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Full Length Research Paper

Biochemical and quality parameters changes of green sweet bell peppers as affected by different postharvest treatments

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In this research, the effects of different postharvest treatments on quality and biochemical properties of "Maxibell F1" California Wonder type peppers at green mature stage were determined. In this content, ultraviolet C (UV-C) at 254 nm treatments for 2.5, 5, 10 min and hot water dipping (HWD) treatments for 2 min at 40, 50, 60°C were done respectively. Besides, low density polyethylene (LDPE) and polyvinylchloride (PVC) based modified atmosphere packaging (MAP) applications were materialized. Some quality and biochemical parameters such as flexibility, soluble solids content, weight loss, decay incidence, ascorbic acid content, total chlorophyll content and membrane leakage were assessed after each storage period on peppers. Furthermore, the gas concentrations inside modified atmosphere packages were daily measured. Treated peppers were stored at 6 - 7°C and 90 - 95% RH conditions for 15, 30 and 45 days with two days shelf life at 18 - 20°C respectively. According to the results, storage period affected the quality and biochemical properties. Thus, quality and biochemical properties reduced with prolonged storage period. Furthermore LDPE based MAP, PVC based MAP and HWD at 40°C were found successful in terms of keeping the parameters as mentioned, respectively. The differences between treatments became evident especially after 30 and 45 days storage.

Key words: Bell pepper, storage period, ultraviolet C, hot water dipping, modified atmosphere packaging, quality.

INTRODUCTION

Bell pepper (*Capsicum annuum* L.) is an important vegetable crop worldwide and may be green (unripe), red, yellow, orange, or brown when ripe. Peppers are rich in vitamins, especially A and C, and are low in calories (Howard et al., 1994). Bell peppers are recommended to be stored at 7 to 10°C and 95 - 98% relative humidity (RH), with a storage life of approximately two to three weeks (Kader, 2002). The main factors of quality degradation of sweet pepper during prolonged storage are decay development, caused primarily by *Botrytis cinerea* and *Alternaria alternata* (Ceponis et al., 1987), shriveling associated with rapid water loss (Maalekuu et al., 2003), and susceptibility to chilling injury (CI), which limits storage to temperatures above 7°C (Paull, 1990). A thorough pre-cooling to 10°C soon after harvest, delayed but did not prevent, soft rot decay (Sherman et al., 1982).

Green peppers for fresh market consumption when pericarp wall becomes thick and the fruit reaches typical size are manually harvested on multiple occasions throughout the growing season (Sargent, 2000). However, estimating pepper maturity at green stage can be difficult even for fruit with similar physical attributes; under certain conditions, green peppers can begin to ripen and change color during shipping (Tadesse et al., 2002).

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Abbreviations: HWD, Hot water dipping; **UV-C,** ultraviolet C; **LDPE,** low density polyethylene; **PVC,** polyvinylchloride; **MAP,** modified atmosphere packaging; **RH,** relative humidity; **CI,** chilling injury; **SSC,** soluble solids content; **HSP,** heat shock proteins.

Postharvest heat treatments of fruits and vegetables for disease control and insect disinfection have been used for many years (Barkai-Golan and Phillips, 1991). Heat can be applied to fruits and vegetables as hot water dips, vapour heat or hot dry air (Couey, 1989). Dipping red sweet pepper for 3 min in water heated to 50°C significantly reduced decay caused by *B. cinerea* and *A. alternata* (Fallik et al., 1996). This treatment has a number of advantages which include relative ease of use, short treatment time, reliable monitoring of fruit and water temperatures, and the killing of skin-borne decay-causing agents (Couey, 1989; Sharp, 1994; Lurie, 1998). Another important economic advantage of hot water immersion technology is that the cost of a typical commercial system is about 10% that of a commercial vapor heat treatment system (Jordan, 1993). However, the physiological responses of cultivars of different fruit or flower species to heat treatments can vary by season and growing location (Shellie and Mangan, 1994; Hara et al., 1996).

Another alternative postharvest treatment that can be an adjunct to refrigeration for preserving fruit and vegetables is the use of nonionizing, germicidal, artificial ultraviolet C (UV-C) radiation (Maharaj and Arul, 1999). Postharvest UV-C treatments with 10 kJ/m^2 dose delayed yellowing of florets on broccoli; furthermore, antioxidant capacity of broccoli could be preserved (Costa et al., 2006). Moreover UV-C treatments reduced chilling injury on peppers (Vicente et al. 2005) and peaches (Gonzalez-Aguilar et al., 2004).

The modified atmosphere packaging (MAP) technique consists of the enclosure of respiring produce in polymeric films in which the gaseous environment is actively or passively altered to slow respiration, reduce moisture loss and decay and extend the shelf life of the products. MAP techniques provide low O_2 and high CO_2 regimes similar to those achieved by using controlled-atmospheric storage and are theoretically able to maintain desired atmospheres throughout the marketing chain (Beaudry et al., 1992). Sealed packaging such as MAP is intended to suppress microbial growth, retard respiration, ripening, and senescence and inhibit oxidative reactions which requires free oxygen (Leistner and Gould, 2002).

Turkey is an important pepper producer country; Marmara and Aegean regions are the most important production regions in Turkey. Thus the aim of the study is to prolong the shelf life and marketing season of green bell pepper grown on field with different postharvest treatments without any residue.

MATERIALS AND METHODS

Plant material

Peppers (*C. annuum* cv. Maxibell F1) were harvested at mature green stage at 01.09.2009 from a commercial yield in Canakkale, Turkey. Fruits without defects were harvested with a short calyx (1 cm long). Fruits were uniform (180±10 g each) and at 90% coloration.

Postharvest treatments and storage

Harvested bell pepper fruits were disinfected with 1% sodium hypochlorite for 2 min and dried at 20 - 22°C for 2 h initially. Then some postharvest treatments such as UV-C radiation at 254 nm, hot water dipping (HWD) and MAP were applied to disinfected bell pepper fruits. In this context; UV-C treatments were materialized in a UV-C cabinet by using 6 UVP lamp (TUV G30T8, 30W, Philips) at 254 nm with an intensity of 300 $mWcm^2$ at a distance of 25 cm for 2.5, 5 and 10 min, respectively. The intensity of the UV-C lamp was determined with a UV light meter (LT Lutron). Furthermore, pepper fruits were immersed for 3 min at 40, 50 and 60°C in a digital water bath, respectively, and dried at 20 - 22°C for 2 h. Selected bell pepper fruits for MAP were placed in low density polyethylene (LDPE) based 1 kg capacity retail bags and 1 kg capacity polystyrene plates covered by polyvinylchloride (PVC) shrink film. The thickness of both packaging materials was 20 µm thickness, measured by a digital micrometer. Fruits without any treatment were used as control. Finally all plant material were precooled at 9 -10°C for 1 day and stored at 6 -7°C with 90 - 95% RH conditions for 15, 30 and 45 days with three days shelf life at 18 -20°C / 50 - 55% RH respectively.

Quality assessments

Weight loss

Weight loss was expressed as percentage of weight loss from the initial weight of ten fruits for each treatment and storage period.

Fruit firmness

Fruit firmness was measured on ten fruit as described by Ben-Yehoshua et al. (1983). Each fruit was placed horizontally between two flat surfaces and a 2 kg weight loaded on top of the flat surface. A dial fixed to a graduated plate recorded the deformation of the fruit in millimeters. Full deformation was measured 15 sec after exerting the force on the fruit, then the weight was removed and the residual deformation was measured 15 sec later.

Soluble solids content

Soluble solids content (SSC) was determined directly by digital hand refractometer as percentage values.

Decay incidence

Fruit pericarp and calyx were considered decayed once fungal mycelia appeared on the six pericarp or calyx. Decay was expressed as a percentage of the total initial fruit number.

Biochemical parameters

Membrane leakage

Membrane leakage was expressed according to the method of Fan and Sokorai (2005). In this context, 5 g of each sample were incubated at 23°C in 100 ml glass bottles containing 50 - 70 ml distiled water. During incubation, samples were agitated using a shaker at a speed of 100 min^{-1}. Electrical conductivity of the bathing solution was measured at 1 min (C1) and 60 min (C60) of incubation using a conductivity meter. The samples were then autoclaved (121°C) for 25 min, and total conductivity (CT) of

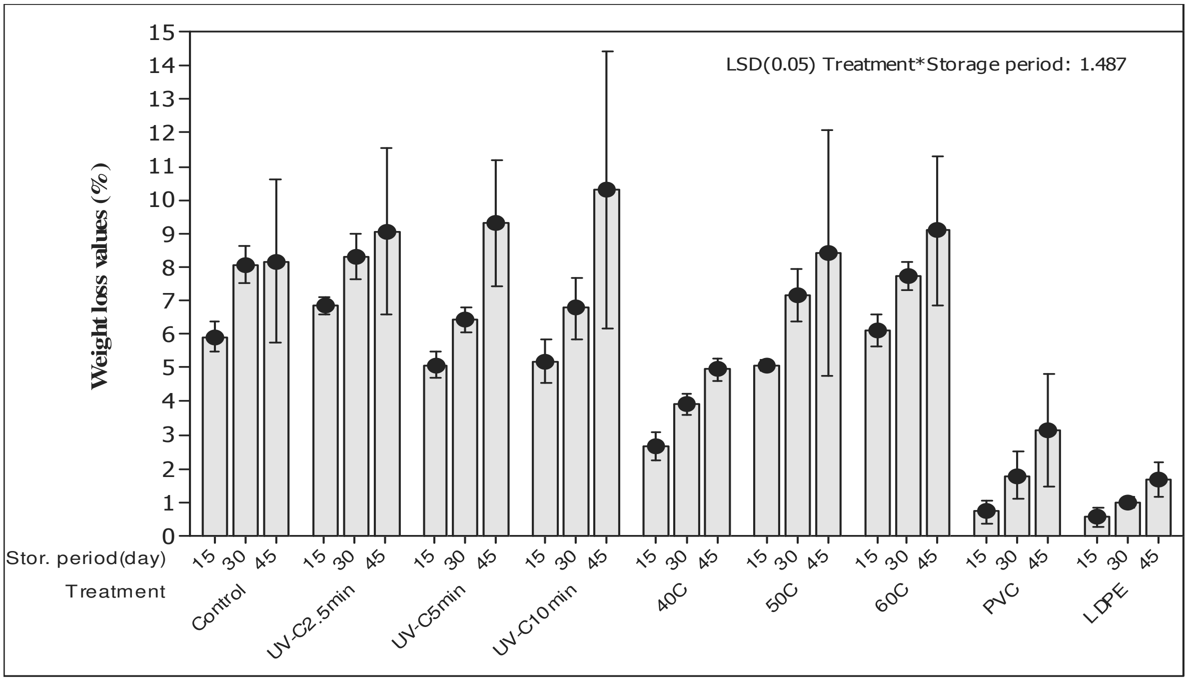

Figure 1. The effects of different postharvest treatments on weight loss (%) of green bell peppers during storage.

bathing solution was then measured after cooling. Electrolyte leakage (E) was calculated from the following equation:

$$E = (C60 - C1)/CT \times 100$$

Total chlorophyll content

Total chlorophyll (mg l^{-1}) was determined with UV-VIS spectrophotometer (wavelength absorbance was measured at 652 nm) for each sample using the extinction coefficient for 80% acetone (Holden, 1976).

Vitamin C content

Vitamin C determinations (mg 100 g^{-1}) were made according to the spectrophotometric method, using 2.6 - dichlorophenolindophenol (Loeffler and Ponting, 1942).

Internal atmosphere of packages

Internal atmosphere of packages were measured by PBI Gas analyzer using a syringe to a silicon septum on packages; thus O_2 and CO_2 values were expressed as percentage.

Statistical analysis

The experiment took the form of a completely factorial randomized design. 20 pepper fruits mean one replicate. Data from three replicates were subjected to analysis of variance (ANOVA) analysis except internal atmosphere package data. Sources of variation were treatment and storage period. Mean comparisons were performed using Least Significant Difference (LSD) range test at P = 0.05 level using Minitab 15 software program.

RESULTS AND DISCUSSION

Weight loss

Weight loss was increased by storage period. In addition, postharvest applications affected weight loss of green bell peppers during storage significantly ($p<0.05$) as shown by fruits in MAP based PVC and LDPE. HWD at 40°C followed these treatments. UV-C treatments for 2.5 and 5 min could reduce weight loss until 15 days storage (Figure 1). However MAP treatments reduced weight loss even for 45 days storage with shelf life. Permeation to water vapor of fruit skin and the rate of water loss in bell pepper decreased with increasing ripeness (Diaz-Perez et al., 2006). Shelf life begins after harvest, therefore maintaining a low rate of weight loss and softening in bell pepper after harvest is important for prolonged storage and sea transport to distant markets (Maalekuu et al., 2003). In this context, maximum permissible weight loss of 4.5% in bell pepper is similar to the 5% reported by Wills et al. (1998).

Fruit firmness

According to the results, fruit deformation was affected by both storage period and postharvest treatments. Thus, firmness decreased with prolonged storage. Significant differences were fixed at each storage period. Furthermore, the difference between treatments were found significant ($p<0.05$). Moreover, LDPE based MAP, PVC based MAP and HWD at 40°C delayed fruit deformation,

Table 1. Changes in fruit deformation (mm) affected by different postharvest treatments during storage.

Treatment	Storage period (day)				Mean
	0	15	30	45	
Control	2.0667 m	2.7333 hij	3.533 c..f	4.4667 ab	3.2 ab
UV-C 2.5 min	2.0667 m	2.7333 hij	3.6667cde	4.5333 ab	3.25 ab
UV-C 5 min	2.0667 m	2.4667 jkl	3.6000 c..f	4.3333 b	3.1167 b
UV-C 10 min	2.0667 m	2.7333 hij	3.8667 c	4.7333 a	3.35 a
HWD-40℃	2.0667 m	2.2667 lm	2.8667 hi	3.2667 fg	2.6167 cd
HWD-50℃	2.0667 m	2.3333 klm	2.9333 gh	3.4667 def	2.7 c
HWD-60℃	2.0667 m	2.7333 hij	3.7333 cd	4.7333 a	3.3167 a
MAP (PVC)	2.0667 m	2.2667 lm	2.6667h..k	3.333 ef	2.5833 cd
MAP (LDPE)	2.0667 m	2.0667 m	2.5333 i..l	3.2667 fg	2.4833 d
Mean	2.0667 d	2.4815 c	3.2667 b	4.0148 a	
LSD (0.05)	0.1238				0.1857

Means within columns followed by different letters are significantly different. LSD (0.05) Storage period treatment: 0.3713.

respectively (Table 1). However HWD at 60℃ and UV-C for 10 min increased deformation in comparison to control. Results of firmness showed similarities to weight loss thus a strong relationship between firmness and weight loss in bell pepper was reported by Lurie et al. (1986). Similar observations on effects of hot water treatments on firmness of bell peppers (Fallik et al., 1999) and apples (Lurie et al., 1996) have being reported.

Soluble solids content (SSC)

Distinct effects of storage period on green bell peppers were determined (Table 2). The differences between storage periods was found significant ($p<0.05$). In addition, MAP was found efficient on green bell peppers as preventing the increase of SSC similar to the effects of LDPE based MAP with wax treatments on SSC of bell peppers stored at 10℃ for 20 days storage (Gonzalez and Tiznado, 1993). The difference between MAP types were found significant ($p<0.05$). Similar differences between LDPE and PVC were also reported on Angeleno plums stored for 120 days at 0 - 1℃ (Kaynaş et al., 2010). A reduction in SSC after 45 days storage was determined on fruits treated with HWD at 50, 60 and UV-C for 2.5 and 10 min respectively. Remittent changes in SSC may have resulted as a consequence of increases in soluble organic acid or due to polysaccharide breakdown of the cell walls (Fenemma, 1985). No effects of UV-C on SSC of peppers was fixed (Vicente et al., 2005).

Decay incidence

Grey mold caused by *B. cinerea* were the most observed decay on green bell peppers followed by Alternaria rot caused by *A. alternata*. The rate of decay increased with prolonged storage significantly. In addition, postharvest treatments were found effective on preventing or delaying the increase of decay ($p<0.05$). Thus LDPE based MAP was fixed as the most effective treatment on decay incidence during the whole storage period (Figure 2). PVC based MAP, HWD at 40℃ and HWD at 50℃ prevented decay incidence until 30 days storage with three days shelf life. However, the rate of decay increased on fruits treated with UV-C for 10 min and HWD at 60℃ in comparison to control by reason of damage in tissues caused by these treatments. Positive effects of hot water dipping on decay incidence were also reported on eggplants (Karasahin et al., 2005). The effects of hot water treatments as brushing at high temperatures around 60℃ on tissue damage were also fixed on red bell peppers (Fallik et al., 1999). Israeli sweet peppers were treated with hot water and stored at 7℃ for 15 days, and no rot was observed after an additional 4 days at 16 - 18℃ (Fallik et at., 1999).

Total chlorophyll content

Total chlorophyll is one of the main quality parameter on green bell peppers. Total chlorophyll content was reduced with storage period significantly ($p<0.05$). Moreover postharvest treatments affected chlorophyll degradation significantly ($p<0.05$). Besides, significant differences between treatments were determined (Table 3) and interactive effects of these factors were found significant ($p<0.05$). LDPE based MAP had the best results at preventing chlorophyll degradation. The following results were fixed on fruits treated with HWD at 40℃ and PVC based MAP. The effects of MAP on chlorophyll content were due to low oxygen concentration and low respiration. Thus MAP has also been shown to delay chlorophyll

Table 2. Changes in SSC (%) affected by different postharvest treatments during storage.

Treatment	Storage period (day)				Mean
	0	15	30	45	
Control	4.18 no	4.55 hij	5.547 a	4.397 jkl	4.6683 ab
UV-C 2.5 min	4.18 no	4.19mno	5.45 a	4.34 k..n	4.54 cd
UV-C 5 min	4.18 no	4.83 ef	4.117 o	4.123 o	4.3125 e
UV-C 10 min	4.18 no	4.29 lmn	4.96 b..e	4.56 hi	4.4975 d
HWD-40℃	4.18 no	4.53 hij	5.013bcd	5.067 bc	4.6975 a
HWD-50℃	4.18 no	4.937 c..f	5.117 b	4.48 ijk	4.6783 a
HWD-60℃	4.18 no	4.363 kl	4.65 gh	4.057 o	4.3125 e
MAP (PVC)	4.18 no	4.35 klm	4.78 fg	5.03 bcd	4.585 bc
MAP (LDPE)	4.18 no	4.33 k..n	4.873def	5.07 bc	4.6133 abc
Mean	4.18 d	4.4856 c	4.9452 a	4.5693b	
LSD (0.05)	0.05597				0.08395

Means within columns followed by different letters are significantly different. LSD (0.05) Storage period treatment: 0.3713.

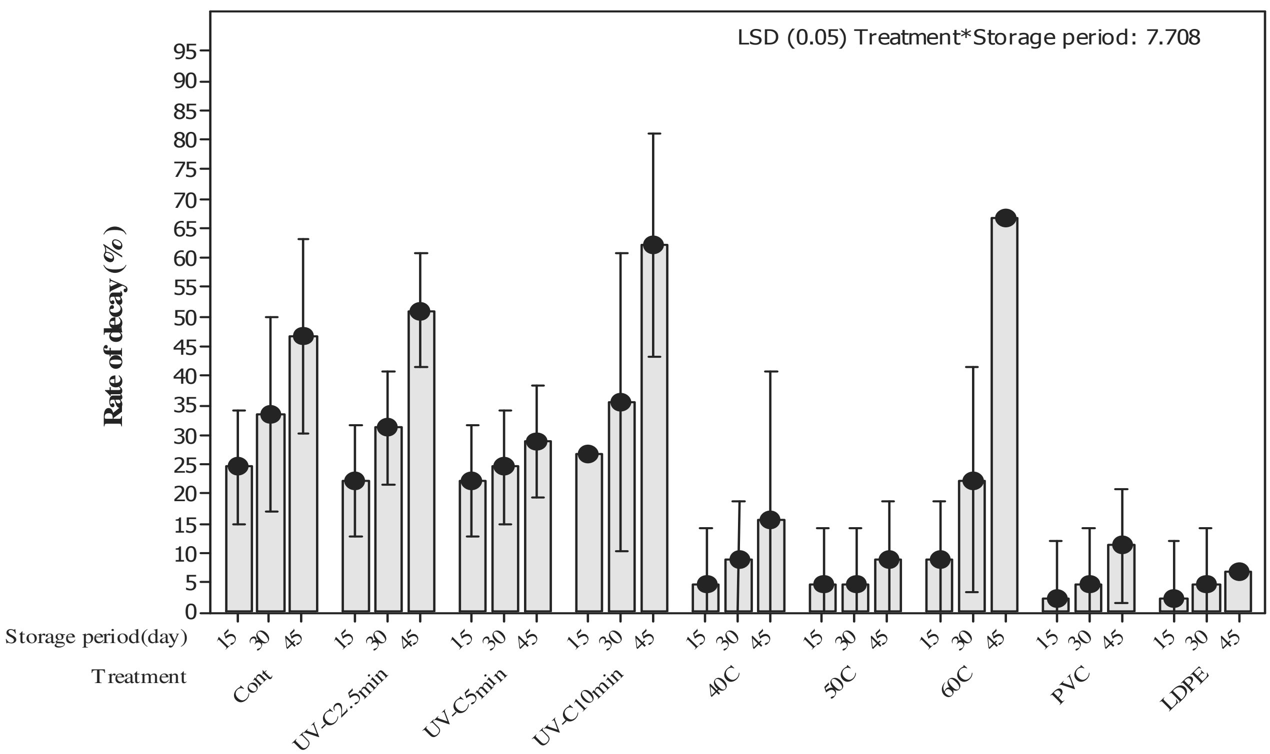

Figure 2. The effects of different postharvest treatments on decay incidence (%) of green bell peppers during storage.

degradation in green vegetables (Barth et al., 1993).

Vitamin C content

Vitamin C content decreased with storage period significantly ($p<0.05$). In addition, postharvest treatments were found effective on preventing vitamin C degradation during storage with significant ($p<0.05$) difference determined after 30 days storage (Table 4). Thus, LDPE and PVC based MAP and HWD at 40 and 50℃ preserved vitamin C during the whole storage period with no significant difference between these treatments ($p>0.05$). UV-C treatments for 5 min and 10 min had slight effects on vitamin C preservation. MAP prevented vitamin C degradations caused by low O_2 concentrations. It has been previously reported that in storage atmosphere with low levels of O_2 the vitamin C level is preserve

Table 3. Changes in total chlorophyll content (mg l-1) affected by different postharvest treatments during storage.

Treatment	Storage period (day)				Mean
	0	15	30	45	
Control	4.9354 a	1.811 mn	2.5391gh	2.0109 klm	2.8241 e
UV-C 2.5 min	4.9354 a	1.9738 lm	2.3908 hi	1.9831 lm	2.8208 e
UV-C 5 min	4.9354 a	2.1128 jkl	3.1692cd	3.0951 cde	3.3281 c
UV-C 10 min	4.9354 a	2.7522 fg	1.251 o	1.7236 n	2.6656 f
HWD-40℃	4.9354 a	3.1692 cd	3.336 c	2.9005 ef	3.5853 b
HWD-50℃	4.9354 a	3.1136cde	2.2425ijk	1.8719 lmn	3.0409 d
HWD-60℃	4.9354 a	2.2724 ij	1.6495 n	1.0657 o	2.4807 g
MAP (PVC)	4.9354 a	3.1414cde	3.0302de	3.0209 de	3.532 b
MAP (LDPE)	4.9354 a	4.9494 a	4.9484 a	3.8457 b	4.6697 a
Mean	4.9354 a	2.8106 b	2.7285 c	2.3908 d	
LSD (0.05)	0.08214				0.1232

Means within columns followed by different letters are significantly different. LSD (0.05) Storage period treatment: 0.3713.

Table 4. Changes in vitamin C content (mg 100g-1) affected by different postharvest treatments during storage.

Treatment	Storage period (day)				Mean
	0	15	30	45	
Control	89.685 ab	74.65 fg	68.298 hi	44.755 k	69.347 c
UV-C 2.5 min	89.685 ab	84.615 a..d	54.895 j	55.420 j	71.154 c
UV-C 5 min	89.685 ab	83.741 b..e	75.058 fg	73.082 gh	80.392 b
UV-C 10 min	89.685 ab	85.392 a..d	72.203 gh	64.452 i	77.933 b
HWD-40℃	89.685 ab	87.238 abc	84.790a..d	80.42 def	85.533 a
HWD-50℃	89.685 ab	87.762 abc	79.953def	77.797efg	83.8 a
HWD-60℃	89.685 ab	72.203 gh	36.247 l	13.345 m	52.87 d
MAP (PVC)	89.685 ab	88.951 ab	82.867 cd	73.893 gh	83.849 a
MAP (LDPE)	89.685 ab	89.126 ab	90.198 a	76.224 fg	86.308 a
Mean	89.685 ab	83.742 b	71.612 c	62.154 d	
LSD (0.05)	2.004				3.006

Means within columns followed by different letters are significantly different. LSD (0.05) Storage period treatment: 0.3713.

(Arvanitoyannis et al., 2005).

Membrane ion leakage

Membrane leakage that represents the deformation of fruit tissues was affected by both storage period and postharvest treatments. The results of membrane leakage showed similarities to the results of weight loss and firmness. Thus, membrane leakage values were increased with prolonged storage significantly. Significant difference were determined between postharvest treatments during storage ($p<0.05$). LDPE based MAP prevented the increase of membrane leakage at the highest level. PVC based MAP, HWD at 40℃ and HWD at 50℃ followed this treatment, respectively. The difference between treatments became more distinct after 30 days storage (Figure 3). However HWD at 60℃ and UV-C treatments for 10 min increased the membrane leakage in comparison to control. This effect means HWD at high temperatures or UV-C treatments for long duration caused membrane damage. Similar results were fixed on peppers stored at 17 or 8℃ and honey peach fruit stored at 2℃, as the effects of MAP on keeping the membrane integrity. Membrane leakage is an important parameter on determining the chilling injury. In this context, the positive effects of heat treatments on chilling injury were previously reported as reducing the production of heat shock proteins (HSP) that are involved in chilling prevention (Sabehat et al., 1996; Porat et al., 2000).

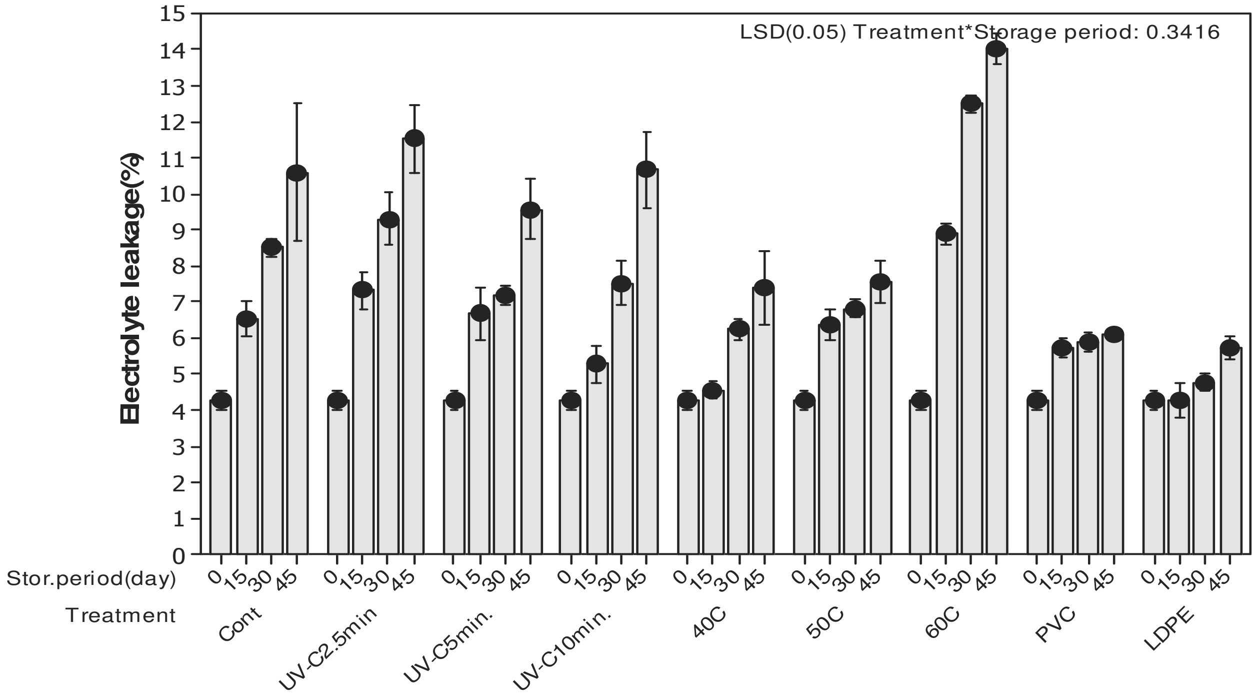

Figure 3. The effects of different postharvest treatments on membrane ion leakage of green bell peppers during storage.

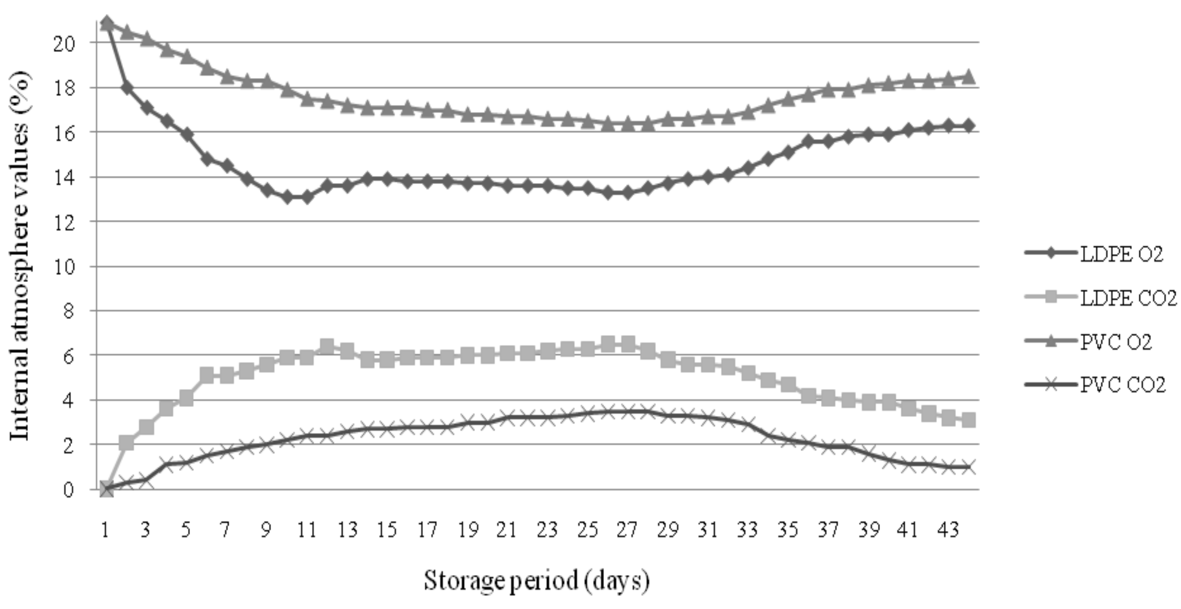

Figure 4. Internal atmosphere changes of different packages during storage.

Internal atmosphere of packages

Concentration of oxygen in packs sealed with semi permeable films decreased and that of carbon dioxide increased rapidly during the first days of storage after which a state of equilibrium was reached between respiration of the produce, and the diffusion of these gases was counter balanced by production and consumption during respiration of green bell pepper fruits. The increase of carbon dioxide and decline of oxygen concentrations were more distinct in LDPE packaging material (Figure 4). It has been reported that these different based applications have different gas permeability (Zagory and Kader, 1988).

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