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Influence of Modified Atmosphere Packaging on Storability and Postharvest Quality of Cornelian Cherry (*Cornus mas* L.) Fruits

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Abstract

Cornelian cherries were stored in two types of polymeric films (low density polyethylene and polypropylene) and three gas combinations (5%O_2 + 20%CO_2+ 75%N_2 , 60%O_2 + 20%CO_2 + 20%N_2 and Air) at 1 °C and 90-95% relative humidity for 35 days. Unpackaged cornelian cherries were used as a control. Samples were taken initially and at intervals of 7-days during storage, when quality parameters were measured. Results showed that modified atmosphere packaging (MAP) allowed the stored fruits to retain their weight and visual quality throughout the experiment, regardless of the gas combinations used, while by the end of the storage period the unpackaged fruit lost over 30% of their weight and consequently visual quality. Overall, packaging in 60%O_2 + 20%CO_2 polypropylene (PP) and Air low density polyethylene (LDPE) could retard soluble solid contents, titratable acidity, ascorbic acid, anthocyanin index decrease and pH increase during the storage time. Additionally, such packaging could lead to better surface color preservation than that of fruits kept in open containers. Furthermore, packaging in air low density polyethylene and 60%O_2 + 20%CO_2 low density polyethylene could delay total phenolics accumulation and increase peroxidase activity to levels higher than those in the control. During the maintenance period, no symptoms of decay were observed.

Keywords: ascorbic acid, ethylene, quality parameters, shelf life, total phenolics

Abbreviations: LDPE, low density polyethylene; MAP, modified atmosphere packaging; POD, peroxidase; PP, polypropylene

Introduction

Studies on human health and disease incidence have shown that the consumption of fruits and vegetables provide protection against certain diseases including cancer and heart disease. This has been attributed to the various natural antioxidants found in fruits and vegetables as well as a number of other health benefits (Shui and Leong 2006; Wang *et al.,* 1996). The cornelian cherry (*Cornus mas* L.) belongs to the Cornaceae family (Rop *et al.,* 2010). It is a wild plant that grows in Asia and Europe (Kalyoncu *et al.,* 2009). The cornelian cherry fruit which has a sour-sweet tasting juice contains high amounts of vitamin C and anthocyanins. It is claimed that anthocyanins have antioxidant and anti-inflammatory effects (Pantilidis *et al.,* 2007). There are several reports about the usage of fruits and various parts of *Cornus* spp. in traditional medicine and as a food preservative (Brindza *et al.,* 2007; Rop *et al.,* 2010; Vareed *et al.,* 2006). Vareed *et al.* (2006) reported antibacterial, antihistaminic, anti-allergic, anti-microbial and anti-malarial activities of cornelian cherry fruits. In Iran, approximately 10,000 tons of cornelian cherry fruits are produced both under rain-fed and irrigated cultivation per annum. This species grows in the temperate zone of Iran including the provinces of East Azerbaijan, Qazvin, Zanjan and Guilan on calcareous, well-drained forest soil. It ranges from a shrub to a small tree of about 4-8 m in height. The species is highly tolerant to diverse abiotic and biotic conditions (Rop *et al.,* 2010). The fruit is either consumed fresh or processed into various products such as jam, pastil (a dried form of marmalade produced in the northwest part of Iran) and sherbet, or it is dried. Unfortunately, the importance of *Cornus* spp. has been neglected and underestimated. Not enough research about the importance and value of this fruit has been performed by food industry, nutrition science and pharmacist experts.

The cornelian cherry, like most small fruits, has a relatively short postharvest life. The use of postharvest treatments with low O_2 and/or high CO_2 concentrations balanced with N_2 is a conventional technique for controlling fungal decay, maintaining fruit sensory quality, and extending the postharvest life of other similar small fruits like the blackberry and the blueberry (Kader, 2002; Ke *et al.,* 1991; Prusky *et al.,* 1997). Super-atmospheric oxygen has been suggested as an alternative to low O_2 modified atmosphere packaging for inhibiting enzymatic

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discoloration, preventing anaerobic fermentation reactions, undesirable moisture and odor losses, influencing aerobic and anaerobic microbial growth, as well as reducing decay of the fresh produce (Day, 1998). It is hypothesized that the production of reactive oxygen species (ROS) caused by elevated O_2 modified atmosphere packaging damages vital cellular macromolecules and thereby inhibits microbial growth when oxidative stresses overwhelm cellular antioxidant protection systems (Amanatidou *et al.,* 1999; Kader and Ben-Yehoshua, 2000). According to Amanatidou *et al.* (1999) and Allende *et al.* (2004), when high O_2 modified atmosphere packaging was used alone, the inhibitory effect on microbial growth in minimally-processed vegetables was highly variable, but the combined treatment of high O_2 concentration and 10 to 20 kPa CO_2 may provide adequate suppression of microbial growth and prolong shelf life. It has been reported that the respiration rate of fresh produce may be stimulated, not affected or reduced, by exposure to high levels of O_2 that depend on the commodity, maturity and the stage of ripeness, O_2 concentration, duration and temperature of storage as well as the O_2 and C_2H_4 concentrations (Kader and Ben-Yehoshua, 2000).

To the best of our knowledge, some studies have been recently published on the physicochemical properties and antioxidant activity of cornelian cherry fruits (Demir and Kalyoncu, 2003; Pantelidis *et al.,* 2007; Paulovicsová *et al.,* 2009; Vareed *et al.,* 2006; Tural and Koca, 2008) yet no studies have been conducted on the postharvest storage of cornelian cherries; therefore, the aim of this study was to evaluate the efficacy of passive modified atmosphere packaging as well as active modified atmosphere packaging, using low and high O_2 combined with high CO_2 concentrations, as a feasible and economical approach to prolonging the shelf life of cornelian cherry fruits and preserving their quality during the storage period.

Materials and methods

Red cornelian cherry fruits (*Cornus mas* L.) were hand-harvested from 7-8 years old trees from an orchard in the province of Qazvin, Iran. After harvesting at the commercial maturation stage, the fruits were transported immediately to the Department of Horticultural Sciences of the University of Tehran. Cherries were selected for uniform color, size and ripeness. Damaged, shriveled and unripe fruits were excluded. Samples of 200 g of cornelian cherries were packaged in two different polymeric films (20 × 30 size): 75-µm thick LDPE film (low-density polyethylene) and 40-µm thick PP film (polypropylene). Three different gas combinations (5%O_2 + 20%CO_2 + 75%N_2, 60%O_2 + 20%CO_2 + 20%N_2, and air) were applied using a vacuum apparatus (model 200A). Table 1 shows the properties of the two selected packages. Unpackaged cornelian cherries were used as the control. All samples were stored at 1 °C with approximately 95% relative humidity for 35 days for subsequent evaluation on product quality and microbial growth. The experiment had three replications at weekly intervals.

Table 1. Permeability of used packages, as related to modified atmosphere

Packaging	Thickness (µm)	Gas transmission rate (cm^3/m^2 day bar)	
		O_2	CO_2
		-	-
Control	-	3250	15730
LDPE	75	2820	18740
PP	40	O_2	CO_2

Visual quality

Thirty fruits per treatment were used for each quality evaluation. Overall quality was evaluated on a 1 to 5 scale according to the overall condition of the fruit, where 1=unacceptable, 2=bad, 3=acceptable, 4=good, and 5=excellent. Results were expressed as an overall quality index (Fernando *et al.,* 2007).

Estimation of fruit decay

Fruit decay was visually evaluated after removal from storage during the course of the experiment and after an additional 1 day in air at 25 °C to simulate retail market conditions. Any cherries with visible mold growth were considered decayed. Fruit decay was expressed as percentage of fruit showing decay symptoms (Zheng *et al.,* 2008).

Weight loss

Weight losses were calculated according to the weights of each package before and after storage. Weight loss was expressed as a percentage of the initial weight of cornelian cherries.

Determinations of pH, total titratable acidity, total soluble solids

The pH was analyzed using an electronic pH meter. Total titratable acidity (TA) was analyzed by the pH meter and by diluting 5 mL aliquot of cherry juice in 50 mL distilled water and then titrating to the pH 8.1 using 0.1 N NaOH. TA was expressed as percentage of malic acid (Demir and Kalyoncu, 2003). The amount of total soluble solids (TSS) was determined at 25 °C using a refractometer on cherry juice (without dilution) after filtering through Whatman #1 filter paper.

Surface color measurement and anthocyanin index

External cherry color was measured with a chromameter which provided L^*, a^* and b^* values. Color was expressed as L^*, a^* values and hue angle. Two readings per fruit were taken on opposite sides for 10 fruits from each replicate. Anthocyanin concentrations were determined using 5 g of fruit tissue homogenized in 10 ml of ethanol and after centrifugation, by reading the absorbance at 530 nm by a UV- Visible spectrophotometer. The absorbance of the ethanol extraction was used as the index for anthocyanin concentration.

Ethylene production

Ethylene concentration was analyzed by a gas chromatograph using about 30 g of fruits kept in 500 ml special polyethylene containers for 2 h. Then 1 ml of the head space was injected into the GC and the result was expressed as nl kg^{-1} h^{-1} (Soleimani Aghdam *et al.,* 2008).

Vitamin C

Vitamin C was determined by titrating 5 ml cherry juice (without dilution) using potassuim iodide (KI) solution. The advent of durable dark blue was the end of the titration.

Total phenolics and peroxidase (POD) activity

The amount of total soluble phenolics in the fruit juice extracts was determined with Folin-Ciocalteu reagent according to the method of Meyers *et al.* (2003) using gallic acid as a standard. Results were expressed as milligram of gallic acid equivalent on a fresh weight basis (mg GAE g^{-1} FW). POD activity was assayed according to the method of Zheng *et al.* (2008). The POD activity was calculated by subtracting the first and last absorbance at 420 nm at intervals of 30 s up to 300 s (at 25%) and the result was expressed at 60 s as ∆OD g min^{-1}FW.

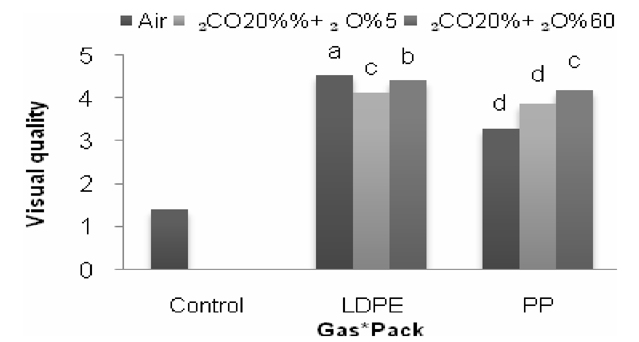
Statistical analysis

Each analysis consisted of triplicate measurements of each sample for 35-days storage and data were averaged over the three measurements. The data was evaluated to determine the effect on fruit of MAP with different polymeric films and gas combinations using SAS 9.1 software package by analysis of variance and by Duncan's multiple range test (DMRT) at a significant level of 1 or 5% (P < 0.01 or 0.05) to determine statistical differences and mean comparisons between control and treatments.

Results and discussions

Visual quality

Fig. 1a shows the effect of packaging with polymeric films (LDPE and PP) in three gas compositions (5%O_2 + 20%CO_2, 60%O_2 + 20%CO_2 and air) in comparison with control (unpackaged fruits) over the visual quality of the cornelian cherry fruit during 35 days of storage at 1 °C. During the storage period, the visual quality of all the fruits from different gas combinations packaged in polymeric films (LDPE and PP) and the control decreased. Control fruits (unpackaged) were scored under the limit of marketability after 2 weeks, while samples of the other treatments were acceptable for consumption according to their visual appearance. Air LDPE-packaged fruits exhibited a significantly better quality compared with other treatments (P< 0.01).



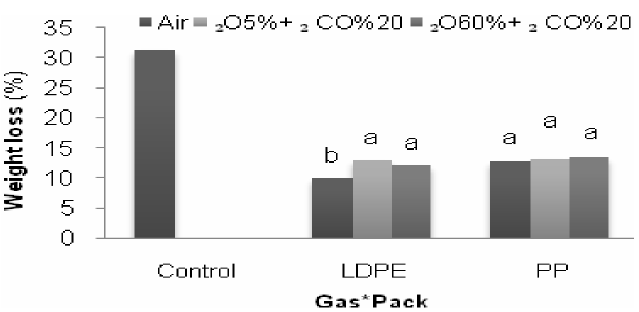


Fig. 1. Changes in visual quality and weight loss of cornelian cherry fruits after 35 days of storage at 1 under three gas combinations: 5%O_2+20%CO_2+75%N_2, 60O_2+20CO_2+ 20%N_2 and Air in two types of polymeric films: LDPE- low density polyethylene, PP- polypropylene compared with control (unpackaged)

Estimation of fruit decay

During the storage period no symptoms of decay were observed in any of the treatments. Cornelian cherry fruits are rich in anthocyanins, flavonoids and phenolic compounds. Most of these compounds have a wide range of biological activities including anti-fungal and antioxidant properties (Kähkönen *et al.,* 2001; Wang and Jiao, 2000). It seems that during the maintenance period these compounds inhibited the growth of fungi and pathogens.

Weight loss

Fig. 1b shows the cornelian cherry weight loss from packages in three gas compositions and the control (unpackaged) during 35 days storage at 1 °C. Weight loss of small fruits is higher than in other commodities not only due to their low skin diffusion resistance, but also due to a higher surface/volume ratio (Conte *et al.,* 2009; Serrano *et al.,* 2005). Predictably, the control (unpackaged) fruits showed the highest percentage of weight loss, losing about a third of their initial weight, whereas fruits that were Air LDPE- packaged exhibited the lowest weight loss. No significant differences were observed in TSS among the other treatments. The intensity of evaporation and subsequent weight loss decreased in MAP as the air around the packaged product is nearly saturated. Saturated air could, therefore, reduce the difference in water vapor pressure between the plant material and the air surrounding it, slowing down moisture diffusion from the plant material. On the other hand, MAP with polymeric films contains variable amounts of water vapor, which could slow down weight loss, regardless of the gas combination used. Similarly, Valero *et al.* (2006) reported that MAP with polymeric films was effective in reducing the weight loss of table grapes in comparison with control fruits.

Determinations of pH, titratable acidity, total soluble solids

Table 2 shows the changes in TSS/TA which occurred during the storage period. During storage, the total soluble solid content of the cornelian cherries in both treated and control fruits decreased marginally, while TA decreased dramatically, resulting in an increase in TSS/TA, which was higher in the control than in the treated fruits. The higher TSS/TA in the control was due to both lower titratable acidity and higher weight loss, as mentioned before, resulting in the condensation of TSS (Crisosto *et al.,* 2003; Conte *et al.,* 2009). The changes in both TSS and TA are in agreement with the results reported by other researchers (Remón *et al.,* 2000; Conte *et al.,* 2009). On the contrast, Ozkaya *et al.* (2009) evaluating the influence of MAP on the quality of strawberries, reported no significant difference in TSS values, but a significant difference in TA values between control and MAP stored strawberries.

Table 2 shows the pH evaluation of cornelian cherry fruits from packages in three gas compositions and control (unpackaged). pH values increased during the storage period.

Table 2. Changes in pH, TA, TSS and TSS/TA of cornelian cherry fruits before (day 0) and after 5 weeks of storage at 1 °C packaged in two types of polymeric films: LDPE: low density polyethylene, PP: polypropylene using three gas combinations: 5%O_2 + 20%CO_2 + 75%N_2, 60%O_2 + 20%CO_2 + 20%N_2, and Air compared with control (unpackaged)

Quality attributes	Treatment	Storage time (days)					
		0	7	14	21	28	35
pH	Control	3^{j}	3.1^{j}	3.2^{ghij}	3.3^{bcdefg}	3.5^{abc}	3.6 a
	Air LDPE	-	3^{hij}	3.15^{f}	3.28^{de}	3.34^{d}	3.53^{a}
	5%O_2 + 20% CO_2LDPE	-	3.1^{j}	3.12^{hij}	3.23^{fghij}	3.4^{abcdef}	3.5^{abc}
	60% O_2 + 20% CO_2 LDPE	-	3.1^{j}	3.12^{ij}	3.2^{ghij}	3.3^{bcdefg}	3.4^{abcd}
	Air PP	-	3.1^{j}	3.16^{ghij}	3.24^{fghij}	3.3^{bcdef}	3.4^{abcd}
	5%O_2 + 20% CO_2PP	-	3.3^{cdefg}	3.1^{ij}	3.2^{ghij}	3.3^{efghi}	3.5^{ab}
	60%O_2 + 20% CO_2PP	-	3.1^{j}	3.12^{hij}	3.2^{ghij}	3.3^{bcdefg}	3.4^{abcd}
TA	Control	3.5^{fghi}	4.1^{cdef}	3.4^{fghi}	2.42^{klm}	1.9^{m}	1.4^{nm}
	Air LDPE	-	3.9^{efg}	3.14^{ghij}	3.32^{hij}	2.12^{m}	1.8^{m}
	5%O_2 + 20% CO_2LDPE	-	4.2^{bcde}	4.5^{abcd}	4.11^{cde}	3.12^{ij}	2.8^{jkl}
	60%O_2 + 20% CO_2LDPE	-	5^{a}	4.6^{abc}	4.3^{abcde}	3.8^{fgh}	3.2^{hij}
	Air PP	-	4.9^{ab}	4.4^{abcde}	4.3^{abcde}	3.5^{fghi}	3.21^{hij}
	5%O_2 + 20% CO_2PP	-	4.5^{abcd}	4.4^{abcde}	4.1^{cdef}	2.84^{ijk}	2.32^{klm}
	60%O_2 + 20% CO_2PP	-	4.6^{abc}	4.4^{abcde}	4.1^{cdef}	3.22^{hij}	2.23^{lm}
TSS	Control	22^{a}	18.7^{a}	16.7^{ab}	15^{abcde}	14.7^{bcdef}	13.3^{def}
	Air LDPE	-	15^{abcde}	13.7^{cdef}	11.7^{ghi}	13^{defgh}	10.3^{i}
	5%O_2 + 20% CO_2LDPE	-	17.3^{a}	16.7^{ab}	15.3^{abcd}	14.3^{bcdef}	13^{defgh}
	%O_2 + 20% CO_2PP		11.7^{ghi}	15a^{bcde}	13^{defgh}	13.3^{def}	10.7^{hi}
TSS/TA	Control	6.29^{a}	4.56^{bc}	4.911^{ab}	6.19^{a}	7.74^{a}	9.5^{a}
	Air LDPE	-	3.85^{c}	4.36^{bc}	3.52^{bc}	6.13^{a}	5.72^{a}
	5%O_2 + 20% CO_2LDPE	-	4.12^{bc}	3.71^{c}	3.72^{c}	4.58^{bc}	4.64^{bc}
	60%O_2 + 20% CO_2LDPE	-	3.46^{c}	3.62^{c}	3.56^{c}	3.77^{c}	4.11^{bc}
	Air PP	-	3.41^{c}	3.71^{c}	3.42^{c}	4.11^{bc}	3.83^{c}
	5%O_2 + 20% CO_2PP	-	3.55^{c}	3.25^{c}	3.11^{c}	4.57^{bc}	5.04^{ab}
	5%O_2 + 20% CO_2PP	-	2.54^{d}	3.41^{c}	3.17^{c}	4.13^{bc}	4.79^{bc}

Data are means of three replications. Values within each column followed by the same letter are not significantly different at $P < 0.01$ (DMRT)

The increase in pH values seems to be normal during the postharvest life of cornelian cherry fruit according to the reduction in titrable acidity (Remón *et al.,* 2000; Serrano *et al.,* 2005).

Fruit color and anthocyanin index

There was a continuous non-significant decrease in the measurement of color lightness (L^*) after harvest in cornelian cherries belonging to packages in three gas compositions and the control (unpackaged) (Table 3), which indicates that the fruits became darker during the storage period. This result matches the finding of other researchers (Fernando *et al.,* 2007; Zheng *et al.,* 2003, 2008). Increases in hue angles were concomitant with less redness (lower a^* values); however, comparable hue angle values were found among the control and packaged fruits (Table 3). The higher hue angle for the control compared with that of the packaged fruits in different atmospheres could be explained by the anthocyanin index (content). There was a continuous decrease in anthocyanin levels in both packaged and unpackaged fruits during storage (Table 3). No significant differences in anthocyanin indexes were found among treated fruits during the experiment, but the control (unpackaged) showed a higher level of decline. This result matches to the ones of Zheng *et al.* (2003, 2008). There were different changes in the hue angle and anthocyanin levels of strawberries under different gas combinations and packaging (Ferreira *et al.,* 1994; Sanz *et al.,* 1999). Different changes in patterns of surface color in Chinese bayberries, strawberries and blueberries were perhaps due to the differences in composition and concentration of the phenolic compounds (Zheng *et al.,* 2008). Such changes could be the reason for different color changes noticed in the cornelian cherries during the storage period. It also appears that these compounds were affected by the gas permeability of the polymeric films to CO_2 and/or O_2, and their content could be affected by anthocyanin synthesis and/or degradation rates. Another reason for the decrease in anthocyanin could be related to the increase in pH (Eiro and Heinonen, 2002; Laleh *et al.,* 2006).

Ethylene production

Table 4 shows the changes in ethylene production rates. In all treatments, an increase in ethylene production was observed. During the storage period, the ethylene production was stable in the control fruits, which most probably is due to the senescence and deterioration of fruits. As was previously mentioned, the control fruits had unacceptable visual quality. Significantly, the highest ethylene production was detected in air LDPE-packaged

Table 3. Changes in color parameters (L^*, a^*, h°) and anthocyanin index of cornelian cherry fruits before (day 0) and after 5 weeks of storage at 1 °C packaged in two types of polymeric films: LDPE- low density polyethylene, PP- polypropylene using three gas combinations: 5%O_2 + 20%CO_2 + 75%N_2, 60%O_2 + 20%CO_2 + 20%N_2, and Air compared with control (unpackaged)

Quality attributes	Treatment	Storage time (days)					
		0	7	14	21	28	35
Lightness	Control	31.75^{a}	30.86^{a}	30.54^{a}	29.84^{a}	29.72^{a}	29.36^{a}
	Air LDPE	-	31. 57^{a}	30.74^{a}	30.62^{a}	30.53^{a}	30.39^{a}
	5%O_2 + 20% CO_2LDPE	-	30.93^{a}	30.7^{a}	30.2^{a}	29.93^{a}	29.76^{a}
	60%O_2 + 20% CO_2LDPE	-	31.5^{a}	30.66^{a}	30.42^{a}	30.54^{a}	30.23^{a}
	Air PP	-	31.6^{a}	30.6^{a}	30.58^{a}	30.62^{a}	30^{a}
	5%O_2 + 20% CO_2PP	-	31.11^{a}	30.7^{a}	30.37^{a}	30.17^{a}	29.81^{a}
	60%O_2 + 20% CO_2PP	-	31.7^{a}	31.25^{a}	30.95^{a}	30.73^{a}	30.65^{a}
Redness	Control	31.84^{a}	26.3 bcd	25.39 cd	26.56 bcd	25.28 d	24.89 e
	Air LDPE	-	27.68^{abcd}	28.09^{abcd}	27.78^{abcd}	26.26^{bcd}	25.54^{cd}
	5%O_2 + 20% CO_2LDPE	-	28.87^{ab}c	28.47^{abcd}	27.8^{abcd}	26.7^{abcd}	25.8^{cd}
	60%O_2 + 20% CO_2LDPE	-	30.84^{abcd}	30.46^{abcd}	29.23^{abcd}	28.14^{abcd}	27.6^{abcd}
	Air PP	-	29.91^{a}	29.1^{abcd}	28.77^{abcd}	26.91^{abcd}	26.65^{abcd}
	5%O_2 + 20% CO_2PP	-	28.85^{abcd}	28.3^{abcd}	27.7^{abcd}	26.21^{bcd}	25.23^{d}
	60%O_2 + 20% CO_2PP	-	28.55^{abcd}	28.12^{abcd}	27.34^{abcd}	26.21^{bcd}	25.53^{cd}
Hue angle	Control	20.49^{c}	22.06^{ab}	22.08^{ab}	22.60^{ab}	23.85^{ab}	25.6^{0a}
	Air LDPE	-	21.64^{ab}	22.36^{ab}	22.71^{ab}	23.06^{ab}	25.1^{a}
	5%O_2 + 20% CO_2LDPE	-	21.41^{ab}	21.96^{ab}	22.3^{ab}	22.66^{ab}	23.73^{ab}
	60%O_2 + 20% CO_2LDPE	-	20.76^{b}	21.19^{ab}	21.91^{ab}	21.14^{ab}	22.54^{ab}
	Air PP	-	20.80^{b}	21.9^{ab}	22^{ab}	22.23^{ab}	22.91^{ab}
	5%O_2 + 20% CO_2PP	-	21.98^{ab}	22.03 a^{b}	22.52^{ab}	23.23^{ab}	24.74^{ab}
	60%O_2 + 20% CO_2PP	-	21.6^{ab}	22.02^{ab}	22.60^{ab}	23.44^{ab}	24.17^{ab}
Anthocyanin (O.D. $_{530}$)	Control	2.42^{a}	2.27^{bcde}	2.10^{bcdef}	1.69^{h}	1.63^{h}	1.40^{i}
	Air LDPE	-	2.36^{abcd}	2.21^{abcde}	2.18^{abcde}	2.06^{efg}	1.77^{h}
	5%O_2 + 20% CO_2LDPE	-	2.36^{abcd}	2.38^{ab}	2.15^{abcdef}	2^{efg}	1.7^{h}
	60%O_2 + 20% CO_2LDPE	-	2.37^{ab}	2.25^{abcde}	2.24^{abcde}	2.15^{abcde}	1.91^{efg}
	Air PP	-	2.37^{a}	2.28^{abcd}	2.22a^{bcde}	2.1^{cdef}	1.85^{efgh}
	5%O_2 + 20% CO_2PP	-	2.36^{abcd}	2.05^{efg}	2.22^{abcde}	2.11^{edf}	1.83^{gh}
	60%O_2 + 20% CO_2PP	-	2.36^{abcd}	2.37^{abc}	2.2^{abcde}	2.13^{bcdef}	1.8^{h}

Data are means of three replications. Values within each column followed by the same letter are not significantly different at $P<0.01$ (DMRT)

cornelian cherries ($P< 0.01$).

Ascorbic acid

During storage, ascorbic acid levels declined after harvest in all of the treatments, which indicates a nutrient loss in cornelian cherries occurring during storage (Table 4). Another reason for the destruction of ascorbic acid is the high pH; the results of pH measurements in this experiment showed that the higher the pH, the larger the decrease in vitamin C content. As shown in Table 4, no significant differences in ascorbic acid content were observed between the packages LDPE and PP, regardless of gas combinations used (5%O_2 + 20%CO_2, 60%O_2 + 20%CO_2, and air). These treatments had better effects compared to control that showed how prolonging storage period cause decreasing in vitamin C concentrations, in contrast with the results reported by Sanz *et al.* (1999) for strawberry storage. Similarly, Amoros *et al.* (2008) reported that MAP was effective in preserving ascorbic acid.

Total phenolics and peroxidase (POD) activity

Table 4 shows the changes in total phenolics content and POD activity of cornelian cherry fruits belonging to the packages in three gas compositions and the control (unpackaged) during 35 days storage at 1 °C. The total phenolics content in both fruits packaged in three gas combinations and the control fruits also increased throughout the experiment period. The POD activity showed a similar pattern of change during storage. A higher level of total phenolics content was observed in the control fruits than in the treated one. The increases in total phenolics were delayed by the use of MAP, especially for fruits packaged in 60%O_2+ 20%CO_2 with the use of both polymeric films (LDPE and PP), while air LDPE showed the lowest total phenolics accumulation. Furthermore, the highest level of POD activity was observed in the control fruits rather than in those stored under MAP conditions, with no significant differences among the treated fruits. It has been claimed that the change of POD activity is related to the ripening processes and that it is increased with the advancing senescence of fruits (Tian *et al.,* 2004). In this sense, the increases in total phenolics and POD-ase activity are most probably due primarily to postharvest ripening and after that, to the senescence progress, as previously mentioned in visual quality, color change and TA, which results agree with the ones reported by Díaz-Mula *et al.* (2011) for plums under MAP storage.

Table 4. Changes in ethylene production, vitamin C, total phenolics and PODase activity of cornelian cherry fruits before (day 0) and after 5 weeks of storage at 1 °C packaged in two types of polymeric films: LDPE- low density polyethylene, PP- polypropylene using three gas combinations: $5\%O_2 + 20\%CO_2 + 75\%N_2$, $60\%O_2 + 20\%CO_2 + 20\%N_2$, and Air compared with control (unpackaged)

Quality attributes	Treatment	Storage time (days)					
		0	7	14	21	28	35
Ethylene production	Control	15^{rs}	24.67^{pqr}	26.52^{pq}	27^{pq}	26.28^{pq}	27.5^{pq}
	Air LDPE	-	62.28^{e}	71.16^{d}	79.9^{c}	84.01^{bc}	95.45^{a}
	$5\%O_2 + 20\% CO_2$LDPE	-	51.23^{hi}	54.06^{gh}	54.53^{gh}	53.58^{gh}	57.2^{fg}
	$60\% O_2 + 20\% CO_2$ LDPE	-	41.44^{klm}	40.5^{lm}	40.9^{lm}	45^{jkl}	60.9^{ef}
	Air PP	-	35.5^{n}	38.95^{mn}	42.71^{jklm}	52.83^{gh}	61.52^{ef}
	$5\%O_2 + 20\% CO_2$PP	-	63.64 a	86.4^{b}	87^{b}	53.3^{fg}	57^{gh}
	$60\%O_2 + 20\% CO_2$PP	-	41.82^{klm}	46 j^{k}	45.53^{jk}	47^{j}	52.1^{gh}
Vitamin C	Control	134.34^{a}	97.4^{b}	88^{c}	81.55^{def}	49.28^{i}	37.55^{j}
	Air LDPE	-	100.84^{ab}	90.35^{bc}	89.2^{c}	68.64^{f}	68.1^{f}
	$5\%O_2 + 20\% CO_2$LDPE	-	115.6^{a}	110.3^{a}	107^{a}	86.2^{cd}	75.1^{ef}
	$60\%O_2 + 20\% CO_2$LDPE	-	109.71^{a}	108.5^{a}	103.9^{a}	91.52^{bc}	73.3^{f}
	Air PP	-	110.88^{a}	109.71^{a}	103.81^{a}	85.1^{cde}	76.9^{def}
	$5\%O_2 + 20\% CO_2$PP	-	109.12^{a}	110.3^{a}	107^{a}	86.24^{cd}	75.1^{ef}
	$60\%O_2 + 20\% CO_2$PP	-	109.71^{a}	108.5^{a}	103.85^{a}	91.5^{bc}	73.3^{f}
Total Phenolic	Control	8764^{abcd}	9867^{a}	10090.67^{a}	10921.33^{a}	11060^{a}	11908^{a}
	Air LDPE	-	7864^{d}	8207.3^{bcd}	8193.3^{bcd}	8373.3^{bcd}	8920.7^{abcd}
	$5\%O_2 + 20\% CO_2$LDPE	-	8167^{bcd}	8656^{abcd}	8813.3^{abcd}	9022.7^{abcd}	9906.3^{a}
	$60\%O_2 + 20\% CO_2$LDPE	-	7706.7^{d}	8080^{cd}	8172^{bcd}	8336^{bcd}	8821.3^{abcd}
	Air PP	-	9026.7^{abcd}	8925.3^{abcd}	9376^{abc}	8934^{abcd}	9844^{a}
	$5\%O_2 + 20\% CO_2$PP	-	8025.3^{cd}	8307.3^{bcd}	8613.3^{abcd}	9244.3^{abc}	9502.7^{ab}
	$60\%O_2 + 20\% CO_2$PP	-	7734.7^{d}	8276^{bcd}	8381.3^{bcd}	8605.3^{abcd}	8917.3^{abcd}
PODase activity	Control	20.24^{c}	25.89^{a}	25.99^{a}	27.78^{a}	28.6^{a}	29.64^{a}
	Air LDPE	-	20.63^{bc}	21.9^{abc}	22.05^{abc}	23.5^{abc}	24.093^{bc}
	$5\%O_2 + 20\% CO_2$LDPE	-	21.30^{abc}	22.86^{abc}	23.97^{abc}	24.56^{abc}	24.67^{abc}
	$60\%O_2 + 20\% CO_2$LDPE	-	20.123^{c}	20.54^{bc}	21.4^{abc}	22.44^{abc}	23.1^{bc}
	Air PP	-	20.57^{bc}	21.1^{abc}	22.5^{abc}	23.54^{abc}	24.74^{abc}
	$5\%O_2 + 20\% CO_2$PP	-	21.12^{abc}	23.3^{abc}	24.1^{abc}	24.9^{ab}	24.92^{a}
	$60\%O_2 + 20\% CO_2$PP	-	20.6^{bc}	21.2^{abc}	22.32^{abc}	23.1^{abc}	24.9^{ab}
		0	7	14	21	28	35

Data are means of three replications. Values within each column followed by the same letter are not significantly different at $P < 0.01$ (DMRT)

Conclusions

The results of the present study indicate that MAP with both polymeric films was suitable to prevent weight loss and retain visual quality of cornelian cherries during 35 days storage as compared to the control (unpacked fruits), regardless of the gas combinations used. The two packaging with $60\%O_2 + 20\%CO_2$ PP and Air LDPE were more effective in retarding the soluble solid contents, titratable acidity, ascorbic acid, anthocyanin index decrease and pH increase, resulting in better surface color preservation than the control. Furthermore, air LDPE- and $60\%O_2 + 20\%CO_2$ LDPE-packaged could more effectively stop total phenolics accumulation and increase POD activity in comparison with control samples. During the maintenance period no symptoms of decay were observed.

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