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EFFECTS OF MODIFIED ATMOSPHERE PACKAGING SYSTEMS, LOW TEMPERATURE AND STORAGE TIME ON THE QUALITY OF FRESH MINIMALLY PROCESSED POMEGRANATE ARILS

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ABSTRACT

The effect of packaging method (air packaging; and modified atmospheres packaging including, MAP1: 5% O_2+85% N_2+10 % CO_2 and MAP2: 70% O_2+20% N_2+10% CO_2), storage temperature (4 and 8˚C), and storage time (0 to 30 days) were studied on chemical, physical and sensory characteristics as well as extending the shelf life of pomegranate arils**.** Mold was detected in arils stored under air packaging after 9 days. The samples packaged with low oxygen atmosphere show no mold attack during 30 days storage. Arils kept in MAP1 and stored at 4˚C maintained their texture and appearance better than those packaged under air and MAP2 packaging. The samples stored in MAP1 were firmer than those stored in air and MAP2 at the end of storage time.

1. Introduction

Pomegranate (*Punica granatum*, L.) is one of the most popular fruits worldwide, which is widely grown in many subtropical and tropical countries, including almost all Mediterranean countries (Gil et al., 1996a; López-Rubira et al., 2005). The total pomegranate production in Iran was 665,000 tons in 2003 (Anonymous, 2003). Pomegranate is consumed as fresh fruit and the seeds are the edible portion of the fruit which surrounded by a sweet and juicy pulp called arils **(**Gil et al., 1995; Melgarejo et al., 2000; Roy and Wasker, 1997). It is a very rich source of vitamins, fatty acids, mineral elements, polyphenolic compounds and high levels of anthocyanin which reduction of liver injury and prevents some types of cancer **(**Gil et al., 1996a; Caleb et al., 2012; Du et al., 1975; Fadavi et al., 2006; Lansky et al., 1998)**.**

Pomegranate fruits contain a considerable amount of arils ranging between 518 to 740 g kg^{-1} of fruit weight depending on cultivar (Safa and Khazaei, 2003). Some studies have been reported on the physical and mechanical properties of fruits pomegranate fruits (Ekrami-Rad et al., 2011; Mansouri et al., 2010). The minimal processing of pomegranate arils mainly consists of washing and/or preprocessing (chlorine and antioxidant solutions), pH modifications, modified atmosphere packaging **(**MAP), and storage under temperature control. (Gil et al., 1995; Ayhan and Eştűrk, 2009; Babic et al., 1992; Sepulveda et al., 2000; Schlimme, 1995).

As a useful conservation method, MAP can be introduced for extending the shelf-life of different perishable food products such as fruits (Oğuzhan et al., 2013; Goktepe, and Moody, 1998; Silva, and White, 1994; Jouki, and Khazaei, 2013;

Jouki, and Dadashpour, 2012). In this method, increasing CO_2 and/or decreasing O_2 levels with diminish the rate of respiration and ethylene production leads to inhibition and of the enzymatic reactions. Moreover, MAP with a reduction in physiological activity of the object causes a better maintaining of the final quality (Soliva-Fortuny and Martin-Belloso, 2003; Dadashpour et al., 2014). In micro-controlled atmosphere, the use of polymeric films has also significant effect on controlling the quality losses. Sepulveda et al. (2000) investigated the influence of different types of semi permeable films and antioxidant solutions on the quality of pomegranate arils in passive modification. They reported that minimally processed pomegranate Var. Wonderful were able to be stored for 14d at 4˚C with the use of semi permeable film. Ayhan and Esturk (2009) studied the shelf life and overall quality of minimally processed and modified atmosphere packaged "ready-to-eat" pomegranate arils Hicaznar packed in PP trays sealed with BOPP film under 4 atmospheres including low and super atmospheric oxygen stored at 5˚C for 18d. They reported the selected packaging material combined with modified atmosphere at low storage temperature provided commercially acceptable shelf life of 18d, quality, and convenience for pomegranate arils sanitized with chlorine. In a similar study by Gil et al. (1996a), the influence of different washing treatments, storage temperatures (8, 4 and 1˚C) and actively or passively modified atmosphere packaging on the quality of the minimally processed pomegranate seeds was investigated. they reported the best out comes in quality and appearance without fungal attacks on off flavor development were obtained for pomegranate seeds washed with chlorine plus antioxidants sealed in OPP film, using an initial atmosphere actively modified stored for 7 d at 1˚C. Accordingly, the objective of this research was to study the effect of packaging method (air packaging and MAP technique in low and super atmospheric oxygen), storage temperature (4 and 8˚C), and storage time (0 to 30 days) on chemical, physical and sensory characteristics as well as extending the shelf life of pomegranate arils.

2. Materials and methods

2.1. Sample preparation

Pomegranate fruits (*Punica granatum* L.) cv. 'Malas-e-Saveh' were obtained from Agricultural Research Center of Saveh, Iran and harvested at the commercial maturity stage. The fruits were collected manually and transported on the same day to the Chemical Engineering Laboratory, University of Tehran, Iran. The damaged fruits were removed and the healthy fruits of uniform mass (with average weight of 280 g), size and appearance were used for tests. The fruits were stored in refrigerator at 4 and 8˚C and 75±5% RH and were kept there for a maximum of 30 days while the experiments were completed. The fruits arils were removed manually. To this, each fruit was washed in chlorine using a brush), drained, and then cut into pieces to separate the arils manually. The chemical, physical and sensory characteristics of fresh arils were measured and assigned as control treatment (without any treatment). Chemicals were supplied from Merck (Darmstadt, Germany).

2.2. Storage conditions

In this study, the effect of packaging method (air packaging with 21% O_2+79% N_2; and modified atmospheres packaging, including MAP1: 5% O_2+85% N_2+10% CO_2 and MAP2: 70% O_2+20% N_2+10% CO_2), storage temperature (4 and 8˚C), and storage time (0, 9, 12, 18 and 30 days) were studied on quality parameters of pomegranate arils, including fruit firmness, total Titratable Acidity (TTA), total soluble solids (TSS), pH, fungal decay and sensory evaluation (color, taste, freshness and overall acceptability). Factorial experiment was conducted as a randomized complete design with three replicates.

For each test, the arils samples of 120±5 g were packed in heat-sealed pouches (20×30 cm) made of oriented polypropylene (OPP) film of 52μm thickness, 230 mL/(m^2 24 h bar) O_2 permeability, 889 mL/m^2 24 h bar CO_2 permeability and a water vapour transmission rate of 0.22 g/m^2 24 h (all values at 75% RH and 5˚C). Measuring and evaluation of the physical, chemical and sensory characteristics of control and treated pomegranate arils were conducted as follow.

2.3. Texture

Textural properties of the arils was carried out using a Testometric Machine M350-10CT (Testometric Co. Ltd., Rochdale, Lancashire, England) according to the method reported by Ayhan and Estuck (2009). For each test, twelve grams of arils were placed into a 28 cm^2 metal container and were compressed using a 5-cm diameter cylindrical probe. For all the tests, the maximum compression force (N) at probe displacement of 7 mm was measured and expressed as arils firmness. A total of 10 replications were made for each packaged aril sample and the average was reported. In this study, all the compression tests were conducted at a speed of 5 mm/s.

2.4. Chemical attributes

A total of 75g of arils were squeezed with hand pressed for extracting the juice and filtered using cheesecloth. The juice obtained was directly analyzed for Total titratable acidity (TTA), Total soluble solid (TSS) and pH. Total titratable acidity (TTA) was determined by titrating with 0.1mol/l NaOH to pH 8.1 and using 10ml of juice diluted with 50 ml of distilled water and expressed as citric acid% (AOAC, 1984). Total soluble solid (°Brix) values were analyzed by Bausch & Lomb Abbe-3L type refractometer at 20˚C. The pH of the arils was analyzed by a pH meter (Metrohm, Herisau, Switzerland) in duplicate measurements on day 0, 9, 12, 18 and 30 (Dadashpour et al., 2014; AOAC, 1984; Khazaei et al., 2011). All analyses were done as triplicate.

2.5. Fungal decay

The presence of fungi in each package was visually evaluated. The arils samples showing surface mycelia development were considered as decayed. Finally, all the samples were classified as presence (+) or absence (-) of fungi.

2.6. Sensory evaluation

Sensory evaluation of the packaged arils was included the assessments of color, freshness, taste and product acceptability. Tests were performed by a sensory panel of 12 trained judges (six females and six males) on a 5-point hedonic scales, where 5 corresponded to extremely liked and 1 corresponded to extremely disliked (López-Rubira et al., 2005; Ayhan and Esturk, 2009; Gil et al., 1996b). Scores of 3 and above were considered as acceptable for commercial purposes.

2.7. Statistical analyses

The experimental data for each independent parameter were individually subjected to analysis of variance by using SAS software (ver. 9.2). The data were analyzed to study the effects of packaging method, storage temperature, and storage time on different chemical, physical and sensory characteristic of pomegranate arils. The difference between the means of main and interaction effects was determined using the Duncan Multiple Range Test in 0.05 and 0.01 levels (López-Rubira et al., 2005; Ayhan and Esturk, 2009; Jouki and Khazaei, 2012; Jouki and Khazaei, 2014).

3. Results and discussions

3.1. pH

The results showed that (Table 1) the mean value of pH for fresh arils (without any treatment at 0 day storage) was in the range of 3.16±0.04, which was in agreement with that reported by Akbarpour et al. (2009). During the storage period, increasing on fruit's pH was observed between the first and the 12th day. These results are in agreement with obtained by Artes et al. (2000), who reported that at the end of the shelf life, all treatments maintained or increased pH values, except pomegranate fruits in perforated PP at 5˚C, which had slightly decreased pH values.

Table 1. The effect of packaging methods, storage temperature and storage time on pH of pomegranate arils

Treatments	Temperature (°C)	Day 0	Day 9	Day 12	Day 18	Day 30
AP	4	3.163±0.049 c	3.440±0.157 b	3.536±0.070 b,A	3.440±0.030 b,C	3.710±0.140 a,B
MAP1	4	3.163±0.049 b	3.400±.0.098 a	3.356±0.810 a,B	3.323±0.068 a,D	3.380±0.017 a,D
MAP2	4	3.163±0.049 c	3.390±0.117 b	3.393±0.470 b,B	3.360±0.020 b,D	3.576±0.056 a,C
AP	8	3.163±0.049 d	3.393±0.060 c	3.580±0.060 b,A	3.760±0.036 a, A	3.713±0.030 a, A
MAP1	8	3.163±0.049 c	3.360±0.065 d	3.513±0.032 c, A	3.630±0.020 b,B	3.720±0.026 a, B
MAP2	8	3.163±0.049 c	3.370±0.111 d	3.590±0.020 c,A	3.716±0.030 b,A	3.796±0.015 a,A

[1]For each column, similar capital letters (superscript) are not significantly different at $P \leq 0.05$ among packaging treatments. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ during storage. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ between storage temperatures.
[2]AP: 21% O_2, 79% N_2; MAP1: 10 % CO_2 + 5 % O_2+85 % N_2; MAP2: 10 % CO_2+ 70 % O_2 + 20 % N_2.
[3] Values in the same column (A-D) and same row (a-d) with different superscripts are significantly different ($p < 0.05$).

Table 2. The effect of modified atmosphere packaging, storage time and temperature on TTA (%) of pomegranate arils

Treatments	Temperature (°C)	Day 0	Day 9	Day 12	Day 18	Day 30
AP	4	1.411±0.182 a	1.076±0.255 ab,B	0.845±0.205 b,B	0.818±0.024 b,B	0.687±0.035 c,B
MAP1	4	1.411±0.182 a	. 1.330±0.170 a,AB	1.236±0.075 a,A	0.290±0.314 a,A	0.883±0.075 b,A
MAP2	4	1.411±0.182 a	1.610±0.200 a,A	1.243±0.240 ,A	1.096±0.114 b,AB	0.758±0.097 c,AB
AP	8	1.411±0.182 a	1.140±0.172 b,B	0.854±0.085 c,B	0.783±0.029 d,B	0.689±0.032 c,B
MAP1	8	1.411±0.182 a	1.360±0.210 a,AB	1.111±0.035 b,A	1.024±0.010 c,AB	0.845±0.052 d,A
MAP2	8	1.411±0.182 a	1.326±0.176 a,AB	1.145±0.012 b,A	1.061±0.029 c,AB	0.714±0.054 d,AB

[1]For each column, similar capital letters (superscript) are not significantly different at $P \leq 0.05$ among packaging treatments. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ during storage. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ between storage temperatures.
[2]AP: 21% O_2, 79% N_2; MAP1: 10 % CO_2 + 5 % O_2+85 % N_2; MAP2: 10 % CO_2+ 70 % O_2 + 20 % N_2.
[3] Values in the same column (A-D) and same row (a-d) with different superscripts are significantly different ($p < 0.05$).

Table 1 shows that storage temperatures had a significant increasing effect (p=0.08***) on the pH of stored packaged arils. The pH of arils stored at 4°C with the mean value of 3.39 was 3.5% less than that for the samples stored at 8˚C. It was also found that storage time had a significant increasing effect (p=0.08***) on the pH of stored packaged arils. At storage temperatures of 4˚C, increasing the storage time from 0 to 30 days, significantly increased the mean value of pH from 3.16 to 3.56, a 13% increase (Table 1). The corresponding values for storage temperature of 8°C were 3.16 to 3.78, respectively with a 20% increase (Table 1). For both storage temperatures of 4 and 8˚C, the minimum variation in pH was belonged to arils packed under MAP1 (i.e. 5% O_2+85% N_2+10% CO_2).

Among the most often used gases in MAP (O_2, CO_2, and N_2), only CO_2 has significant and direct antimicrobial activity due to alteration of cell membrane function including effects on nutrient uptake and absorption, direct inhibition of enzymes, or decreases in the rate of enzyme reactions, penetration of bacterial membranes leading to intracellular pH changes and changes to the physicochemical properties of proteins (Farber, 1991). During the refrigerated storage at 4 or 8˚C, the pH increased significantly in AP or MAP-stored fruits, mainly due to a decrease in TA (Table 1). The pH of pomegranate arils increased from 3.16 to 3.71 and 3.81 at the end of storage time for air-packaged samples stored at 4˚C and 8˚C respectively, and was lower in samples under MAP1 than samples under MAP2. At the end of shelf life, all treatments significantly increased pH values, except MAP1 at 4˚C fruits**,** which had slightly increased values**.** However, no significant differences were found between MAP2 and control at 8˚C ($P \leq 0.05$). The difference became significant between low oxygen (MAP1) and the other applications were found at 8 and 4˚C. There was no significant difference between MAP1 at 8˚C and control at 4˚C, although. The pH of pomegranate arils packaged under low oxygen (MAP1) was significantly lower than the other applications of storage for all temperatures. The pH increased when stored at 8 and 4˚C but increasing this value at 4˚C was lower than at 8˚C.

3.2. Total Titratable Acidity

In general, no significant difference was observed between atmospheres in terms of total titratable acidity (TTA; P>0.05). However, storage time had significant effect on TTA at all applications ($P \leq 0.05$). TTA significantly decreased in all applications especially at the 12th day ($P \leq 0.05$) and stayed almost unchanged for the rest of the storage (Table 2). Decrease in acidity during storage is in agreement with the results of Artes et al. (2000) and Maghoumi et al. (2013). This could be related to metabolic activities of pomegranate during storage (Babic et al., 1992). Caleb et al. (2012) reported that the variability of pH, TSS, and TTA values could be explained by several factors such as cultivar differences and the relative solubility effect of CO_2 in water molecules surrounding the freshly packed pomegranate arils. TTA of arils decreased when stored at 8 and 4˚C but increasing this value at 4˚C was lower than at 8˚C. Thus, storage temperature at 4˚C was selected as the best for keeping quality non-significant differences were observed for control at 8˚C but there was a significant effect between control and other applications for all temperatures in terms of TTA ($P \leq 0.05$).

3.3. TSS

The TSS value of arils increased when stored at 8 and 4˚C. Hence, only slight differences were observed for TSS at 4˚C. At the 30 day of storage, TSS of pomegranate arils under enriched oxygen (MAP2) and stored at 8˚C was slightly higher than the other applications (Table 3). This result is in agreement with the results of Ayhan and Esturk (2009) for 18d. They reported that there was no significant but slight changes observed in TSS of pomegranate during cold storage. They also reported that changes in total acidity and TSS content influenced the diversity of the amounts of total phenolic content during storage, which in return affected the total anthocyanin content and total antioxidant activity and Anthocyanins are responsible for the color of the pomegranate seeds. In general, total anthocyanin content decreased as the storage time increased for all treatments.

3.4. Physical quality

The firmness characteristics of pomegranate arils are presented by Table 4. While the firmness value was 90.87 N day 0, it was significantly increased at 9 d of storage to 128.91, 116.96 and 112.23 for normal air (AP), MAP1 (Low oxygen) and MAP2 (enriched oxygen); respectively (for samples were stored under 4˚C). Increase in firmness during storage is in agreement with the results of Ayhan and Esturk (2009). There was no significant difference between MAP applications until 9 d of storage in terms of texture. However, at the end of storage time the most firmness was related to MAP1 (104.067 N) (Table 4). Ayhan and Esturk (2009) reported that Changes in firmness could be due to changes in water content during storage.

After 18 d of storage time firmness decreased when stored at 8 and 4˚C but decreasing this value at 8˚C was higher than at 4˚C. Shamsudin et al. (2009) surveyed physico-mechanical properties of the Josephine pineapple fruit. They reported the firmness of the fruits was decreased with the stage of maturity.

3.5. Sensory quality

Figure 1 shows the effects of MAP, storage time and temperature on the sensory attributes and acceptance of pomegranate arils during cold storage. The minimally processed pomegranate arils were acceptable in terms of product attributes such as aril color, freshness and taste under normal air, low and enriched oxygen atmosphere until the end of the storage time (30 days). Overall, the pomegranate arils packed with enriched oxygen and low oxygen were acceptable by the sensory panelists on 12th day; however, it was limited to 9 d for the normal air. The overall acceptance score of pomegranate arils packaged under low oxygen atmosphere was 3.82, which was higher than the acceptable level (score 3) on the storage day of 30. The pomegranate arils packed with normal air, enriched and low oxygen weren't acceptable by the sensory panelists on 30 day. Jacxsens et al. (2003) reported that LAB showed low counts (about 5 log cfu g^{-1}) after 10 days of storage, without any trace of fermentative metabolism which could lead to the production of lactic and acetic acids responsible for off-flavour. It should be taken into account that high amounts of yeasts (>5 log cfu g^{-1}) can provoke an off-flavour of fresh-cut produce due to the production of CO_2, ethanol, organic acids and volatile esters (Babic et al. 1992; Fleet, 1992). In terms of colour, taste, freshness, overall acceptability, MAP1-treated arils were still acceptable for consumption up to 30 days at 4˚C. However, MAP2-treated arils were below the limit of usability according to the sensory evaluation, even when stored at 4˚C.

3.6. Fungal decay

The effects of modified atmosphere packaging on pomegranate arils were restricted in the counts of microbial flora with the concomitant benefit of prolonging refrigerated shelf-life on the samples. No mold growth was detected after 9 days of storage, but after day 9 mold growth was observed on the arils stored at AP (air packaging). These results were similar to those achieved by Lopez-Rubira et al. (2005), who reported that microbial counts of minimally fresh processed arils increased throughout shelf life at 5˚C. Even though they treated the arils with MAP2, the shelf life was limited to 12 d due to the mold growth. Farber (1992) stated that CO_2 has significant and direct antimicrobial activity due to alteration of cell membrane function including effects on nutrient uptake and absorption, direct inhibition of enzymes, or decreases in the rate of enzyme reactions, penetration of bacterial membranes leading to intracellular pH changes and changes to the physicochemical properties of proteins. No mold growth was detected during 30 days of storage on the arils in MAP1 (not shown). In our study, the arils were treated with chlorine. MAP1 (low levels of O_2) has been found to be effective in inhibiting mold growth.

Table 3. The effect of modified atmosphere packaging, storage time and temperature on TSS (°Brix) of pomegranate arils.

Treatments	Temperature (°C)	Day 0	Day 9	Day 12	Day 18	Day 30
AP	4	14.533 ± 0.642^{bc}	14.250 ± 1.298^{c}	$15.250 \pm 0.250^{b,A}$	$15.333 \pm 0.288^{ab,AB}$	$15.750 \pm 0.050^{a,AB}$
MAP1	4	14.533 ± 0.642^{b}	14.416 ± 1.025^{b}	$13.83 \pm 0.400^{b,B}$	$14.000 \pm 0.019^{b,B}$	$15.333 \pm 0.288^{a,C}$
MAP2	4	14.533 ± 0.642^{b}	14.083 ± 0.629^{b}	$14.166 \pm 0.288^{b,B}$	$14.166 \pm 0.288^{b,B}$	$15.706 \pm 0.090^{a,B}$
AP	8	14.533 ± 0.642^{b}	15.000 ± 1.000^{ab}	$15.933 \pm 0.115^{a,A}$	$16.033 \pm 0.057^{a,A}$	$16.100 \pm 0.100^{a,A}$
MAP1	8	14.533 ± 0.642^{bc}	14.333 ± 0.763^{bc}	$13.833 \pm 0.040^{c,B}$	$15.383 \pm 0.332^{b,AB}$	$15.866 \pm 0.125^{a,AB}$
MAP2	8	14.533 ± 0.642^{b}	14.750 ± 0.443^{a}	$15.666 \pm 0.377^{a,A}$	$15.706 \pm 0.476^{a,A}$	$15.933 \pm 10.115^{a,A}$

[1]For each column, similar capital letters (superscript) are not significantly different at $P \leq 0.05$ among packaging treatments. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ during storage. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ between storage temperatures.
[2]AP: 21% O_2, 79% N_2; MAP1: 10 % CO_2 + 5 % O_2+85 % N_2; MAP2: 10 % CO_2+ 70 % O_2 + 20 % N_2.
[3] Values in the same column (A-D) and same row (a-d) with different superscripts are significantly different ($p < 0.05$).

Table 4. The effect of modified atmosphere packaging, storage time and temperature on firmness (N) of pomegranate arils

Treatments	Temperature (°C)	Day 0	Day 9	Day 12	Day 18	Day 30
AP	4	90.871 ± 6.855^{c}	$128.911 \pm 0.971^{a,A}$	$105.287 \pm 21.287^{bcd,A}$	$94.022 \pm 18.878^{cd,AB}$	$90.355.11 \pm 036^{c,AB}$
MAP1	4	90.871 ± 6.855^{c}	$116.961 \pm 8.145^{ab,B}$	$104.502 \pm 5.698^{bcd,A}$	$114.548 \pm 7.246^{ab,A}$	$104.067 \pm 34.633^{bcd,A}$
MAP2	4	90.871 ± 6.855^{c}	$112.235 \pm 6.745^{bc,B}$	$107.829 \pm 19.821^{bcd,A}$	$118.831 \pm 20.888^{ab,A}$	$98.053 \pm 6.181^{c,A}$
AP	8	90.871 ± 6.855^{c}	$110.199 \pm 17.972^{ab,AB}$	$93.977 \pm 2.976^{bc,AB}$	$86.199 \pm 4.418^{cd,B}$	$78.866 \pm 5.300^{d,AB}$
MAP1	8	90.871 ± 6.855^{c}	$113.185 \pm 6.284^{ab,B}$	$109.851 \pm 4.285^{bc,A}$	$96.355 \pm 5.263^{bc,AB}$	$88.407 \pm 6.623^{c,AB}$
MAP2	8	90.871 ± 6.855^{c}	$112.916 \pm 17.971^{b,AB}$	$106.628 \pm 15.197^{bcd,A}$	$91.961 \pm 7.680^{cd,B}$	$81.295 \pm 6.442^{d,AB}$

[1]For each column, similar capital letters (superscript) are not significantly different at $P \leq 0.05$ among packaging treatments. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ during storage. For each parameter, similar small letters (subscript) in rows are not significantly different at $P \leq 0.05$ between storage temperatures.
[2]AP: 21% O_2, 79% N_2; MAP1: 10 % CO_2 + 5 % O_2+85 % N_2; MAP2: 10 % CO_2+ 70 % O_2 + 20 % N_2.
[3] Values in the same column (A-D) and same row (a-d) with different superscripts are significantly different ($p < 0.05$).

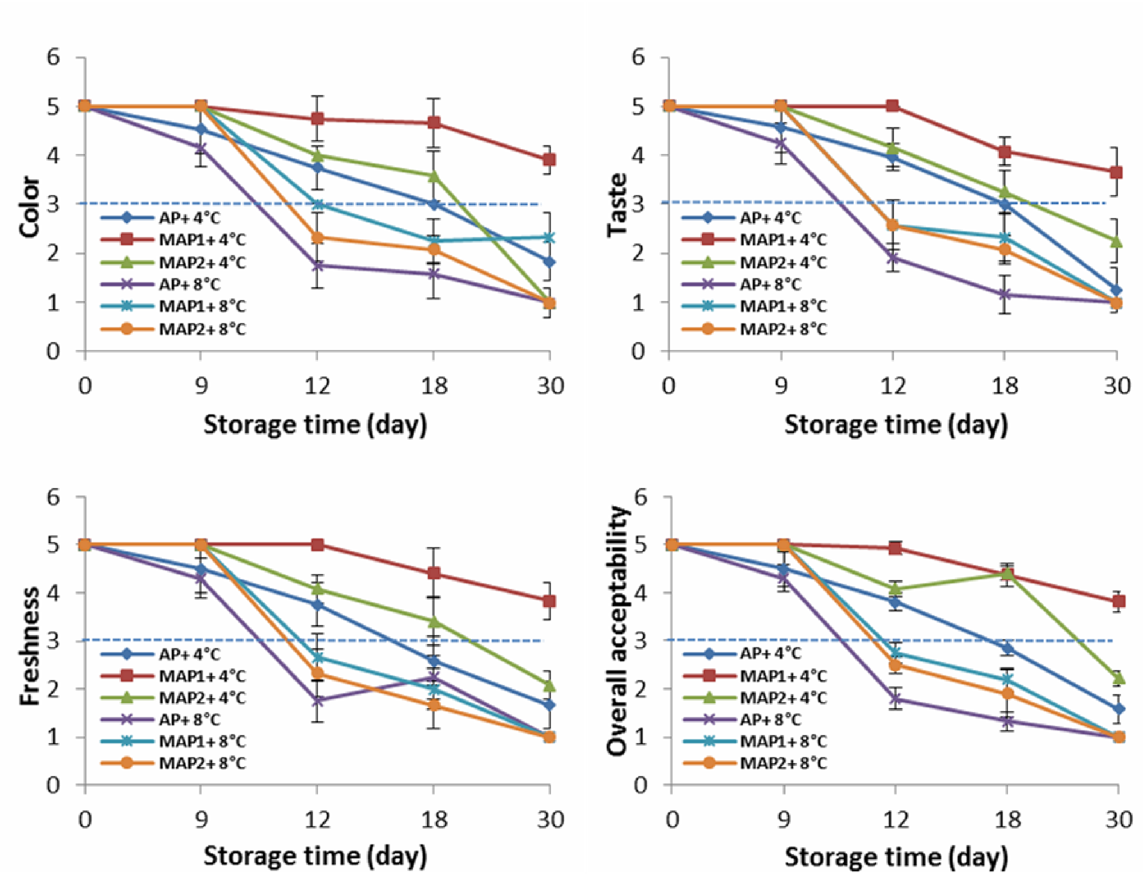

Figure 1. The effect of MAP, storage time and temperature on the sensory attributes of pomegranate arils during cold storage.

4. Conclusions

The shelf life of pomegranate arils of was suggested as 9 d under air, 12d under MAP2 (the enriched oxygen atmosphere), and 30d under MAP1 (the low oxygen atmosphere) at 4˚C storage. The low oxygen modified atmosphere at low storage temperature (4˚C) provided commercially acceptable shelf life of 30d, quality, and convenience for pomegranate arils sanitized with chlorine. This study demonstrated the effects of modified atmosphere packaging on the quality of pomegranate arils stored at 4 and 8˚C. The results showed that the pomegranate arils kept in MAP1 (low oxygen atmosphere) maintained their texture and appearance significantly ($p < 0.05$) better than those packaged under air and MAP2 (enriched oxygen atmospheres). The arils stored at 4˚C by MAP1 increased their post-harvest life from 9 to 30 days, without any attack of fungus or any change in their external appearance. At the end of storage time firmness significantly ($p < 0.05$) decreased during storage of arils in MAP2 and air packed, but intensely in arils stored at 4˚C and packaged by MAP1. Mold was detected in arils stored under air packaging after 9 days. However no mold growth was detected on day 30 of storage in the sample under MAP1 and stored at 4˚C.

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