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Influence of Modified Atmosphere Packaging on Quality and Shelf Life of Cornelian Cherry Fruits

Sheida Mohebbi* • **Younes Mostofi**** • **Zabihollah Zamani**

Department of Horticultural Sciences, Faculty of Agriculture, University of Tehran, Karaj 31587, Iran

Corresponding author: * **shmohebbi@ut.ac.ir; ** ymostofi@ut.ac.ir**

ABSTRACT

Cornelian cherries were stored in two types of polymeric film (polypropylene and low density polyethylene) 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 7-day intervals during storage and quality parameters were measured. The results showed that MAP could retain their weight and acceptable visual quality throughout the experiment, while the unpackaged fruits lost over 35% of their weight at the end of storage period and consequently their visual quality. Storage in MAP could retard soluble solid contents, titrable acidity, ascorbic acid, anthocyanin index decrease and pH increase during the storage time, than if kept in air in open containers. Furthermore, it also could significantly delay total phenolics accumulation and POD activity increase and led to better surface color preservation than the control. During the maintenance period no symptoms of decay was observed.

Keywords: MAP, quality, total phenolics, shelf life
Abbreviations: LDPE, low density polyethylene; **MAP**, modified atmosphere packaging; **PP**, polypropylene

INTRODUCTION

Studies on human health and disease incidence have shown that the consumption of fruits and vegetables provide protection against diseases including cancer and heart diseases, and this has been attributed to the various natural antioxidants in them, in addition to a number of other health benefits (Wang *et al*. 1996; Shui *et al*. 2006). Cornelian cherry (*Cornus mas* L.) belongs to the family *Cornaceae* (Rop *et al*. 2010). It is a wild plant that grows in Asia and Europe (Kalyoncu *et al*. 2009). Cornelian cherry fruit, which has sour-sweet tasting juice, contains a high amount 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 usage of the fruit and various parts of *Cornus* spp. in traditional medicine and as a food preservative (Vareed *et al.* 2006; Brindza *et al*. 2007; Rop *et al*. 2010). Also antibacterial, antihistamine, anti-allergic, anti-microbial, and anti-malarial activities has been reported by Vareed *et al.* (2006). In Iran, approximately 10,000 tons of cornelian cherry fruit is produced both under rainfed and irrigated cultivation, per annum. This species grows in the temperate zone of Iran including East Azerbaijan, Qazvin, Zanjan and Gilan on calcareous, well-drained forest soils. 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 is dried. Unfortunately, the importance of *Cornus* spp. has been neglected or even underestimated. This is because, not enough researches about the importance and value of this fruit has been performed by food industry, nutrition science and pharmacist experts.

Cornelian cherry, like most of small fruits, has a relatively short postharvest life. Commercial storage conditions (0-5°C and 80 to 95% relative humidity (RH)) are evaluated as a proper situation for other similar small fruits like blackberry, blueberry (Kader 2002). The use of controlled atmosphere (CA) or modified atmosphere packaging (MAP) are considered as a supplement to proper temperature and RH management to limit water loss, suppress diseases and prolong shelf life of fruit and vegetables (Smith *et al.* 1987; Beaurdy 1999; Kader 2002). Packaging with polymeric films in order to generating a desirable atmosphere with low O_2 and high CO_2 in addition to influencing the metabolism of the produce being packaged, or the activity of decay-causing organisms to increase storage life, can also maintains a high humidity environment inside the package which can have a great influence on quality preservation (Mangaraj and Goswami 2009). Modified atmosphere evolves inside the package as a result of the respiration rate of commodity, temperature and film permeability characteristics. Obviously, the suitability of plastic films for MAP is important, because an appropriate atmosphere inside the sealed package can passively evolve by proper matching of film permeability rates for O_2 and CO_2 with the respiration rate of packaged fresh fruit (Kader *et al.* 1989; Zanderighi 2001; Mangaraj and Goswami 2009). The beneficial effects of the MAP technique for preserving quality and prolonging shelf life of fruits and vegetables are well known (Kader *et al.* 1989). However, MAP performance is sensitive to temperature and under certain conditions like accumulation of carbon dioxide and/or low oxygen levels, it can cause "off flavor" and other problems (Kader *et al.* 1989; Golias and Bottcher 2003).

To the best of our knowledge, no studies on cornelian cherry postharvest storage have been conducted; therefore; in this study the efficacy of MAP as a feasible and economical approach to prolong the shelf life of cornelian cherry fruits as well as quality preservation during storage period was evaluated.

MATERIALS AND METHODS

Fruits and treatments

Cornelian cherry fruits with red colour (*Cornus mas* L. cv. 'Youzbashchay') were hand-harvested from 7-8 years old trees from an orchard in the country of Qazvin State, Iran. After harvesting in commercial maturation stage were transported immediately to the

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postharvest laboratory at the Department of Horticultural Sciences of University of Tehran, and selected for uniform size, color, ripening and freed from damaged, shriveled and unripe fruits. Samples of 200 g of cornelian cherry were packaged in two different polymeric films (20 × 30 cm), to passively generate atmospheres using fruit respiration; 75-µm thick LDPE film (low-density polyethylene) and 40-µm thick PP film (polypropylene). **Table 1** shows the properties of the two selected packages. Unpackaged cornelian cherries were also used as the control. All samples were stored at 1°C with approximately 95% RH for 35 days for subsequent evaluation on product quality and microbial growth. The experiment had three replications for weekly intervals.

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 the storage during the course of the experiment and after an additional 1 day in air at 25°C to simulate retail market conditions. Any berries with visible mold growth were considered as decayed. Fruit decay was expressed as percentage of fruit showing decay symptoms.

Weight loss

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

Determination of TSS/ TA, total soluble solids, total titrable acidity and pH

Total soluble solids (TSS) was determined at 25°C using a refractometer (model RF-40, Extech Instrument Corp., Waltham, USA) on berries juice, after filtering through Whatman #1 filter paper. Total Titrable acidity (TA) was analyzed by the pH meter and by diluting 5 mL aliquot of berry 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). pH was analyzed using an electronic pH meter (AMEL334-B, Milan, Italy).

Surface color measurement and anthocyanin index

External berry color was measured with a chromometer (CR 400, Minolta, Ramsey, NJ) which provided L^*, a^* values and hue angle. Color was expressed as L^*, a^* values and hue angle. Two readings per fruit were taken on opposite sides of 10 fruits from each replicate. Anthocyanin concentration were determined using 5 g of fruit tissue homogenised in 10 ml of ethanol and after centrifugation, by reading the absorbance at 530 nm by a UV-Visible spectrophotometer (UV-160, Shimadzu, Osaka, Japan). The absorbance of the ethanol extraction was used as the index for anthocyanin concentration.

Ethylene production

Ethylene concentration was analyzed by a gas chromatograph (GC-14-A, Shimadzu) using about 30 g of the fruit 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 of 5 ml berry juice using potassium iodide (KI) solution. Advent of durable dark blue was the end of the titration.

Total phenolics and peroxidase (POD) activity

Total soluble phenolics in the fruit juice extracts were determined with Folin-Ciocalteu reagent according to the method of Meyers *et al.* (2003) using gallic acid as a standard and results was 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). POD activity was calculated by subtracting of 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 ΔOD $gmin^{-1}$ $f.w.^{-1}$.

All experiments were repeated three times for 35-day storage. The average values with standard deviations were obtained over the three replicates and used in the analysis. The data were evaluated to determine the effect of polymeric films using SAS 9.1 software package (SAS Institute Inc., Cary, NC) by analysis of variance and by Duncan's multiple range test (DMRT) at significant level of 1 or 5% ($P \leq 0.01$ or 0.05) to determine statistical differences, mean comparisons between control and treatments.

RESULTS AND DISCUSSION

Visual quality

Table 1 shows the effect polymeric films (LDPE and PP) in comparison with control on the visual quality of cornelian cherry fruit during 35 days storage at 1%. During storage period both in the fruits from polymeric films and control the visual appearance decreased. Control fruits (unpackaged), were scored under the limit of marketability after 2 weeks whilst samples from the both polymeric films (LDPE and PP) were acceptable for consumption according to their visual appearance.

Table 1 Permeabilities 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	-	-	-
LDPE	75	3250	15730
PP	40	2820	18740

Estimation of fruit decay

During storage period in fruits from both of the used packaging films and control no symptoms of decay were observed. 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 (Wang and Jiao 2000; Kähkönen *et al*. 2001). It seems that during maintenance period these compounds have been inhibited the growth of fungi and pathogens.

Weight loss

It is clear that with increasing storage duration, the percentage of weight loss increased (**Table 2**). Polymeric films differently affected weight loss of cornelian cherries during 35 days storage at 1°C. Predictably, control (unpackaged) fruits had the highest percentage weight loss with losing about a third of its initial weight. Fruit weight loss strictly depending on the gas permeability of polymeric films. As a consequence, LDPE film showed less fruit weight loss, whilst higher weight loss was found in PP-packaged fruit.

Determination of TSS/TA, total soluble solids total titrable acidity and pH

Table 3 shows the changes in TSS/TA during the storage period. During storage total soluble solid content of cornelian cherry in both of the used packaged and unpackaged decreased marginally while TA decreased dramatically, resulting in an increase in TSS/TA in packaged and control

Table 2 Changes in visual quality and weight loss of cornelian cherry fruits after 5 weeks of storage at 1°C packaged in two types of polymeric films: PE: polyethylene, PP: polypropylene than control (unpackaged).

Quality attributes	Packaging	Storage time (days)					
		0	7	14	21	28	35
Visual quality	Control	5 a	2 f	2 f	1 g	1 g	1 g
	LDPE	-	4.6 b	4.4 bc	4.3 c	4 d	3.6 e
	PP	-	5 a	4.3 c	4 d	3.7 e	3.7 e
Weight loss	Control	0 i	21.73 c	31.2 b	30.23 b	35.36 a	37.83 a
	LDPE	-	4 h	6 h g	10 gf	14.6 de	16 dc
	PP	-	5.3 hg	12 ef	12.7 e	15.6 de	18.3 dc

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

Table 3 Changes in TSS/TA, TSS, pH, TA of cornelian cherry fruits after 5 weeks of storage at 1°C packaged in two types of polymeric films: PE: polyethylene, PP: polypropylene than control (unpackaged).

Quality attributes	Packaging	Storage time (days)					
		0	7	14	21	28	35
TSS	Control	22 a	15.7 bcd	15.7 bcd	13.7 def	10.7 hi	8.7 j
	LDPE	-	15 bcde	13.7 def	11.3 efg	13 hij	10.3 ij
	PP	-	16.7 b	16.3 bc	14.7 bcde	14.3 cde	12.3 hfg
TA	Control	5.5 a	4.08 c	3 e	2.42 f	1.85 gh	1.4 h a
	LDPE	-	3.9 dc	3.14 e	3.3 e	2.1 fg	1.8 gh
	PP	-	4.9 b	4.4 c	4.3 c	3.5 ef	3.2 e
pH	Control	3 g	3.1 fg	3.2 f	3.3 de	3.5 b	3.6 a
	LDPE	-	3 g	3.15 f	3.28 de	3.34 d	3.53 ab
	PP	-	3.1 fg	3.16 f	3.24 e	3.3 de	3.4 c
TSS/TA	Control	4.02 c	3.84 c	5.3 ab	5.7 a	5.8 a	6.3 a
	LDPE	-	3.84 c	4.4 bc	3.55 c	6.2 a	5.8 a
	PP	-	3.42 c	3.84 c	3.42 c	4.17 bc	3.9 c

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

Table 4 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: PE: polyethylene, PP: polypropylene than control (unpackaged).

Quality attributes	Packaging	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
	LDPE	-	31. 57 a	30.74 a	30.62 a	30.53 a	30.39 a
	PP	-	31.60 a	30.60 a	30.58 a	30.62 a	30 a
Redness	Control	31.84 a	26.30 bcd	25.39 cd	26.56 bcd	25.28 cd	24.89d
	LDPE	-	27.68 ab	28.01 abc	27.7 8 abcd	26.26 bcd	25.54 bcd
	PP	-	29.91 bcd	29.09 abcd	28.78 bcd	26.91 bcd	26.65 cd
Hue angle	Control	20.49 c	22.06 abc	22.08 abc	22.60 abc	23.85 abc	25.60 a
	LDPE	-	21.63 abc	22.49 abc	22.91 abc	23.06 abc	25.13 ab
	PP	-	20.93 bc	21.92 abc	22.07 abc	22.39 abc	24.83 abc
Anthocyanin (O.D. $_{530}$)	Control	2.42 c	2.27 abcd	2.10 ef	1.69 g	1.63 g	1.40 h
	LDPE	-	2.36 abc	2.21 bcde	2.18 cdef	2.06 f	1.77 g
	PP	-	2.37 ab	2.28 abc	2.22 bcde	2.08 def	1.85 f

Data are means of three replications. Values within each column followed by the same letter are not significantly different at $P \leq 0.05$ (DMRT).

fruits throughout storage, which were respectively higher in control and PP-packaged fruits than LDPE-packaged, with regarding of the changing of the TSS and TA contents, this seems to be normal during the storage of cornelian cherry. The changes of both TSS and TA were in agreement with results reported by other researches (Remón *et al*. 2000; Conte *et al.* 2009). In contrast, Ozkaya *et al*. (2009) evaluating the influence of MAP on quality of strawberry, reported no significant and significant differences in TSS and TA values respectively, between control and MAP stored strawberries.

Table 3 shows the pH evaluation of cornelian cherry fruits from packages with polypropylene and polyethylene and control during 35 days at 1°C. pH values increased during storage period. The increase in pH values seems to be normal during the postharvest life of cornelian cherry fruit according to reduction in titrable acidity (Remón *et al.* 2003; Serrano *et al*. 2005).

Surface color measurement and anthocyanin index

There was a continuous non-significant decrease in the measurement of the color lightness (L^*) after harvest in cornelian cherries from packages and control (**Table 4**), which indicates the fruit became darker with storage period. This result matches to Zheng *et al*. (2003 and 2008). Increases in hue angle were concomitant with less redness (lower $a*$ values), however, comparable hue angle values were found among control and two different packages during storage period (**Table 4**). The higher hue angle for control compared to packaged fruits could be explained by the anthocyanin index (content). There was a continuous decreasing in anthocyanin in the both packaged and unpacked fruits during storage (**Table 4**), no significant differences in anthocyanin indexes were found between two packages during the experiment, but the control showed higher level of declining. There were different changes in hue angle and anthocyanin of strawberry under different film packages (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 phenolic compounds (Zheng *et al*. 2008), so it could be the reason for the different color changes in cornelian cherries than the mentioned berries during storage period. And also it seems that these compounds were affected by the gas permeability of polymeric films to CO_2 and/ or O_2 and the content of them that can be affected anthocyanin synthesis and/ or degradation rates. Another reason for anthocyanin decrease could be related to

Table 5 Changes in ethylene production, vitamin C, total phenolics and PODase activity of cornelian cherry fruits after 5 weeks of storage at 1°C packaged in two types of polymeric films: PE: polyethylene, PP: polypropylene than control (unpackaged).

Quality attributes	**Packaging**	**Storage time (days)**					
		0	**7**	**14**	**21**	**28**	**35**
Ethylene production	Control	15 i	24.67 h	26.52 h	27 h	26.28 h	27.5 h
	LDPE	-	62.28 d	71.16 c	79.9 b	84 b	95.45 a
	PP	-	35.5 g	38.95 fg	42.71 f	52.83 e	61.52 d
Vitamin C	Control	134.34 a	97.4 de	88 f	81.55 fg	49.28 i	37.55 j
	LDPE	-	100.84 cd	90.35 ef	89.17 ef	68.64 h	68 i
	PP	-	110.88 b	109.7 bc	103.8 bcd	85 fg	76.85 gh
Total Phenolic	Control	8764 e	9867 de	10090.67 de	10926.67 d	11060 bc	11060 a
	LDPE	-	7864 c	8207.33 bc	8193.33 bc	8373.33 bc	8924.6 abc
	PP	-	9026.66 abc	8925.66 abc	81934 ab	9376 abc	9844 a
PODase activity	Control	20.24 a	25.89 cde	25.99 def	27.78 ef	28.6 gh	29.64 h
	LDPE	-	20.63 c	21.85 def	22 def	23.46 def	24 gf
	PP	-	20.59 b	21 c	22.45 cd	23.55 cd	24.73 cde

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

increasing pH (Eiro and Heinonen 2002; Laleh *et al*. 2006).

Ethylene production

An increase in ethylene production in all of the treatments was observed (**Table 5**). During the storage period, the ethylene production was stable in control that most probably, it is because of the senescence and deterioration of fruits as was mentioned in visual quality, control fruits were unacceptable. Significantly the highest ethylene production was detected in fruits packaged in polyethylene ($P \leq 0.01$).

Vitamin C

During storage ascorbic acid levels declined after harvest both in packaged and unpacked fruits, which indicates the nutrition loss in cornelian cherries with storage (**Table 5**). Another reason which causes the destruction of vitamin C is high pH; the results of pH measurements in this experiment showed that the higher pH, the more decrease in the vitamin C contents. As shown in **Table 5**, no significant differences in ascorbic acid content were observed between fruits packaged in two types of polymeric films (LDPE and PP) and they had best effect compared to control that showed the highest decreasing in vitamin C with prolonging storage period in contrast with the results reported by Sanz *et al.* (1999) for strawberry storage. Similarly, Amors *et al.* (2008) reported that MAP was effective in preserving of ascorbic acid.

Total phenolics and POD activity

Table 5 shows the changes in total phenolics content and POD activity of cornelian cherry fruits from packages with polypropylene and polyethylene and control during storage. The total phenolics content in both packaged and control fruits increased throughout the experiment period. The POD activity showed a similar change pattern during storage. Significantly higher level of total phenolics content in control fruit was observed ($P \leq 0.01$). The increases in total phenolics were delayed by the use of MAP, especially fruits packaged with LDPE showed significantly the lowest total phenolics accumulation ($P \leq 0.01$). Also, the highest POD activity was observed in control fruits than those stored under MAP conditions, without significant differences between PP and LDPE films. It was claimed that the change of POD activity is related to ripening processes and it is increased with advancing senescence of fruits (Tian *et al.* 2004), in this sense, the increases in total phenolics and PODase activity, most probablydue due to postharvest ripening and after that, senescence progress, as afore mentioned in visual appearance, color change and TA in agreement with the results reported by Díaz-Mula *et al.* (2011) for plum under MAP storage.

CONCLUSIONS

The results of present research showed that in comparison with control (unpackaged fruit), MAP with both polymeric films retard TSS, TA, vitamin C, anthocyanin index decrease and pH increase, was more effective in inhibiting the increase of total phenolics and POD activity, as well as prevented weight loss of fruits, maintained visual quality and extended storage life of cornelian cherry fruit.

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