{MW}\times\text{DF}\times 1000}{\varepsilon} \tag{2}$$

Where A=absorbance; MW= molecular weight of cyanidin-3-glucoside; DF=the degree of dilution; ε= molar absorptive coefficient.

Weight loss

To determine weight loss, the individual fruit was weighed at harvest time (day 0) and after storage period (day 90). The weight loss was calculated as follows (3):

$$\text{W}=\frac{\text{W1}-\text{W2}}{\text{W1}}\times 100 \tag{3}$$

Where W = weight loss (%) of fruit; W1 = initial weight (g) of the fruit at the beginning of storage and W2 = final weight (g) of the fruit at end of storage period. Weight loss was calculated for each storage temperature on 3 individual fruits.

Electrolyte leakage (EL) measurement

Leakage of ions from disks of fruit peel was measured according to the method by Li et al. (2014) with some modifications. 2.5 cm diameter disks of fruit skin per replication were taken from fruit and placed in 20 ml of deionized water at ambient temperature for 24 hours. Conductivity was measured with an electrical conductivity meter (C1). The same disks were kept in a boiling water bath (100°C) for 1 hour to release all electrolytes, cooled at the ambient temperature and conductivity was recorded (C2). The EL was expressed in percentage using the following formula (4) (Beckerson & Hofstra, 1980):

$$\text{El}=\frac{C_1}{C_2}\times 100 \tag{4}$$

Chilling injury (CI) index and unmarketable fruit

The chilling injury occurrence and its intensity symptoms was recorded visually on a 4-point hedonic scale based on the percentage of peel surface affected by CI symptoms (dehydration, browning, and pitting): 1= (no CI symptoms), 2= (1–25% of surface damaged), 3= (26–50% of surface damaged), 4= (>51% of the surface damaged). The unmarketable fruit was evaluated as a result of overall visual quality based on undesirable fruit after 12 weeks of storage. Any fruits with visible CI and/or decay symptoms were considered unmarketable. The percentage of unmarketable fruit (UF) was calculated with the following formula (5):

$$\text{UF}=\frac{\text{Number of fruit in each treatment that was undesirable}}{\text{Number of fruit in each treatment}}\times 100 \tag{5}$$

Peel color measurement

The color of pomegranate fruits was measured by using colormeter (TES-135A, Taiwan) to evaluate L* (lightness: 0, dark; 100, white), a* (-greenness to +redness) and b* (-blueness to +yellowness). The different color indexes (hue and chroma) were also calculated according to the following equations (6, 7):

$$\text{hue}^{\circ} = \text{arc tang}\ \frac{b}{a} \tag{6}$$

$$\text{Chroma} = \sqrt{a^2 + b^2} \tag{7}$$

Organoleptic evaluation

Sensorial quality for aril taste was evaluated by a panel of seven trained panelists after 12 weeks of storage. The evaluation was scored on a scale of 1–5, where a score of 5 indicated that the fruit was very good (evident harvest freshness, bright pink juicy arils, and absence of off-flavor), and a score of 1 was considered a very bad degree (complete dislike, desiccated fruits with tough brown peel, brown color arils with low juiciness and becoming dry). A score of 3 (like moderate with retention of freshness, color, and juiciness of arils) and above was considered acceptable for marketing.

Statistical analysis

The experiment was done as a completely randomized design with three replications. Data were analyzed using GenStat program (version 12.1, VSN, International, Ltd., UK, 2009). The difference between the mean values of parameters was investigated by using LSD's test to examine if differences were significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Titratable acidity, pH and total soluble solids

Data in Table 1 shows that TA of vacuum packaged fruits was lower than control that was in agreement with findings of Artés et al. (2000) on Spanish Mollar de Elche sweet pomegranate, which reported that modified atmosphere packaging (MAP) with different polypropylene films reduced TA values compared to control. Vacuum packaging did not affect fruit TSS and pH. A significant decrease was occurred in titratable acidity of pomegranate fruit in vacuum packaged fruit compared to control and reduced with storage time (Table 4).

Total anthocyanin content

The results showed that the total anthocyanin content was significantly affected by the vacuum package (Table 1). Total anthocyanin increased in vacuum packed fruit in date 50 of storage, compared with control. However, there was no significant difference between them in day 70 of cold storage (Table 4). Longer duration of storage decreased total anthocyanin content. Somboonkaew and Terry (2010) reported that the anthocyanin content of litchi was higher in packed fruit with different films. Artés et al. (2000) reported that total anthocyanin content decreased at the end of shelf life on packaged pomegranate fruit. In another study on pomegranate aril, it was found that storage of aril in polypropylene bags preserved anthocyanin pigments and a slight increase in most anthocyanins occurred (Gil et al., 1996).

Fruit weight loss

The results showed that the amount of weight loss was significantly higher (11.3 g) in the control than vacuum packaged fruits (Table 2). Vacuum packaged fruits showed a lower amount of weight loss at all days of storage than control (Table 5). One way to reduce evaporation through the skin is film coatings (Hernandez-Munoz et al., 2008) included cellophane, polyethylene, and green polyethylene, which are impermeable to water and raises the humidity around the commodity and decrease moisture loss (Farooqi et al., 1975). This might be due to a reduction in respiration by the modified atmosphere. The wrappers in some treatments are barriers to the movement of water vapour and can help in the maintenance of high relative humidity (RH) and fruit turgor (Zagory & Kader, 1988). This was in agreement with Selcuk and Erkan (2014) who stated that MAP significantly reduced weight loss of pomegranate after 120 days of storage.

Electrolyte leakage (EL)

Results indicate that EL percentage of vacuum packaged fruits was significantly lower than control (Table 2) that was in agreement with previous studies who stated that chilling injury of some commodities (e.g., avocado, citrus, okra, and peppers) may be reduced by modified atmospheres (Risse et al., 1987; Scott & Chaplin, 1978). Metabolic processes including respiration and ripening rate, are sensitive to temperature. Biological reactions generally increased two to three fold every 10 °C rise in temperature; however, every commodity has a lower temperature limit. The optimum temperature may vary depending upon other conditions, for example, reduced O_2 or elevated CO_2 can overcome this impact of the low-temperature injury.

Table 1. Effect of bulk vacuum packaging (VP) on chemical attributes of pomegranate fruit cv. Shishe-kab after 90 days of storage at 5 °C

Packaging conditions	Anthocyanin (%)	pH	TSS (%)	TA (%)	TSS/TA (%)
Control †	14.67a	6.12a	18.0a	1.22a	14.75b
VP	12.88b	5.81a	17.70a	0.67b	25.79a

† Control, fruit without any packing in the air; VP, bulk vacuum packaging. Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test (n =20).

Table 2. Effect of bulk vacuum packaging (VP) on weight loss (WL), electrolytes leakage (El), chilling injury index (CI), unmarketable and taste of pomegranate fruit cv. Shishe-kab after 90 days of storage at 5 °C

Packaging conditions	WL (%)	EL (%)	CI index	Unmarketable fruit (%)	Taste and flavor
Control†	11.3a	79.2a	2.45a	32b	3.1a
VP	0.9b	57.4b	0.0b	0a	2.5a

† Control, fruit without any packing in the air; VP, bulk vacuum packaging. Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test (n =20).

Table 3. Effect of bulk vacuum packaging (VP) on peel color properties of pomegranate fruit cv. Shishe-kab after 90 days of storage at 5 °C

Packaging conditions	*L**	*a**	*b**	*h°*	*C*
Control†	32.68	27.06b	6.60	15.20a	28.38b
VP	38.42	52.34a	11.95	14.11b	52.96a

† Control, fruit without any packing in the air; VP, bulk vacuum packaging. Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test (n =20).

Table 4. Effect of bulk vacuum packaging (VP) and storage duration on chemical attributes of pomegranate fruit cv. Shishe-kab stored at 5°C

VP and storage duration (days)	Anthocyanin (%)	pH	TSS (%)	TA (%)	TSS/TA (%)
Control (90)	14.67a	6.12a	18.0a	1.22a	14.75c
VP30†	21.11a	5.47a	16.90a	0.89b	18.98b
VP40	19.70a	6.02a	17.92a	0.92b	19.47b
VP50	15.05a	5.83a	16.80a	0.73b	23.01a
VP70	10.18b	5.71a	17.20a	0.94b	18.29b
VP90	13.08b	5.85a	17.80a	0.69b	25.79a
VP130	12.20b	5.19b	15.80b	0.65c	23.84a

† VP30, VP40, VP50, VP70, VP90 and VP130 mean bulk vacuum packaging for 30, 40, 50, 70, 90 and 130 days, respectively. Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test (n =20).

Chilling injury (CI) index and unmarketable fruit

According to the results shown in Tables 2 and 5 vacuum packaged fruits had lower unmarketable fruits during different storage time than control, which was in agreement with Selcuk and Erkan (2014) who reported that storage of pomegranates in different MAP treatments significantly reduced weight loss and decay and maintained visual appearance. Microbial activities lead to changes in texture, color, flavor and nutritional value of those products that kept in conventional condition, due to moisture loss or uptake, reaction with oxygen and the growth of aerobic microorganisms.

Storage of crops in a modified gaseous atmosphere can protect the quality and extend product shelf life, by slowing chemical and biochemical deteriorative reactions and by slowing the growth of spoilage organisms (Coles et al., 2003). Carbon dioxide has a powerful inhibitory effect on bacterial growth. It is particularly effective against gram-negative, aerobic spoilage bacteria. In reviewing the effects of MA on pathogens of fruits and vegetables, El-Goorani and Sommer (1981) noted that delaying the senescence of fruits and vegetables reduces their susceptibility to pathogens. Modified atmosphere packaging of fruits can result in a reduction of respiration, delay in softening and ripening and a reduced incidence of various physiological disorders and pathogenic infestations (Artés et al., 2006). In vacuum packages, the growth of aerobic organisms is prevented mainly by removing oxygen from the in-pack environment. Spoilage then develops at a later time as a consequence of the proliferation of slower-growing organisms that tolerate anaerobic conditions (Yahia, 2009).

As shown in the Table 2 vacuum packaging preserved pomegranate fruits from chilling injury up to 90 days of cold storage. Pomegranates have been reported to be susceptible to chilling injury if stored longer than 1 month at temperatures below 5 °C (Elyatem & Kader 1984; Kader et al., 1984), with symptoms such as skin rotting, etiolating and cracking, browning of the rind, necrotic pitting and internal discoloration and browning of seeds (Elyatem & Kader 1984; Köksal, 1989).

Table 5. Effect of bulk vacuum packaging (VP) and storage duration on weight loss (WL), electrolytes leakage (El), chilling injury index (CI), unmarketable and taste of pomegranate fruit cv. Shishe-kab stored at 5 °C

VP and storage duration (days)	WL (%)	EL (%)	CI index	Unmarketable fruit (%)	Taste and flavor
Control (90)	11.3a	79.2a	2.45a	32b	3.1a
VP30 †	0.1b	54.4c	0.0c	0a	3.5a
VP40	0.1b	55.0c	0.0c	0a	3.6a
VP50	0.3b	55.5c	0.0c	0a	3.2a
VP70	0.4b	57.4c	0.0c	0a	3.2a
VP90	0.7b	56.4c	0.0c	0a	2.4a
VP130	0.9b	67.4b	0.6b	10a	1.8b

† VP30, VP40, VP50, VP70, VP90 and VP130 mean bulk vacuum packaging for 30, 40, 50, 70, 90 and 130 days, respectively. Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test (n =20).

Table 6. Effect of bulk vacuum packaging (VP) and storage duration on peel color properties of pomegranate fruit cv. Shishe-kab stored at 5 °C

VP and storage duration (days)	*L**	*a**	*b**	*h°*	*C*
Control (90)	32.68	27.06b	6.6	15.2b	28.38c
VP30†	44.22	43.32b	18.91	23.5a	47.58b
VP40	40.35	56.23a	15.93	15.90b	58.72a
VP50	42.90	52.25a	15.40	16.43b	54.95a
VP70	36.69	54.21a	12.95	13.32c	55.84a
VP90	38.79	51.74a	12.32	13.91c	53.47a
VP130	37.52	53.45a	8.74	9.20c	54.38a

† VP30, VP40, VP50, VP70, VP90 and VP130 mean bulk vacuum packaging for 30, 40, 50, 70, 90 and 130 days, respectively. Columns with different letters indicate significant differences at $P \leq 0.05$ according to LSD test (n =20).

Peel color

The evaluation of the simple effect of packaging showed no significant difference between control and packaging in *L* and *b** values (Table 3). The highest *a** and chroma values and also the lowest Hue angle observed in packaging treatment, compared with control (Table 3) that was in agreement with Selcuk and Erkan (2014) on pomegranate fruit. The *a** value of peel color was higher in vacuum packaged fruits than control. Previous studies have reported similar results showing that polyethylene packaging can extend the shelf life and favor the quality attributed color due to modifying the atmosphere by reducing the O_2: CO_2 ratio (Gonzalez-Aguilar et al., 1999; Zewter et al., 2012). The interaction between packaging and evaluation time showed significant effects of treatments on *a** and chroma and hue angle. The lowest *a** and chroma observed in control and packed fruit after 30 days. The lowest hue angle obtained in MA packed fruits evaluated since date 70 (Table 6).

Organoleptic

Vacuum packaging had no significant effect on pomegranate fruits taste (Table 2). However, after 130 days of cold storage, vacuum packed fruits had lower taste and high off-flavor compared to control. Off-flavor is a common problem with MAP and vacuum packaging of fresh products when they are stored for long period. The low permeability of the LDPE film to oxygen and carbon dioxide probably created an injurious atmosphere inside the package and altered metabolism of the fruit (Yamashita et al., 2002). This is probably due to reducing oxygen level to less than about 1-2% in the bulk vacuum package in long-term storage. At a level of 2% oxygen anaerobic respiration may result in the development of off-flavors and off-odors (Sandhya, 2010).

CONCLUSION

MAP as a progressive technology has been developed for preservation and storage of many fresh fruits and vegetables. The advantages of the MAP are extending the shelf-life, preserving or stabilizing the desired properties of fruits and vegetables. Generally, the results of this study revealed that bulk vacuum packaging improved the product overall quality in terms of maintenance of organoleptic and other quality properties, and interestingly alleviate chilling injury, reduce weight loss and the postharvest losses of pomegranate fruits. However, further studies are needed to evaluate the response of different commercial cultivars of pomegranate to vacuum packaging.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

REFERENCES

Artés, F., Gómez, P. A., & Artés-Hernández, F. (2006). Modified atmosphere packaging of fruits and vegetables. *Stewart Postharvest Review, 2*, 1-13. Doi: 1016/S0260-8774(01)00106-6

Artés, F., Villaescusa, R., & Tudela, J. A. (2000). Modified atmosphere packaging of pomegranate. *Journal of Food Science*, *65*(7), 1112-1116. Doi: 10.1111/j.1365-2621.2000.tb10248.x

Beckerson, D. W., & Hofstra, G. (1980). Effects of sulphur dioxide and ozone, singly or in combination, on membrane permeability. *Canadian Journal of Botany*, *58*(4), 451-457. Doi: 10.1139/b80-053

Caleb, O. J., Opara, U. L., & C.R. Witthuhn. (2012). Modified atmosphere packaging of pomegranate fruit and arils: a review. *Food Bioprocess Technology*, *5*(1), 15-30.

Coles, R., McDowell, D., & Kirwan, M. J. (Eds.). (2003). *Food Packaging Technology* (Vol. 5). CRC Press. Doi: 1016/j.tifs.2008.09.011

El-Goorani, M. A., & Sommer, N. F. (1981). Effects of modified atmospheres on postharvest pathogens of fruits and vegetables. *Horticultural Review*, *3*, 412-461.

Elyatem, S. M., & Kader, A. A. (1984). Post-harvest physiology and storage behaviour of pomegranate fruits. *Scientia Horticulturae*, *24*(3-4), 287-298.

Farooqi, W. A., Ahmad, M., Hussain, A. M., & Qureshi, M. J. (1975). Effect of thiabendazole and packing materials on Kinnow mandarin during storage. *Nucleus (Karachi)*, *12*(1-2), 25-29.

Gil, M. I., Artes, F., & Tomas-Barberan, F. A. (1996). Minimal processing and modified atmosphere packaging effects on pigmentation of pomegranate seeds. *Journal of Food Science*, *61*(1), 161-164. Doi: 10.1111/j.1365-2621.1996.tb14749.x

González-Aguilar, G. A., Cruz, R., Baez, R., & Wang, C. Y. (1999). Storage quality of bell peppers pretreated with hot water and polyethylene packaging. *Journal of Food Quality*, *22*(3), 287-299. Doi: 1111/j.1745-4557.1999.tb00558.x

Hernández-Muñoz, P., Almenar, E., Del Valle, V., Velez, D., & Gavara, R. (2008). Effect of chitosan coating combined with postharvest calcium treatment on strawberry (*Fragaria× ananassa*) quality during refrigerated storage. *Food Chemistry*, *110*(2), 428-435. Doi: 1016/j.foodchem.2008.02.020

Kader, A. A. (1994). Regulation of fruit physiology by controlled/modified atmospheres. *Postharvest Physiology of Fruits*, *398*, 59-70.

Kader, A., Chordas, A., & Elyatem, S. (1984). Responses of pomegranates to ethylene treatment and storage temperature. *California Agriculture*, *38*(7), 14-15.

Kader, A. A., 2004. Increasing food availability by reducing postharvest losses of fresh produce. In *V International Postharvest Symposium*, *682*, 2169-2176. Doi: 10.17660/ActaHortic.2005.682.296

Kitinoja, L., & Gorny, J. R. (1999). *Postharvest technology for small-scale produce marketers: economic opportunities, quality and food safety*. Postharvest Horticulture Series-Department of Pomology, University of California, (21).

Köksal, A. (1988, August). Research on the storage of pomegranate (cv. Gök Bahçe) under different conditions. In *International Symposium on Postharvest Handling of Fruit and Vegetables*, *258*, pp. 295-302.

Lako, J., Trenerry, V. C., Wahlqvist, M., Wattanapenpaiboon, N., Sotheeswaran, S., & Premier, R. (2007). Phytochemical flavonols, carotenoids and the antioxidant properties of a wide selection of

Fijian fruit, vegetables and other readily available foods. *Food Chemistry*, *101*(4), 1727-1741. Doi: 1016/j.foodchem.2006.01.031

Li, M., Pietrowski, M. J., De Souza, R. A., Zhang, H., Reaney, I. M., Cook, S. N., & Sinclair, D. C. (2014). A family of oxide ion conductors based on the ferroelectric perovskite Na 0.5 Bi 0.5 TiO 3. *Nature Materials*, *13*(1), 31.

Moradinezhad, F., & Khayyat, M. (2014). Effects of intermittent warming and prestorage treatments (hot water, salicylic acid, calcium chloride) on postharvest life of pomegranate fruit cv.'Shishe-Kab' during long-term cold storage. *International Journal of Horticultural Science and Technology*, *1*(1), 43-51. Doi: 10.22059/IJHST.2014.50517

Moradinezhad, F., Khayyat, M., & Saeb, H. (2013). Combination effects of postharvest treatments and modified atmosphere packaging on shelf life and quality of Iranian pomegranate fruit cv. Sheshi-kab. *International Journal of Postharvest Technology and Innovation*, *3*(3), 244-256. Doi: 10.1504/IJPTI.2013.059286

Moradinezhad, F., Khayyat, M., Ranjbari, F., & Maraki, Z. (2018). Physiological and quality responses of Shishe-Kab pomegranates to short-term high CO_2 treatment and modified atmosphere packaging. *International Journal of Fruit Science*, *18*(3), 287-299. Doi: 10.1080/15538362.2017.1419399

Pareek, S., Valero, D., & Serrano, M. (2015). Postharvest biology and technology of pomegranate. *Journal of the Science of Food and Agriculture*, *95*(12), 2360-2379. Doi: 10.1002/jsfa.7069

Ranjbari, F., Moradinezhad, F., & Khayyat, M. (2016). Effect of nitric oxide on biochemical and antioxidant properties of pomegranate fruit cv. Shishe-kab during cold storage. *International Journal of Horticultural Science and Technology*, *3*(2), 211-219. Doi: 10.22059/IJHST.2016.62920

Ranjbari, F., Moradinezhad, F., & Khayyat, M. (2018). Effect of nitric oxide and film wrapping on quality maintenance and alleviation of chilling injury on pomegranate fruit. *Journal of Agricultural Science and Technology*, *20*(5), 1025-1036.

Risse, L. A., Chun, D., & Miller, W. R. (1987). Chilling injury and decay of film-wrapped and conditioned bell peppers during cold storage. *Tropical Science*. *27*, 85-90.

Sandhya, E. (2010). Modified atmosphere packaging of fresh produce: Current status and future needs. *LWT-Food Science and Technology*, *43*(3), 381-392.

Scott, K. J., & Chaplin, G. 1. (1978). Reduction of chilling injury in avocados stored in sealed polyethylene bags. *Tropical Agriculture*, 55-87.

Selcuk, N. & M. Erkan. (2014). Changes in antioxidant activity and postharvest quality of sweet pomegranates cv. Hicrannar under modified atmosphere packaging. *Postharvest Biology and Technology*, *92*, 29-36. Doi: 1016/j.postharvbio.2014.01.007

Somboonkaew, N., & Terry, L. A. (2010). Effect of packaging films on individual anthocyanins in pericarp of imported non-acid treated litchi, *Acta Horticulturae*, *876*, 173-178. Doi: 10.17660/ActaHortic.2010.876.21

Yahia, E. M. (Ed.). (2009). *Modified and controlled atmospheres for the storage, transportation, and packaging of horticultural commodities*. Boca Raton, FL: CRC Press, Taylor & Francis. Doi: 1016/j.tifs.2010.07.004

Yamashita, F., Miglioranza, L. H. D. S., & Miranda, L. D. A. (2002). Effects of packaging and temperature on postharvest of atemoya. *Revista Brasileira de Fruticultura*, *24*(3), 658-660. Doi: 10.1590/S0100-29452002000300021

Zagory, D., & Kader, A. A. (1988). Modified atmosphere packaging of fresh produce. *Food Technology*, *42*(9), 70-77.

Zewter, A., Woldetsadik, K., & Workneh, T. S. (2012). Effect of 1-methylcyclopropene, potassium permanganate and packaging on quality of banana. *African Journal of Agricultural Research*, *7*(16), 2425-2437. Doi: 10.5897/AJAR11.1203

بهبود کیفیت و کاهش ضایعات پس از برداشت میوه انار با بسته بندی تحت خلاء

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چکیده:
میوه انار بسیار حساس به از دست دادن آب و سرمازدگی در طی نگهداری در انبار سرد در مرحله پس از برداشت است. بنابراین آزمایشی جهت ارزیابی تأثیر بسته بندی با اتمسفر تغییر یافته بر ماندگاری و مقاومت به سرما در شرایط انبار سرد انجام شد. تیمارها شامل میوه‌های بسته بندی شده و بدون بسته بندی (شاهد) بودند که در انبار سرد در دمای ۵ ± ۰/۵ درجه سلسیوس و رطوبت نسبی ۵ ± ۸۰ درصد نگهداری شدند. در پایان هر مدت زمان نگهداری (۳۰، ۴۰، ۵۰، ۷۰، ۹۰ و ۱۳۰ روز)، میوه های بسته بندی شده برای پارامترهای شیمیایی و کیفی ارزیابی شدند، در حالیکه میوه‌های شاهد بعد از ۹۰ روز انبار سرد مورد ارزیابی قرار گرفتند. نتایج نشان داد که بسته بندی باعث بهبود شاخص قند به اسید، برخی از مولفه‌های رنگ و کاهش آنتوسیانین، اسیدیته کل، کاهش وزن، نشت الکترولیت، شاخص آسیب پذیری و میوه های غیر قابل فروش شد. ارزیابی صفات در زمان‌های مختلف نشان داد که بسته بندی تحت خلاء به طور معنی‌داری موجب کاهش وزن، نشت الکترولیت، شاخص سرمازدگی شد و جالب اینکه میزان میوه‌های غیر قابل فروش را در مقایسه با شاهد تا ۳۰ درصد کاهش داد. میزان آنتوسیانین پس از ۷۰ روز از نگهداری میوه به طور معنی‌داری کاهش یافت. مقادیر a^* و chroma پوست به طور معنی‌داری در تیمارهای بسته‌بندی به طور معنی‌داری افزایش یافت همچنانکه دوره نگهداری بیشتر شد، اما مقدار هیو به طور معنی‌داری در مقایسه با شاهد کاهش یافت. نتایج پیشنهاد می‌کند که بسته بندی خلاء میوه بصورت توده‌ای می‌تواند تا ۳ ماه برای کاهش سرمازدگی، کاهش وزن و ضایعات پس از برداشت و افزایش انبارمانی میوه انار در طول نگهداری در انبار سرد به طور موفق مورد استفاده قرار گیرد.

کلمات کلیدی: سرمازدگی، بسته بندی با اتمسفر تغییر یافته، انار، افت وزن