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Effect of Storage Temperature and Packaging Material on Shelf Life of Thornless Blackberry

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Abstract
Blackberry is a highly perishable fruit and its quality decreases very quickly during postharvest period. In this research, two types of container including: oriented poly styrene (OPS), a petroleum-based material, and oriented poly corn starch (OPCS), a bio-based material, was analyzed over 14 days to determine their effects on shelf life of thornless blackberry. Packages were placed in freezer (0˚C), refrigerator (4˚C) and room (25˚C) temperatures in a factorial format based on completely randomized design. Results showed a strong positive correlation between fruit weight and marketability (R^2 = 0.726). It was confirm that fruit weight loss and shriveling can be an important reason for marketability reduction in blackberry. Blackberries were survived for 14 days at 0˚C, 8 days at 4˚C and only 3 days at room temperature. A downward trend was observed for pH, TA and TSS during the storage as well as for fruit taste and visual color. Fruits TSS was decreased regardless of the packaging materials and storage. Blackberries that were kept in OPS had significantly higher marketability and lower weight loss in comparison with OPCS that caused a reduction in fruit visual color and marketability. Results indicated that OPCS permeability caused higher fruit weight loss in comparison with other treatments. Blackberries in OPCS container had the highest amount of phenolic components following 14 days at 0˚C, which was significantly more than amount of phenolic components of fruits in OPS container. Compared to OPS, OPCS container did not make any improving in its characteristics to reduce fruit water loss that can be possible by using Nano clay particles.

Keywords: postharvest, container, fruit quality, anthocyanin, antioxidant activity**.**

Introduction

Blackberry (*Rubus* sp.) is a rich source of antioxidant substances including dietary polyphenolics and anthocyanins, which reduce risk of various diseases (Perkins-Veazie et al., 2002). This small fruit is becoming increasingly popular due to nutritional values and its positive effects on consumer health (Peretto et al., 2014). In addition to the sensitive and fragile skin, high respiration and transpiration rates of blackberry make it a highly perishable fruit with quick decrease in its quality at postharvest period (Joo et al., 2011; Peretto et al., 2014).

A rapid decrease in temperature for reducing respiration is vital especially for highly perishable fruits like berries (Morales et al., 2014). Duo to the effects of low temperature on deceleration of metabolism and fungal growth, keeping the blackberries at cold storage is the primary strategy for extending its shelf life (Antunes et al., 2003;

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Joo et al., 2011). Research showed transcriptional, post-transcriptional and post-translational regulation of critical expressed genes under cold temperatures (Chinnusamy et al., 2007). Rezaee Kivi et al. (2014) reported longer shelf life for raspberry at 0˚**C** than 5˚**C** or 10˚**C**, whereas antioxidant capacity and bioactive compounds were higher at 10˚**C**.

Appropriate packaging can prolong shelf life and protect fruits from damage and prevent secondary contamination (Seglina et al., 2010). In blackberry, weight loss occurs rapidly due to moisture movement from fruit into the surrounding drier air, as the fruit has no protective rind or cuticle (Perkins-Veazie, 2017). Closed packaging is becoming increasingly popular due to the reduction of water loss from fresh produce, via making a physical barrier around products and decreasing air movement across the product surface (Joo et al., 2011). Evaporated water molecules from fruit surface cannot escape through the package, so moisture loss can be significantly reduced depending on container material (Joo et al., 2011). Peretto et al. (2014) evaluated the effect of 8 different micro-perforations in polypropylene film packaging on the quality and shelf life of fresh blueberry and blackberry fruits that were kept at 4, 10 and 18°C as optimal, usual and poor postharvest conservation condition. Strong interaction was found between micro-perforations and temperatures for both fruits. The most common package for fruits and vegetables is plastic packages, which are not biodegradable. In addition, these kinds of packages can lead to water condensation on fruit or vegetable surface that is undesirable because it contributes to defects in the external appearance and microbial growth (Linke and Geyer, 2013). Decomposition of polymer packaging wastes take more than hundred years but biodegradable biopolymers can be a promising alternative (Seglina et al., 2010). The main kinds of renewable bio-packaging are comprised of polylactic acid, polyhidroxyalkanoates and thermoplastic starch (Weber et al., 2002). Permeability degree of biodegradable containers is their main problem, causing more amount of water loss (Seglina et al., 2010). Joo et al. (2011) compared bio-based packaging materials with petroleum-based ones and they reported ‘‘US standard No 1’’ grade for blackberries in both containers at 3˚C which showed suitable commercialization properties for more than 12 days.

In Iran, most of blackberry fruits are wild grown which are marketed in petroleum-based containers in room (25^{o}C), refrigerator (4^{o}C) and freezer (0^{o}C) temperatures as retail, supermarket and long distance markets, respectively. Developing standard orchards with effective thornless cultivars besides increased demand for the fresh blackberry, especially in south region of Caspian Sea as touristic region, resulted in huge plastic residual from fresh fruit containers. Serious environmental risk of petroleum-based materials highlighted the need for appropriate alternates for fruit packaging. This research aimed to study the interaction between packaging materials and storage temperatures on visual, edible quality and bioactive compounds of thornless blackberry during its postharvest.

Materials and Methods

Samples preparation and packaging system

A commercial thornless cultivar of blackberry (*Merton*) grown in a home garden located in the south of the Caspian Sea in Mazandaran, Iran, was hand harvested at a commercially mature stage, sorted and selected for similar size and color in July 2015.

Quantities of approximately 100 g of berries were weighted (A&D™ Jewelry balance, Fx-300GD, Japan) and placed in packages. All packages (Fig. 1) included closed system with a snap-fit lid, differed in material: half of them were made from oriented poly styrene (OPS), a petroleum-based material, and the others from oriented poly corn starch (OPCS), a bio-based material (Amelon Industry, Iran). Packages were managed in freezer (0^oC), refrigerator (4^oC) and room (25^oC) temperatures. Ten samples of each treatment were isolated after 0, 3, 8, and 14 days based on Perkins-Veazie, (2017) data and immediately analyzed for traits. Three replicates of each treatment were used for analyses. The characteristics such as fruit appearance (length and width of fruit, fruit weight, fruit color and marketability), edible quality (total soluble solids or TSS, pH, titrable acidity or TA, TSS/TA ratio, aroma and taste) and bioactive compounds (total antioxidant activities, total anthocyanin, total phenols and total flavonoids) were evaluated during the storage time.

Fig. 1. Two type of snap-fit closed container OPCS (left) and OPS (right) used for packaging thornless blackberry.

Visual quality evaluation

The weight of blackberry fruits in each package was measured on day 0, 3, 8, and 14. The average length and width of fruits were measured by digital caliper. The fruit visual color, marketability, aroma, and taste were scored from 0 to 100 by trained judges including six native students and academic staffs from University of Agricultural sciences and Natural Resources (SANRU), Sari, Iran. The jury members were fixed during experiment and judgeship carried out in same condition without any information about the experiment and the scores were written in separate sheets from 0 (minimum) to 100 (maximum) after fruit testing.

Edible quality evaluation

Blackberries of each package were analyzed based on Hassanpour (2015). Total soluble solids of ice cooled fruit juices were determined using a calibrated refractometer PR-32 (ATAGO, Japan) to avoid enzyme degradation of samples during measurements. Three measurements were taken for each sample and the results were reported in percent. A 5-10 g of the berries puree was diluted with 50 ml distilled water then titrable acidity of the juice was measured by titration with 0.1 N NaOH to an end-point of pH 8.2 (Ranaand Singh, 1992) by a PT/15/P calibrated pH meter (Sartorius, Germany). The acidity was expressed as percentage citric acid (%). Before titration, the pH of extracts was measured for each sample.

Bioactive compounds evaluation

Total anthocyanin content was measured with the pH differential absorbance method, according to Wroslstad (1976) in room temperature using homogeneous mixture of fruits. The fruit extracts were stirred with Sodium acetate (pH=1) and Potassium chloride (pH= 4.5) buffers separately, and each sample was read in 520 and 700 nm by uv-1800PC spectrophotometer (MAPADA, China). Results were expressed as mg cyanidin 3-glucoside per liter fruit juice (mg/l). The stable 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical method was used to determine the free radical scavenging activity of the fruit juice (Ebrahimzadeh et al., 2010). Two ml of diluted fruit extract was added to DPPH and the tubes were stored in dark condition for 15 minutes to be prepared for reading in 517nm by spectrophotometer.

The total phenolic compound contents were determined using the Folin-Ciocalteu method (Nabavi et al., 2008). In summary, distilled water, Folin-Ciocalteu and Sodium carbonate was added to 20 µl of fruit extract, then incubated for 30 minutes and was read in 765 nm by spectrophotometer. The results were expressed as Gallic acid equivalents.

Total flavonoids were estimated according to Chang et al. (2002). In this protocol the fruit extract mixed with Aluminum Chloride, potassium acetate 1M, and distilled water. The mixture was read in 415 nm by spectrophotometer after 30 minutes incubation. Its contents were calculated as quercetin equivalent by performing a calibration curve.

Statistical analysis

The experiment was performed in a factorial format based on a completely randomized design with three replications containing 100 gr fruit in each replication.The data were subjected to ANOVA analysis and the means were compared by Duncan's multiple range test at $p < 0.01$ significance levels in SAS (Software Version 9.1 SAS) as well as by Pearson coefficient correlation.

Results

Visual quality

As shown in Table 1, 2 and 3, the blackberries that were kept in both kinds of containers survived (were marketable) following 14 days at 0 ˚C, 8 days at 4 ˚C and only 3 days at room temperature.

Fruit length and width were significantly decreased during storage period (Table 1). Although non-significant difference was observed between two kinds of containers at 25˚C, reduction in the quantity of fruits in OPS container was less than those kept in OPCS at 0 and 4˚C. Similarly, there was a sharp downward trend in fruit weight in OPCS container (Fig.2). However, weight loss of fruits on day 8 and 14 was not significant which is indicative of occurrence of most water loss during the early days (before 8th day).

Table 1. Mean comparison of postharvest conditions effect on blackberry visual quality

Containers	Temperature (˚C)	Day	Fruit length (cm)	Fruit width (cm)	Fruit color (%)	Marketing (%)
Biodegradable	0	0	1.885 ^{a}	1.869 ^{a}	90.00 ^{a}	86.66 ^{a}
		3	1.712^{gh}	1.682 ^{f}	53.33 ^{de}	60.00 ^{fgh}
		8	1.697 ^{hi}	1.659 ^{g}	50.00 ^{ef}	63.33 ^{efg}
		14	1.683 ^{i}	1.641 ^{h}	41.67 ^{f}	56.67 ^{gh}
	4	0	1.885 ^{a}	1.869 ^{a}	90.00 ^{a}	86.66 ^{a}
		3	1.776 ^{cde}	1.743 ^{c}	73.33 ^{b}	80.00 ^{ab}
		8	1.724 ^{g}	1.643 ^{h}	60.00 ^{cd}	53.33 ^{h}
		14	-	-	-	-
	25	0	1.885 ^{a}	1.869 ^{a}	90.00 ^{a}	86.66 ^{a}
		3	1.772 ^{de}	1.657 ^{gh}	53.33 ^{de}	53.33 ^{h}
		8	-	-	-	-
		14	-	-	-	-
Non-biodegradable	0	0	1.885 ^{a}	1.869 ^{a}	90.00 ^{a}	86.66 ^{a}
		3	1.792 ^{c}	1.774 ^{b}	73.33 ^{b}	73.33 ^{bcd}
		8	1.761 ^{ef}	1.728 ^{d}	53.33 ^{de}	71.67 ^{bcde}
		14	1.743 ^{f}	1.713 ^{e}	45.83 ^{ef}	68.33 ^{def}
	4	0	1.885 ^{a}	1.869 ^{a}	90.00 ^{a}	86.66 ^{a}
		3	1.810 ^{b}	1.768 ^{b}	76.67 ^{b}	78.33 ^{abc}
		8	1.754 ^{f}	1.702 ^{e}	73.33 ^{b}	70.00 ^{cde}
		14	-	-	-	-
	25	0	1.885 ^{a}	1.869 ^{a}	90.00 ^{a}	86.66 ^{a}
		3	1.782 ^{cd}	1.651 ^{gh}	63.33 ^{c}	53.33 ^{h}
		8	-	-	-	-
		14	-	-	-	-

Different letters following the values indicate significant differences according to the Duncan test at $p \leq 0.01$

Table 2. Mean comparison of postharvest conditions effect on blackberry edible quality

Containers	Temperature (˚C)	Day	TSS %	pH	TA%	TSS/TA	Flavor %	Taste %
Biodegradable	0	0	12.2[a]	4.8[a]	0.53[i]	22.6[a]	90[a]	90[a]
		3	11.4[b]	3.7[bcd]	0.71[f]	16.1[c]	76.6[b]	75[cd]
		8	10.5[cd]	3.5[fg]	0.91[bc]	11.6[g]	66.6[bcd]	68.3[d]
		14	10.3[de]	3.5[g]	0.94[b]	10.9[h]	61.6[cd]	61.6[e]
	4	0	12.2[a]	4.8[a]	0.53[i]	22.6[a]	90[a]	90[a]
		3	10.8[c]	3.8[b]	0.57[hi]	19.1[b]	76.6[b]	86.6[a]
		8	10.2[e]	3.6[efg]	0.77[e]	13.2[e]	70[bc]	76.6[cb]
		14	-	-	-	-	-	-
	25	0	12.2[a]	4.8[a]	0.53[i]	22.6[a]	90[a]	90[a]
		3	9.8[f]	3.2[i]	0.67[g]	14.6[d]	35.8[e]	45.8[f]
		8	-	-	-	-	-	-
		14	-	-	-	-	-	-
Non-biodegradable	0	0	12.2[a]	4.8[a]	0.53[i]	22.6[a]	90[a]	90[a]
		3	11.5[b]	3.8[bc]	0.90[c]	12.8[ef]	76.6[b]	76.6[bc]
		8	10.6[c]	3.7[de]	0.85[d]	12.5[f]	68.3[bcd]	71.6[cd]
		14	9.93[f]	3.6[ef]	0.98[a]	10.1[i]	56.6[d]	70[cd]
	4	0	12.2[a]	4.8[a]	0.53[i]	22.6[a]	90[a]	90[a]
		3	11.4[b]	3.7[bcd]	0.583[h]	19.6[b]	76.6[b]	86.6[a]
		8	10.8[c]	3.7[cde]	0.73[f]	14.7[d]	76.7[b]	83.3[ab]
		14	-	-	-	-	-	-
	25	0	12.2[a]	4.8[a]	0.53[i]	22.6[a]	90[a]	90[a]
		3	10.7[c]	3.3[h]	0.66[g]	16.1[c]	60[cd]	56.6[e]
		8	-	-	-	-	-	-
		14	-	-	-	-	-	-

Different letters following the values indicate significant differences according to the Duncan test at $p \leq 0.01$

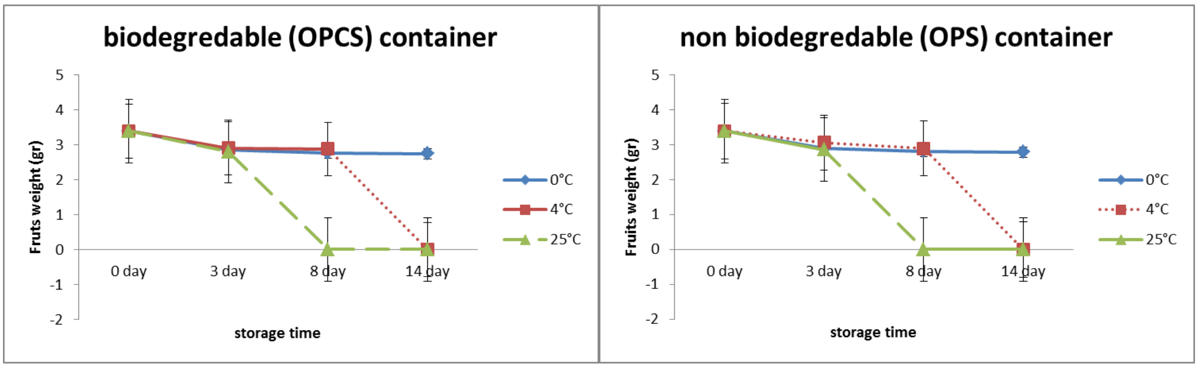

Fig. 2. Interaction of storage time and temperature on fruit weight of thornless blackberry in OPCS (left) and OPS (right) containers.

Fruit marketability was rapidly declined in both containers during the first three days; however, blackberries did not lose extra marketability after 3 days of storage, based on panel taste results. Blackberries kept in OPS had significantly higher marketability in comparison with OPCS ones. High humidity inside the OPS container prevented water loss and shriveling which led to higher fruit marketability. As shown in Fig. 3, a strong positive correlation between fruit weight and marketability (r= 0.8522) was observed at 0.01 level, that confirmed importance of fruit weight loss and shriveling on marketability reduction of blackberry fruits. The lowest fruit marketability was recorded for blackberries stored at 25˚C regardless of the containers. Only a little more than half of the fruits were marketable following 14 days of storage at 0˚C and the difference in container types was significant toward OPS ones due to less color losing related to Anthocyanin. Fruit visual color was decreased during storage period, based on the panel taste results (Table 1). The lowest decrement of visual color was observed in OPS container after 8 days of storage at 4˚C, none of the other treatments could keep fruit color until then. There was no significant difference between the treatments of both 0 and 4˚C on 3rd day.

Edible quality

Total soluble solid (TSS) of fruits decreased regardless of the packaging materials and storage temperature but this decline was sharp at 25˚C in comparison with other storage temperatures (Table 2).

A downward trend was observed in pH during the storage that is in accordance with TA increment trend. In addition, the pH reduction of blackberries kept in OPS included lower trend than OPCS (Table 2) as well as for TSS/TA ratio. That is related to material characteristics of container as well as weight loss.

TSS to TA ratio, as an appropriate indicator of blackberry maturity, was significantly decreased during postharvest period (Table 2 and Fig. 4). High TSS to TA ratio indicates sweetness and conversely low ratio shows sour taste.

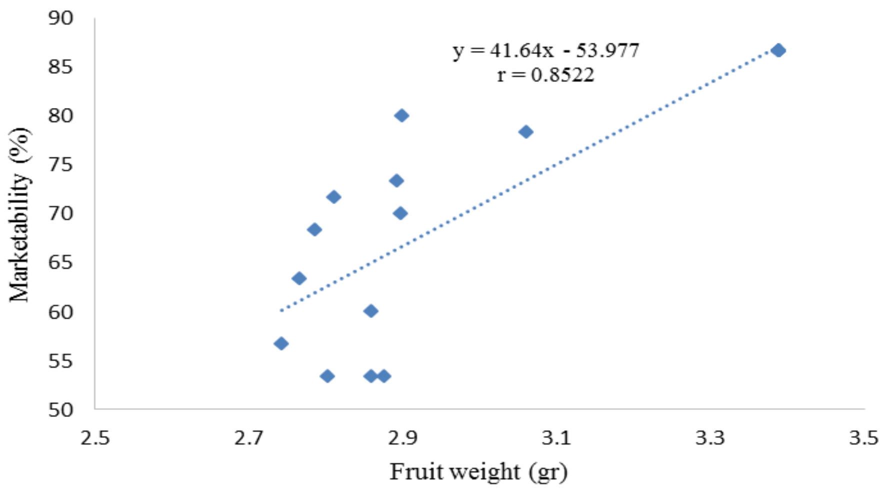

Fig. 3. Correlation between fruit weight and marketability (significant at 0.01 level) for thornless blackberry fruits

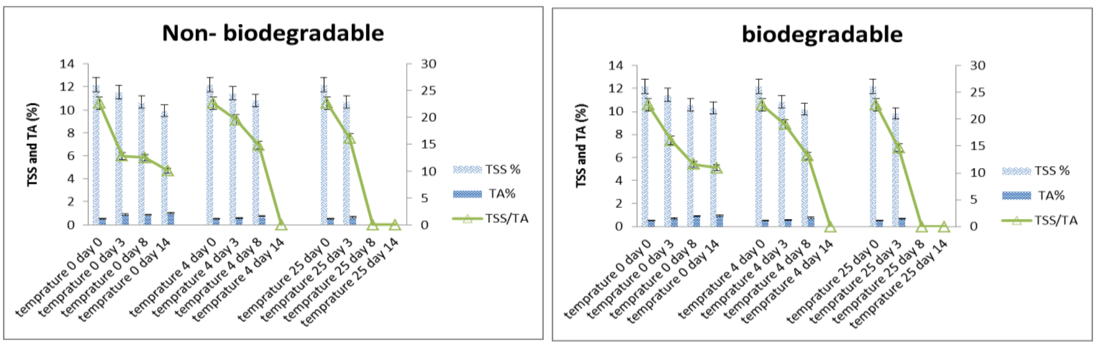

Fig. 4. Interaction between storage time and temperature for TSS, TA and TSS/TA of thornless blackberry in OPCS (left) and OPS (right) containers.

No significant differences in fruit flavor were observed for the same storage temperatures for both containers (Table 2).

Fruit taste decreased in different storage temperatures during the storage period, based on panel taste results; however, no significant difference was observed for blackberries stored in OPS container at 4°C on first, third and eight days (Table 2). So it can be concluded that 4°C is better than freezing for preserving fruit taste and flavor.

Healthy compounds

Total antioxidant activity was not significantly different during the storage period for both containers (Table 3). Due to significant changes in phenol and flavonoid content, it can be concluded that antioxidant activity of thornless blackberry cultivar is not affected by phenol content.

Total phenol content of blackberry fruits that were stored in cold conditions (0 and 4°C) showed a slight upward trend (Table 3). Blackberries in OPCS container had the highest amount of phenolic components after 14 days when held at 0°C that was significantly more than phenolic components of fruits in OPS container. On the third day of storage at 25°C, total phenolic content in OPS container was significantly more than OPSC containers (Table 3). Total flavonoids content was generally reduced during post-harvest period, though this downward trend was violated in OPS container especially at 0°C (Table 3).

Anthocyanin content was significantly decreased during storage period at 4 and 25°C. Anthocyanin of blackberry at 0°C in both containers did not consistently change (Table 3). It decreased on the 3rd day but increased on the 8th day and finally deceased on 14th again (Table 3). A steady decrease in fruit visual color during post-harvest (Table 2) is in accordance with the overall trend of total anthocyanin content. According to Fig. 5, correlation between visual color and anthocyanin content was not significant (r= 0.446) even though it was positive.

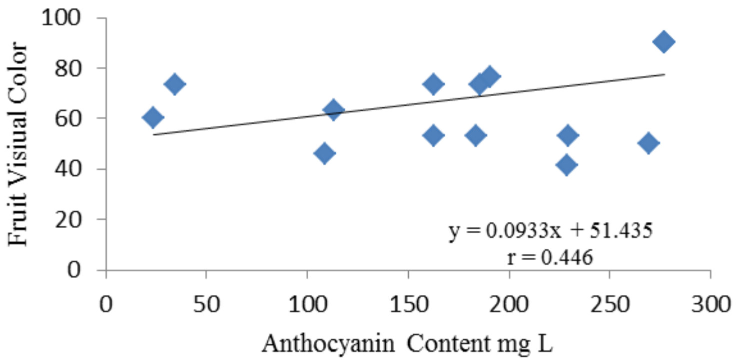

Fig. 5. Correlation between fruit visual color and anthocyanin content (non-significant) for thornless blackberry fruits

Discussion

Decrease in fruit weight was considered as a sign of fruit dehydration. Fruit shriveling as an important postharvest problem of blackberries is directly related to dehydration. Moisture loss from the fresh produce is directly proportional to the difference between the water vapor pressure at the surface and the air surrounding the product (Joo et al., 2011) and it could be accelerated by warm temperature via triggering cell death by cytoplasmic dehydration by a small family of genes encoding transcriptional activators known as dehydration responsive element (DRE) (Lissarre et al., 2010; Cook et al., 2004). Higher permeability of the OPCS material to water vapor is responsible for higher weight loss and size reduction that is dependent on material characteristics of container like molecular weight, molecular weight distribution, and thickness. Auras et al. (2005) demonstrated that the water vapor transmission rate of biodegradable material was three times higher than that of the non-biodegradable materials. Joo et al. (2011) reported that the weight losses of blackberry in the packages made from poly lactic acid was higher than in the OPS ones. The effective dispersion of nanostructured layered silicates with high aspect ratios may improve the mechanical, thermal and barrier characteristics of polymers, even at very low concentration by using nano clay particles and polyethylene (Pegoretti et al., 2007). In summary, it can be concluded that both temperature and container materials can be effective on fruit dehydration.

The best temperature for preserving visual color of thornless blackberry was 4˚C. In higher temperatures, the color pigments can degrade quicker and freezing the fruits may reduce shininess of fruit skin. Rapid change in fruit color had been reported by Wang and Camp (2000) and Seglina et al. (2010) as well. Shamaila et al. (1993) evaluated the correlation of sensory attributes, chemical and flavor volatile compounds to help good selection for marketing. They observed correlation among TSS, TA, TSS/TA ratio and pH with sensory attributes. However, they did not find correlation between sensory attributes, and chemical volatiles.

High respiration rate following exposure to high temperatures is a primarily reason for rapid TSS reduction at 25˚C. The decline trend of TSS in post-harvest period was reported for different berry fruits including strawberry (Ayala-Zavala et al., 2004), wild genotype (Rezaee Kivi et al., 2014) and blackberry cultivars (Joo et al., 2011).

Although a downward trend was predicted for TA as a general idea, the results of current experiment contradicted this accepted idea. Postharvest TA increase can be considered as a specific feature of thornless blackberry in subtropical climate of Mazandaran province, Iran. Also, results can be interpreted by the presence of unripe fruits or harvesting before shiny black stage.

Also, it could be related to cold acclimation that is reported in Arabidopsis metabolome evaluation under cold stress via increase in carbohydrate and organic acids for up-regulation of citric acid cycle (Cook et al., 2004).

Development of off-flavor is one of the important factors that limit blackberry's quality in post-harvest period due to the great role of flavor in consumer consent (Morales et al., 2014). Fruit flavor decreased significantly with increasing storage time. Nunes et al. (2003) reported that the raspberries that stored at 15 or 20˚**C** lose their aroma and taste very fast. Morales et al. (2014) reported opposing trends for volatile compound composition for two raspberry cultivars during storage, in which one of them lost compounds and another was enriched.

In raspberry, most of the identified volatile and aromatic compounds were terpenes, benzaldehyde, benzyl alcohol and p-cymene, respectively (Shamaila et al., 1993) which accumulation of ethanol and alcoholic off-flavors disorders will increase via modification of internal atmosphere of packages (Park et al., 1994). Constant TSS in cooler storage conditions of blueberry fruits could be related to reduction in respiration under low temperature (Almenar et al., 2008).

OPS containers can be suggested for keeping acceptable taste at 25^{o}C in comparison with OPCS because the fruit taste was significantly better in this condition. Almenar et al. (2008) reported blueberry aroma profile was slightly affected by package type especially for biodegradable containers. Ethanol increased slightly, regarding off-flavor development during storage. More CO_2 levels in the biodegradable packages with lower slots resulted in higher ethanol levels and off-flavor production.

Stability of antioxidant activity can be considered as an important feature of this valuable small fruit that could guarantee human health. Cold acclimation in temperate fruit trees make them tolerant to freezing via numerous physiological, biochemical and molecular changes that occurring during cold acclimation, including upregulation of antioxidative mechanisms, synthesis and accumulation of cryoprotectant solutes and proteins (Lissarre et al., 2010). The oxygen radical absorbing capacity of blackberry was not significantly different between distinct harvest times (shiny and dull black stages) as mentioned by Perkins-Veazie et al. (2002) for thornless and thorny cultivars.

Mechanism of changes in phenol and flavonoids content is too complicated and there are inconsistent results. Wu et al. (2010) reported decreasing in total phenol content in evergreen variety of blackberry but increase in Marion variety. They also pointed out that the phenols in Marion increased on 3rd day and reduced on 9th day.

Reduction in the anthocyanin levels of ‘Chester’ blackberries was reported by Joo et al. (2011) via the study of biodegradable and non-biodegradable containers but it was not a consistent decrease. They also found no significant effect on the fluctuation of the anthocyanin content in two kinds of containers. There are inconsistent results about anthocyanin changes over time. For example, Kalt et al. (1993) claimed increase in anthocyanin content of several small fruits at temperatures >0^{o}C. Some researchers have attested to the unpredictable nature of anthocyanin, so considered them as ‘‘relatively unstable’’ (Giusti and Wrolstad, 2001).

Shamaila et al. (1993) reported positive correlation between anthocyanin and visual color of raspberry (r= 0.58), which is in according with our results. Changing superficial anthocyanin content is not necessarily linked to inner anthocyanin. For instance, carbon dioxide caused decrease in anthocyanin of internal tissue whereas no effect was observed on outside tissues (Holcroft and Kader, 1999). So, the lack of a strong correlation between visual color and anthocyanin content can be related to different properties of different fruit tissues for release or degrade of anthocyanin.

Conclusion

In this study, blackberry fruits that were kept in two types of containers survived for 14, 8 and 3 days at 0 ˚C, 4 ˚C and room temperature respectively. There was a sharp downward trend in fruit weight in OPCS container due to higher permeability and dehydration than in OPS which resulted in triggering cell death by cytoplasmic dehydration via small family of genes encoding dehydration responsive element (DRE). The marketability of fruits decreased based on its significant and positive correlation with fruit weight. Although the visual color of fruits and their TSS decreased, increase in fruits TA during postharvest period was related to cold stress effect on carbohydrate and organic acids up-regulation. However, no significant difference was observed for blackberries stored in OPS container at 4 ˚C on the first, third and eighth days. So it can be concluded that 4 ˚C is better than freezing temperature for preserving fruit taste and flavor. Total antioxidant activity, as an important feature of this valuable small fruit was not significantly different during the storage period in both containers. Blackberries in OPCS container had the highest amount of phenolic components after 14 days when held at 0 ˚C that was significantly more than OPS container. Reducing municipal solid waste is another advantage of this package.

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