

Effect of Polypropylene and Polyvinyl Chloride Plastic Film Packaging Materials on the Quality of ‘Yalova Charleston’ Pepper (*Capsicum annuum* L.) during Storage

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The long pepper (*Capsicum annuum* L. cv. ‘Yalova Charleston’) was stored in plastic film with various oxygen (O₂) and carbon dioxide (CO₂) permeabilities consisting of 7±1°C temperature and 90±5% relative humidity (RH). Physico-chemical changes were recorded on 0, 10, 20 and 30 days of storage. Weight loss was higher in pepper stored under normal atmosphere (NA) compared to modified atmosphere packaging (MAP). Initial total soluble solids of 4.20% increased to 5.27% in NA. The acidity and ascorbic acid contents of peppers decreased during storage. The highest values were recorded at the end of storage from the fruit stored under PP (polypropylene). Changes in fruit color at the end of storage proceeded more slowly in the treated fruit. Total chlorophyll values exhibited significant decline in the fruits subjected to NA. However, the chlorophyll content in the fruits subjected to PP was low. The color values obtained from fruits supported the chlorophyll findings. At the end of the study, 35µ PP packaging material gave the best result at the end of 30 day-storage with respect to the parameters evaluated in the study. Therefore, especially 35µ PP treatment was effective with regard to delaying the maturity along the storage and fruit quality in peppers.

Keywords: *Capsicum annuum*, modified atmosphere, postharvest cold storage, quality parameters

Introduction

Food marketplace with the new products and changing trends, and fresh-cut produce remains at the top of the list of products meeting the needs of busy consumers. The value of fresh-cut produce lies in the primary characteristics of freshness and convenience. Food safety, nutrition and sensory quality are required while providing extended shelf-life and freshness. However, physical damage during preparation of minimally processed products causes an increase in respiration rates, biochemical changes and microbial spoilage, which may result in degradation of color, texture and flavor of the produce (Gonzalez-Aguilar *et al.*, 2004).

In recent years, a number of new food processing and packaging technologies have been applied to fresh produce by the food industry. Modified atmosphere packaging (MAP) has been successful in maintain quality of fruits and vegetables. Moreover, packaging and low temperature storage has been shown to increase shelf life by slowing the

growth of spoilage organisms (Hussein *et al.*, 2000). MAP has been used to prevent or retard postharvest fruit ripening and associated to biochemical and physiological changes by favorably altering the O₂ and CO₂ levels around the products (Gonzalez-Aguilar *et al.*, 2004, Gonzalez-Aguilar *et al.*, 1998, Morales-Castro *et al.*, 2002, Qi *et al.*, 1999). Therefore, the primary purpose of the present study is to prolong the storage period of pepper fruits by alternative storage techniques (MAP), and to investigate their effects on weight loss, total soluble solids (TSS), titratable acidity (TA), ascorbic acid, fruit color, total chlorophyll, the ratio of O₂, CO₂ and ethylene (C₂H₄) content and overall appearance during storage.

Materials and Methods

Plant materials, growth medium and growth conditions
The study was conducted during the 2004–2005 growing season at the Uludag University, Research and Training Greenhouse (glasshouses with automatically temperature and humidity control). Seedlings produced from surface disinfected seeds (with a 60% solution of commercial bleach for 10 min

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and rinsed four times with distilled water) were grown from 5 January to 15 May in 1.5 L capacity pots (one seedling per pot) containing soil and sand mixture (soil : sand, 75:25, v/v). Growing conditions consisted of a day/night temperature regime of $22 \pm 2/18 \pm 2$ °C and 16 h photoperiod. Plants were watered as needed and fertilized weekly with N-P-K formulations were 15-15-15.

Fruit material The pepper cultivar 'Yalova Charleston' (*Capsicum annum* L.) (yellow-green color, thick fruit wall, sweet, charleston type pepper) which are intensively grown under protected cultivation in Turkey was used in the trial (Anonymous, 2003). Fruits of the same size, shape and injury free were selected for the experiment.

Treatments Five hundred grams pepper cultivars were enclosed in plastic film packages (25×30 cm) and sealed by a Petra FS 500 plastic covering machine. The permeabilities of the plastic film packages were determined in the Scientific and Technical Research Council of Turkey in Gebze county, Turkey. MAP studies were carried out by using 35µ PP (polypropylene) with O₂ permeability of 431.10 mL/m² day atm at 7 °C, and CO₂ permeability of 1381.50 mL/m² day atm at 7 °C and by using with 35µ PVC (polyvinyl chloride) O₂ permeability of 62.70 mL/m² day atm at 7 °C, and CO₂ permeability of 35.90 mL/m² day atm at 7 °C. All treatments in normal (NA) and MAP were stored in 7 °C and 90±5% RH.

Quality parameters Parameters such as weight loss (%), TSS (%), TA (%), ascorbic acid (mg/100 g), fruit color (L, a, b), total chlorophyll (mg/100 g), the ratio of O₂ and CO₂ (%) and C₂H₄ content (ppm) in MAP and overall appearance were observed in the peppers along the storage period at 10 day-intervals.

Weight losses occurred in fruits at each analytical period during storage were determined using Densi AC 100 precision balance (5 mg precision) (Densi Industrial Balance Systems Co., Istanbul, Turkey), considering former weight value in each analytical period. TSS of pepper juice were determined using a NOW refractometer (0–32%) (Tech-Jam International Inc., Tokyo, Japan) at 20 °C and results were reported as percentage. TA of pepper was titrated with 0.1 M NaOH to pH 8.1, and the results were expressed as percentage of citric acid. Ascorbic acid was determined by subjecting the samples taken from the fruits forming the replicate to extraction with oxalic acid (0.4%) and then reading and calculating the absorbancy values at 520 nm in the spectrophotometer (Shimadzu UV-120-01) (Shimadzu Co., Duisburg, Germany) (Holden, 1976). The colors of fruits were measured using a Minolta CR-300 (Konica-Minolta, Osaka, Japan) colorimeter calibrated with a white standard tile. Total chlorophyll was determined by subjecting the samples taken

from the fruits forming the replicate to extraction with acetone (90%) and then reading and calculating the absorbancy values at 652 nm in the spectrophotometer (Holden, 1976). Dräger Multiwarn II gas analyzer (Drägerwerk AG, Lübeck, Germany) was used in determining the O₂, CO₂ and C₂H₄ concentrations under plastic film material forming the MAP. Overall appearance changes in the external appearances of normal atmosphere (NA) fruits, as well as MAP fruits, during storage were evaluated by a jury of 5 persons (as 1–2 unusable, 3–4 unsalable, 5–6 salable, 7–8 good, 9–10 very good).

Statistical analysis The research was conducted using randomized plots factorial experimental design. The analyses were made in three replicates, being 500 g fruits in each replicate. Pepper cultivar and each analyses period used in the study were evaluated independently. Analysis of variance (ANOVA) was performed; means were compared by the least significant difference (LSD) tested at a significant level of 0.05.

Results and Discussion

Weight loss Significant increases in weight loss took place during a prolonged storage period and the greatest losses occurred in NA treatment (Fig. 1A). Weight losses up to 20–25% were observed in peppers that could be stored in NA, whereas this rate was no higher than 3–5% in MAP. Due to a low permeability, the packages have the high relative humidity. The type of packaging films significantly affected the maturity, where PP most effectively lowered maturity for peppers, thus extending the storage-life. Weight loss occurred due to moisture loss could have been led by the smaller vapor pressure gradient between fruits and environment in the direction of fruits. Moreover, MAP reduced the water loss by minimizing the contact of fruits with the surrounding air or by inhibiting the diffusion of water vapor with permeability of vapors of the films. Rona *et al.* (2003) also reported significant weight loss especially in untreated pepper fruit.

Total soluble solids The TSS values of the peppers generally exhibited nonsignificant increases throughout storage. In peppers, MAP slowed down the changes in TSS values, indicating the retardation of ripening due to the treatments. Moreover, the minimum increases in this parameter were recorded from PP and PVC treatments with 3.93% and 4.13%, respectively (Fig. 1B). TSS values were lower in PP and PVC in the fruits is an important result with respect to retarding the ripening in fruits. TSS contents of MAP peppers changed less, and in this way, TSS changes in plastic material treated fruits were suppressed, thus the ripening of fruits was inhibited. The TSS ratio which is generally related to

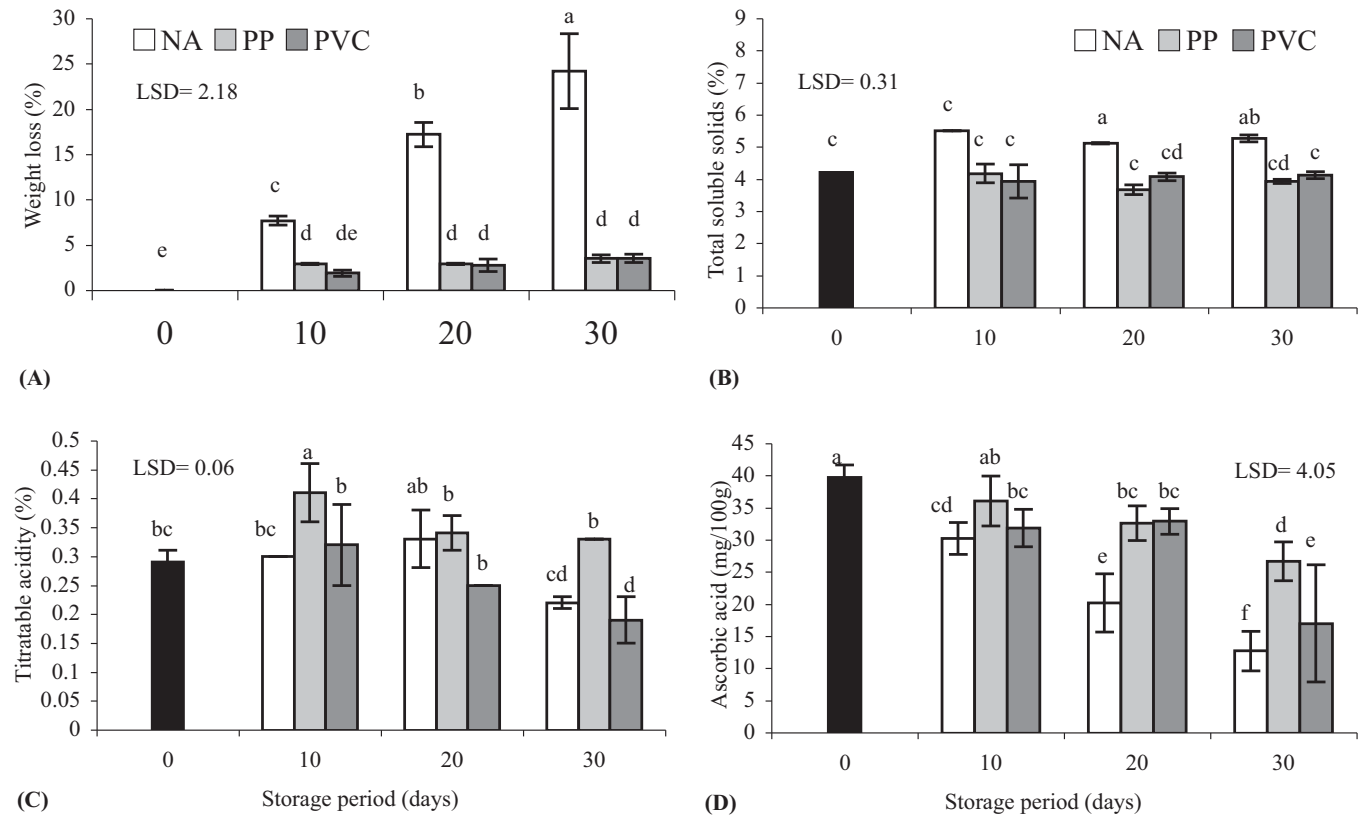


Fig. 1. Changes related to weight loss (A), total soluble solids (B), titratable acidity (C) and ascorbic acid (D) of pepper cv. 'Yalova Charleston' during NA and MAP ($P < 0.05$).

sugar-acid metabolism and mineral content shows different changes depending on the storage temperature, atmosphere combination, and maturity stage of the fruit. Especially optimum low O_2 and high rate of CO_2 restricts this change under MAP conditions, which can be explained by more limited change of carbohydrate content resulting from the suppression of respiration metabolism. Gonzalez-Aguilar and Tiznado (1993), Ozden and Bayindirli (2002) examined the changes in TSS during the storage of pepper and determined that the TSS contents of peppers increased during storage. But, especially at the end of storage, decreases were also determined. The loss of soluble solids during the storage period is natural, as sugars, which are the primary constituent of the soluble solids content of a produce, are consumed by respiration and used for the metabolic activities of the peppers. Similar results were obtained in our study.

Titratable acidity It was determined that increases and reductions occurred in TA values of peppers during storage period. The lowest TA values were observed in NA and PVC fruits; whereas the highest TA values were obtained from PP application with which ripening proceeded more slowly (Fig. 1C). The PP plastic wrapper treatment caused TA contents of fruits to be higher than NA and PVC. Therefore, the loss of acidity in fruits was retarded through this treatment. These

results are similar to those of a study conducted by Gonzalez-Aguilar and Tiznado (1993) and Martinez *et al.* (2003) on storage of pepper. The reduced TA in the fruit was the result of the acids being involved in physiological processes such as respiration. This is another important factor with regard to the treatments, especially in terms of slowing the loss of fruit quality. With these methods changes in fruit quality during storage could be kept within certain limits, since sugar accumulation was stable and loss of acidity was retarded in the fruit stored under the MAP.

Ascorbic acid Ascorbic acid contents of peppers show variations on treatments basis. In our study, reductions were observed in ascorbic acid values during storage. Also, in some other studies, there were statistically significant decreases in ascorbic acid over a 10 day storage period of unpacked and packaged peppers (Martinez *et al.*, 2003, Gonzalez-Aguilar *et al.*, 2004). However, the highest results with respect to ascorbic acid content in our study were obtained from PP treatment with 26.64 (Fig. 1D). High CO_2 treatment retarded the change in ascorbic acid content as described above, but not in large amounts. Similar to the results obtained from our study, ascorbic acid loss was determined in the peppers stored at high temperatures under normal conditions; in a number of studies in which the ascorbic acid

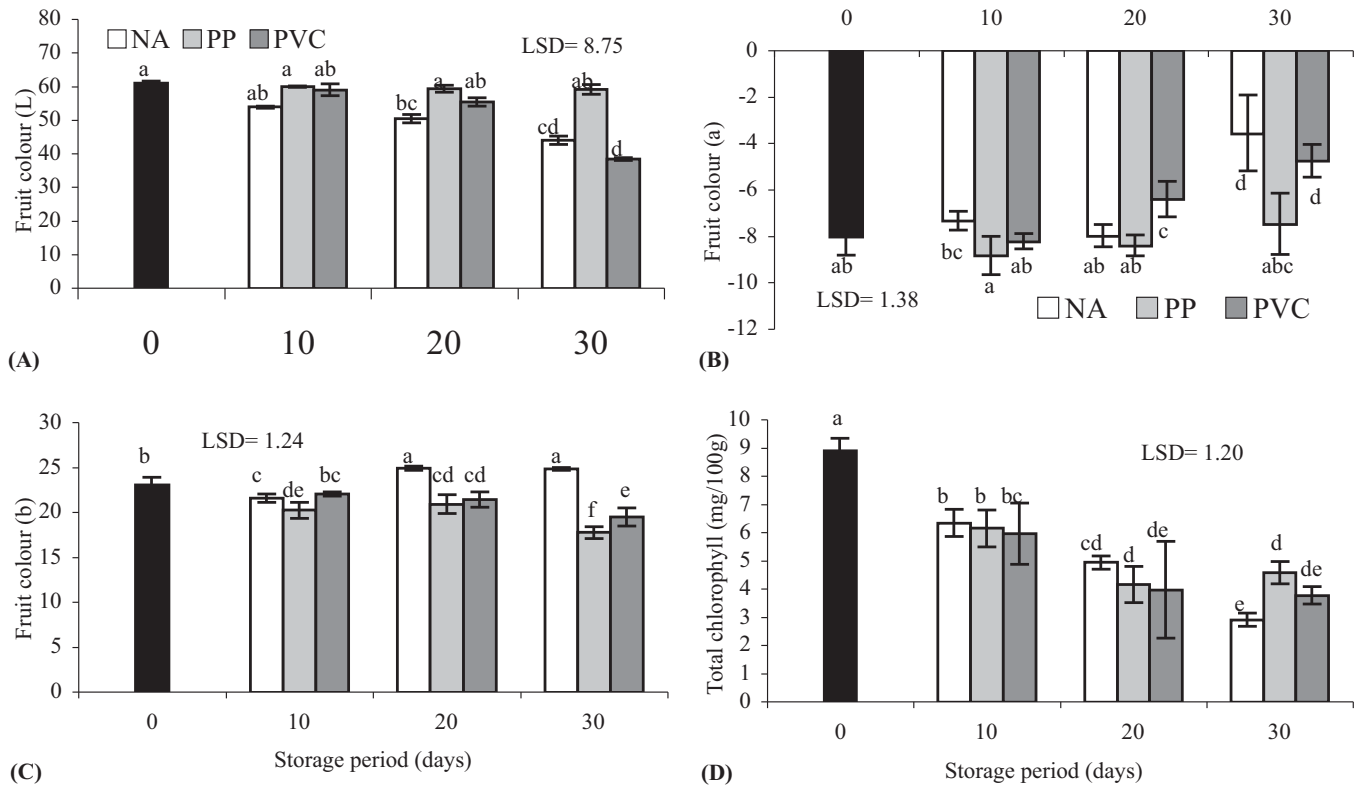


Fig. 2. Changes related to fruit color (L, a, b) (A, B, C) and total chlorophyll (D) of pepper cv. 'Yalova Charleston' during NA and MAP ($P < 0.05$).

changes occurred during the storage of peppers were investigated (Jecheon *et al.*, 2001).

Fruit color The fruit color was also examined in the study. Changes in fruit color at the end of storage proceeded more slowly in MAP. For example, the closest value to the initial color at the end of storage with MAP was observed with PP. The colors of fruits stored under NA conditions, changed rapidly and became dark. These results are in accordance with the findings of Martinez *et al.* (2003), Naik *et al.* (2001) and Meir *et al.* (1995).

There was a positive correlation between color values and chlorophyll values. Both values obtained from the fruits were observed to coincide with each other. Decreases occurred in the L values (brightness) of fruits in NA at the end of day 20th. L values decreases in MAP were found less than NA (Fig. 2A). It was observed that MAP treatments inhibited the decreases in the fruit brightness which was occurred by ripening. Therefore, a (green) values of the fruits subjected to NA and PVC treatments were found close to each other, as for the total chlorophyll values (Fig. 2B). The lowest total chlorophyll values were obtained from the NA. The b (yellow) values, which indicate the yellow color quantity, were notably higher in the fruits of PP treatment compared with the other treatments (Fig. 2C).

Total chlorophyll In general, reductions were observed

in the total chlorophyll of peppers in NA and MAP. In the study, lower levels of chlorophyll quantity observed in NA was noted as a remarkable result (Fig. 2D). Chlorophyll is degraded by light as well as enzymes. Color changes occur in green peppers during ripening. Peppers that are green in color will have a chlorophyll content of 0.170 mg/g, while yellow green peppers have less chlorophyll (0.082 mg/g) (Anonymous 1997). Ozden and Bayindirli (2002) investigated the effects of controlled atmosphere, cold storage and edible coating applications on shelf life and quality attributes of green peppers. In this study, chlorophyll, the primary pigment responsible for the green color of the peppers, decreased in all conditions during the storage period.

In-package atmosphere Fig. 3 (A, B and C) shows the in-packaged atmosphere (O_2 , CO_2 and C_2H_4) changes during MAP. Reductions in O_2 (Fig. 3A) and increases in CO_2 and C_2H_4 (Fig. 3B) occurred following the transfer of peppers into MAP. Extreme reductions and increases in O_2 , CO_2 and C_2H_4 ratios originating from the permeabilities of plastic film materials led to physiological disorders in fruits. High rates of CO_2 accumulation and C_2H_4 formation was determined at the end of storage, especially with PVC treatment. This situation caused quality losses in fruits. These results are similar to those of a study conducted by Lee *et al.* (2006a) on MAP of fruit using plastic packaging materials. They re-

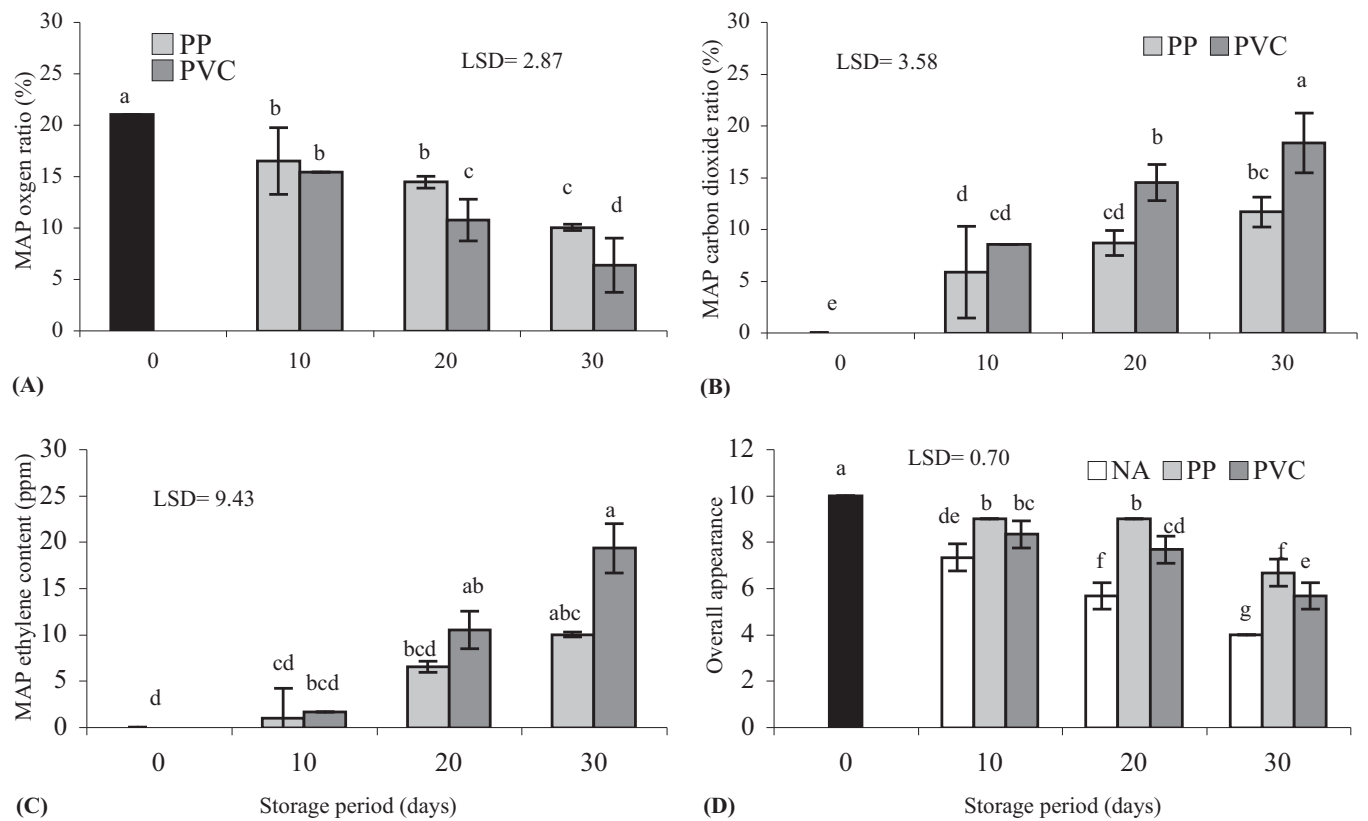


Fig. 3. Changes related to MAP oxygen (A) and carbon dioxide (B) ratio, MAP ethylene content (C) and overall appearance (D) of pepper cv. 'Yalova Charleston' during NA and MAP ($P < 0.05$).

ported that pepper packages using 25 μm low-density polyethylene and 30 μm cast polypropylene could attain modified atmosphere close to the optimal gas concentrations (3% O₂ and 5% CO₂), and therefore provided better quality retention compared with unpackaged controls. Concentration of O₂ in packs sealed with permeable films decreased and that of CO₂ increased during the 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 the peppers and no further changes in the gas concentration within the packs occurred with fruit kept at constant temperature (Thompson 1998). In a different study, the respiration rates of fresh-cut bell peppers under diverse high and low O₂ levels, with or without 20 kPa CO₂, at 2, 7 and 14°C, were studied. In the study, a constant respiration rate of pepper dices throughout 3 days under different conditions was found. Fresh-cut peppers exposed to 0, 0.5, 1, 3 and 9 kPa O₂ (all CO₂-free), and to 0 kPa O₂ + 20 kPa CO₂, had a lower respiration rate than peppers in the range 20–100 kPa O₂ with or without CO₂. Under high O₂, 20 kPa CO₂ increased the respiration rate by about 20–40% compared to that in free-CO₂ atmospheres, this effect being lower at low temperature. High O₂ had little (at 14°C) or no effect (at 2 and 7°C) in stimulating both CO₂

production and O₂ consumption compared to normal air. High CO₂ in the range 20–100 kPa O₂ increased the respiratory activity of pepper dices, probably because physiological injury occurred at 14°C. However, 20 kPa CO₂ combined with superatmospheric O₂ neither induced a poor visual appearance nor off-odors. Consequently 50–80 kPa O₂ combined with 20 kPa CO₂ could be used in innovative modified atmosphere packaging of pepper dices to avoid fermentation and inhibit growth of spoilage microorganisms (Conesa *et al.*, 2007). Moreover, elevated CO₂ levels can reduce the products sensitivity to C₂H₄; it can also slow the loss of chlorophyll which is the green color of fruit and vegetables. High CO₂ can also slow the growth of many of the postharvest fungi that cause rots. All these effects can help to extend the storage and shelf life of fresh produce (Jobling 2001, Lee *et al.*, 2006a; Lee *et al.*, 2006b; Conesa, 2007). Kang and Lee (1997) and Fallik *et al.* (1999) reported that respiration rate of green pepper increased during storage. In general, the reduction in O₂ levels was accompanied with an increase in CO₂. In another a study, respiration of green peppers at 10°C was characterized by the closed-system method as a function of O₂ and CO₂ concentrations, and was incorporated into mass balance equations of O₂ and CO₂ gases in order to predict the gas composition inside the package over time. From

the prediction of atmospheres inside packages constructed of the available plastic films, retail packages were designed and studied experimentally for their ability to modify the package atmosphere and to retain quality (moisture, ascorbic acid and chlorophyll). Pepper packages using 25 μm low-density polyethylene and 30 μm cast polypropylene could attain modified atmosphere close to the optimal gas concentrations (3% O_2 and 5% CO_2), and therefore provided better quality retention compared with unpackaged controls (Lee *et al.*, 2006a).

The highest accumulation of C_2H_4 was observed in the product packaged in PVC (Fig. 3C). C_2H_4 accumulation gradually increased during the storage, this fact was due to the permeability to gases observed commonly in MAP. Similar results have been observed using green pepper, where C_2H_4 increased to a maximum during the storage (Gonzalez-Aguilar *et al.*, 2004; Senesi *et al.*, 2000). Rona *et al.* (2003) reported that CO_2 and C_2H_4 contents were highest in non-perforated bags.

Overall appearance Different results were obtained on the basis of treatments as a result of overall appearance of peppers. NA fruits got lower scores compared with the other treatments. Moreover, variation was observed between all treatments at the end of storage. PP treatment got the highest scores at the end of storage period. Nevertheless, higher rates of deterioration in NA fruits caused to get low scores with respect to overall appearance (Fig. 3D).

When the overall appearance of fruits was considered, high rates of deterioration were observed in NA, in which high rates of weight loss was determined. The fact that these rates were especially high in NA may be stem from plastic covering treatments with these fruits. Thus, the result that the rates of overall appearance were better in MAP treated fruits, compared with NA fruits were considered as an important result with respect to the retention of quality of fruits during storage. These changes were supported by the results obtained from the studies carried out in different pepper cultivar by Ozden and Bayindirli (2002), Gonzalez-Aguilar *et al.* (2004) and Maalekuu *et al.* (2004). In addition to atmosphere modification, MAP vastly improves moisture retention, which can have a greater influence on preserving quality than O_2 and CO_2 levels. Furthermore, packaging isolates the pepper from the external environment and helps to ensure conditions that, if not sterile, at least reduce exposure to pathogens and contaminants (Mir and Beaudry, 2004).

Conclusion

When the overall appearance of fruits was considered, high rates of rotten fruit were observed in NA fruits, in which high rates of weight loss was determined. Moreover, decays

and spoilages were intensively observed in these fruits as a result of rapidly proceeding physiological events and fungal effects. Especially, slower physiological processes in fruits subjected to MAP and lower incidence of spoilages in these fruits may be explained by the retention of fruit quality through MAP in terms of water loss. Moreover, the fact that these rates were especially high in NA fruits might stem from the high O_2 and low CO_2 . These results suggest that the most important parameters to prolonging pepper storage period are storage temperature and atmosphere combinations. In this study, two film materials were used in order to see the effects of MAP treatments on the storage period and fruit quality of pepper cv. 'Yalova Charleston'. In the study, the spoilage and maturity was accelerated in NA treatment. Moreover, changes in the quality criteria of fruits could be kept within determined ranges by different atmosphere treatments. Disorders were reduced with low O_2 and high CO_2 during cold storage. However, higher quantities of CO_2 and C_2H_4 associated with PVC cover material compared with PP cover material accelerated the quality losses in the peppers involved in this treatment. In conclusion, the fruits of pepper cv. 'Yalova Charleston' could successfully be stored for 30 days using 35 μ PP in the best quality and with slight changes in quality at 7 °C and 90 \pm 5% RH storage conditions.

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