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Full Length Research Paper

Evaluation of quality parameters of strawberry fruits in modified atmosphere packaging during storage

Okan Ozkaya[1]*, Omur Dündar[2], Giulia Camerata Scovazzo[3], Giorgio Volpe[3]

[1]Cukurova University, Karaisali Vocational School, Karaisali-Adana, Turkey.
[2]Cukurova University, Horticulture Department, Adana, Turkey.
[3]University of Palermo, Horticuluture Section, Palermo, Italy.

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The objective of the present study is to evaluate the effect of modified atmosphere packaging (MAP) during storage on some quality parameters of strawberries. Strawberries (cv. Camarosa) were harvested when mature, forced air cooled and divided into two groups as fruits in MAP and control. After packaging, fruits were stored at 0°C, 90 - 95% RH for 10 days plus 1 day at 20°C and 50 - 55% RH for the evaluation of shelf life. Changes in fruit quality, mass loss, decay, color, firmness, total soluble solids (TSS), acidity, glucose, fructose, saccharose and color were investigated. The mass loss and decay were lower in MAP than observed in the control whereas firmness, TSS, acidity and color did not change during storage and shelf life. The results suggested that MAP can be beneficial for reducing mass loss and decay after 10 days storage plus one day shelf life under these conditions in Camarosa strawberry variety.

Key words: Modified atmosphere packaging (MAP), storage, shelf life, strawberry, quality.

INTRODUCTION

Packaging technologies are important to fulfil the requirements of a longer shelf life of perishable fruits and to reduce the inclusion of additives. Efficient post-harvest management and techniques are particularly important to preserve fruit quality. Advanced ripening causes excessive softening making berries more sensitive to pathogen attacks, increasing losses and decreasing the shelf life (Brummel and Harpster, 2001).

Several studies have been performed to extend berry fruit shelf life, using alternative methods rather than chemicals to avoid residues such as fungicide residues from the fruit itself (Peng and Sutton, 1991) and moreover to avoid pathogen populations from developing resistance to pesticides (Peng and Sutton, 1991; Hunter et al., 1987; Wszelaki and Mitcham, 2003; Kovach et al., 2000; Ceponis et al., 1987; Mertley et al., 2002; Romanazzi et al., 2001; Zhang et al., 2007).

Strawberries are highly active metabolically (giving out 50 - 100 ml of CO_2 per kg per hour at 20°C) and may deteriorate in a relatively short time, even without the presence of decay-causing pathogens (DeEll, 2006). They produce very little ethylene (<0.1 ppm per kg per hour at 20°C) and do not respond to exogenous ethylene treatments by stimulating the ripening process. Refrigeration is the most common and well used way to delay berry ripening and perishability. Rapid removal of field heat is critical to retard deterioration of strawberries (Peng and Sutton, 1991). Pre-cooling to near 0°C within 1 h of harvest and maintaining at 0°C throughout marketing channels is recommended for maximum quality retention of strawberries (Hardenburg et al., 1986; Pérez et al., 1999; Kader, 1992).

Refrigeration accompanied with modified atmosphere during transit or storage (Peng and Sutton, 1991) also revealed good results. MAP (modified atmosphere packaging) is diffused to prevent softening in fresh strawberries (Kader, 1992); slow respiration by keeping levels of carbon dioxide between 10 and 30%, while over 30% can cause off-flavour (Peng and Sutton, 1991). It is demonstrated that carbon dioxide is of little benefit when storage temperatures were maintained below 5°C (Smith, 1992).

The objective of this work is to evaluate the potential of modified atmosphere packaging in preserving the quality parameters of harvested Camarosa strawberries and to determine the quality losses after 24 h at 20°C.

*Corresponding author. E-mail: oozkaya@cu.edu.tr.

MATERIALS AND METHODS

Camarosa strawberry variety was used in the current study. The fruits were harvested and forced air cooled before the experiment was set up. The fruits were divided into 2 groups for the experiment, modified atmosphere packaging (MA; Stepak®) and control, with four replicates including 1 kg-box of fruit in each. After the experiment was set up, fruits were stored in a cold room maintained at 0°C, 90 – 95% relative humidity conditions for 10 days. Quality parameters were evaluated after 5 and 10 days of cold storage plus one day shelf life at 20°C and 50 - 55% RH. All analyses were performed in the laboratory of Cukurova University, Department of Horticulture.

Mass loss during post-harvest storage was determined by subtracting sample weights from their previous recorded weights and presented as a percentage of mass loss (%) compared to initial weight. Decayed fruits were separated, weighted and calculated as a percentage of total weight for each replicate. Surface color of berries was measured on two sides of each of the 20 fruits using a tristimulus colorimeter (CR300, Minolta, Ramsey, N.J.). The parameters of 'a' and 'b', were measured and the final results were expressed as hue angle (h°) (McGuire, 1992). Flesh firmness was measured on both cheeks of each fruit with a hand penetrometer equipped with 1.9 mm diameter plunger. The fruits obtained from each treatment were pooled, and mixed with a laboratory mixer then filtered through Whatman's No. 1 filter to obtain a clear juice. Total soluble solids (TSS; °brix) was determined by hand held refractometer (ATAGO-Japan), using two drops of filtered fruit juice in replicates. 1 ml of fruit juice was titrated to end point of pH 8.10 with 0.1 NaOH to obtain the total titratable acidity. Total acidity was determined as a percentage of citric acid/100 ml of juice. Dilution with ultra pure water (18.2 MΩ cm, Millipore Corp., Bedford, MA) and filtration (Whatman's nylon syringe filters, 0.45 µm and13 mm in diameter) was performed for the determination individual sugars. The individual sugars of fruits (%) were analyzed by high-performance liquid chromatography (Shimadzu LC 10A Kyoto, Japan) equipped with an in-line degasser, pump, manual injection (20 µ injection volume) interfaced to a PC running Class VP chromatography manager software (Shimadzu-Japan).

All averages were evaluated by Duncan test while significant differences between treatments were evaluated with p = 0.01 and p=0.05 confidences.

RESULTS AND DISCUSSION

The findings of the current study suggested that modified atmosphere packaging resulted in less mass losses during storage (0.49%), than in control (5.05%). Storage time was also found to be effective on this parameter such that it was 3.58% in strawberries stored for 10 days compared to fruits stored for 5 days which was calculated as 1.96% (Table 1). Interaction between mass loss and storage duration was also significant: modified atmosphere pack-aging resulted in a mass loss of 0.31% only when stored for 5 days, whereas the loss was 0.68% when stored for 10 days. Control fruits had a 3.62 and 6.48% mass loss when stored 5 and 10 days respectively. Moreover the results suggested that MAP influenced mass losses during shelf life (Table 2).

Modified atmosphere was also found to influence fruit decay. Modified atmosphere packaged strawberries had a lower decay (3.07%) than control fruits (5.77%). Storage time had a negative influence on fruit decay as it gets longer. Storage for 10 days resulted in 6.35% of fruit decay which was more than double the losses in strawberries stored for 5 days that resulted in 2.49% (Table 1).

Considering the interaction in-between, it is worth noting that strawberries packaged in modified atmosphere stored for 5 days did not result in fruit decay at all. More decay has been recorded in strawberries stored for 10 days in control fruits with 6.57%.

Total soluble solids determined on strawberries suggested that MAP did not influence this parameter such that 11.27 and 11.10% TSS were found in control and MAP stored strawberries respectively. On the contrary, storage time influenced total soluble solids as 0 day stored strawberries contained 12.35% TSS while 5 and 10 days stored fruits had a 10.52 and 10.98% TSS on average (Table 1). No statistically significant differences have been observed between the treatments after 1 day shelf life at 20°C. In addition, fewer amounts were observed in respect to the day before (Table 2).

Higher acidity was found on 5 days stored strawberries (1.25) while the lower values were found on 10 days stored strawberries (0.87), and strawberries had an intermediate acidity at the beginning (Table 1). After one day of storage at 20°C, acidity decreased on both atmosphere conditions, as observed the day before and the modified atmosphere packaged strawberries content was lower than the control (1.02 and 0.9 respectively) with statistically significant differences (Table 2). Acidity decreased in 5 days stored strawberries in respect to the day before while the same acidity was recorded in 10 days stored fruit. However the 5 days stored strawberries had a higher content in respect to the others with statistically significant differences. The higher content was on 5 days stored control fruits while the lower content was recorded on 10 days stored fruits packaged in modified atmosphere.

Firmness was not influenced by the two different atmosphere packaging (Table 1). The mean values were 0.91 kg in both control and MAP fruits after storage. Firmness of 0.95 and 0.91 were calculated on 0 and 10 days stored strawberries; a little softening was observed on 5 days strawberries in respect to the others even the firmness was acceptable (0.87 kg). After one day at 20°C very little change was recorded on fruits, without differences between the control and modified atmosphere packaging (Table 2). A lower firmness was observed on 10+1 days stored strawberries than in 5+1 days' stored strawberries with statistically significant differences. The stronger firmness was observed on the 10+1 MAP strawberries (0.92 kg).

Modified atmosphere packaged strawberries had 3.03% glucose with statistically significant differences in respect to control that had 2.74% glucose amount after 10 days of storage. The glucose content decreased with increasing storage time (3.65%, 2.66% and 2.35% in 0, 5 and 10 days of storage respectively), with statistically significant differences (p=0.01).

Table 1. Changes in internal fruit quality parameters during storage.

Parameter	Treatment	Storage time (day)			Mean value (atmosphere)
		0	5	10	
Mass loss (%)	Control	---	3.62 bB	6.48 aA	5.05 aA
	MAP	---	0.31 dD	0.68 cC	0.49 bB
	Mean value (storage time)	---	1.97 bB	3.58 aA	
Decay (%)	Control	---	4.97 aA	6.57 aA	5.77
	MAP	---	0.00 bA	6.14 aA	3.07
	Mean value (storage time)	---	2.49 bB	6.35 aA	
TSS (%)	Control	12.35 aA	10.90 bAB	10.55 bAB	11.27
	MAP	12.35 aA	10.15 bB	10.80 bAB	11.10
	Mean value (storage time)	12.35 aA	10.52 bB	10.98 bB	
TA (%)	Control	1.12 bB	1.31 aA	0.95 cC	1.13
	MAP	1.12 bB	1.19 bAB	0.79 dD	1.04
	Mean value (storage time)	1.12 bB	1.25 aA	0.87 cC	
Firmness (kg)	Control	0.95 aA	0.86 bA	0.92 abA	0.91
	MAP	0.95 aA	0.88 abA	0.89 abA	0.91
	Mean value (storage time)	0.95 aA*	0.87 bA	0.91 abA	

*Small letters show the significant difference, p = 0.05; while capital letters show significant difference, p = 0.01.

Table 2. Changes in internal fruit quality parameters during shelf life.

Storage time (day)	Treatment	Mass loss (%)	TSS (%)	TA (%)	Firmness (kg)
5+1	Control	1.86 aA	10.82	1.11 aA	0.80 cB
	MAP	1.67 abA	10.30	0.95 bAB	0.86 bAB
10+1	Control	1.22 bcAB	10.70	0.94 bAB	0.86 bAB
	MAP	0.76 cB	10.11	0.85 bB	0.92 aA
Mean values	Control	1.54 aA	10.76	1.02 aA	0.83
	MAP	1.21 bA*	10.20	0.90 bB	0.89

*Small letters show the significant difference, p = 0.05; while capital letters show the significant difference, p=0.01

The higher glucose content was found in control and modified atmosphere packaged strawberries with 3.65% at the beginning of the storage time whereas the lowest average was observed in 10 days stored control strawberries which had the mean value of 1.92% glucose (Figure 1). It was found that treatments with carbon dioxide and nitrous oxide increased sweetness and may be useful especially for cultivars with high acidity.

MAP did not influence the fructose level in strawberries, and calculated as 4.44% in control and 4.38% in MAP after 10 days of storage on average. Fructose content of fruits increased after 10 days of storage reaching 5.17% compared to 4.05 and 4.02% at 0 and 5 days of storage respectively (Figure 2).

Fructose content was stable during shelf life. The same trend was observed during sampling times of storage as different atmospheres has not affected the fructose content while the storage time had since a higher content recorded on the 10+1 stored strawberries than in the 5+1 (Figure 2).

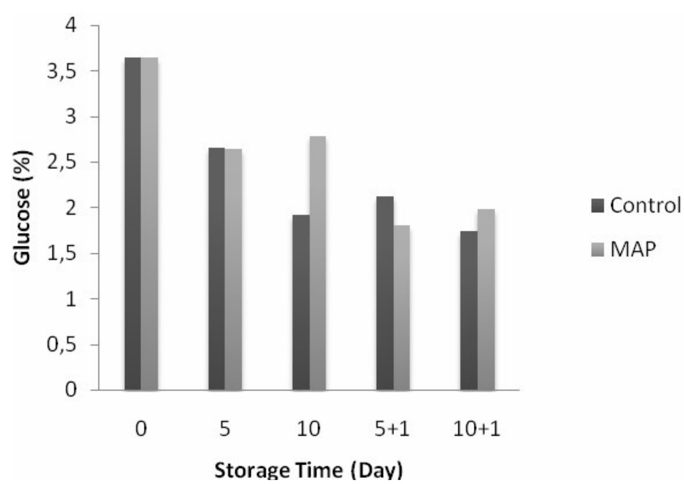

Figure 1. Changes in glucose amount during storage.

Saccharose content was 3.68 and 3.56% on average

Table 3. Changes in surface color parameters during storage.

Color parameters	Treatments	Storage time (day)			Mean value (atmosphere)
		0	5	10	
a*	Control	46.10 aA	43.47 abAB	41.66 bAB	43.77 aA
	MAP	46.10 aA	44.43 abAB	41.28 bB	43.93 aA
	Mean value (storage time)	46.10 aA	44.00 aAB	41.47 bB	
b*	Control	52.48 bB	53.12 bAB	57.44 abAB	54.35 aA
	MAP	52.48 bB	54.01 bAB	59.86 aA	55.45 aA
	Mean value (storage time)	52.48 bB	53.56 bB	58.65 aA	
h^o	Control	47.84 bA	50.29 abA	53.71 aA	50.61 aA
	MAP	47.84 bA	50.19 abA	55.02 aA	51.01 aA
	Mean value (storage time)	47.84 bA*	50.24 bAB	54.36 aA	

*Small letters show the significant difference, p = 0.05; while capital letters show the significant difference, p=0.01

Table 4. Changes in surface color parameters during shelf life.

Storage time (day)	Treatments	a*	b*	h^o
5+1	Control	41.76 abA	55.99 aA	53.04 abA
	MAP	42.66 aA	55.78 aA	52.04 bA
10+1	Control	39.85 bA	60.08 aA	56.11 aA
	MAP	40.45 abA	60.52 aA	55.86 aA
Mean values	Control	40.81 aA	58.04 aA	54.87 aA
	MAP	41.56 aA*	58.15 aA	53.95 aA

*Small letters show the significant difference, p = 0.05; while capital letters show the significant difference, p=0.01

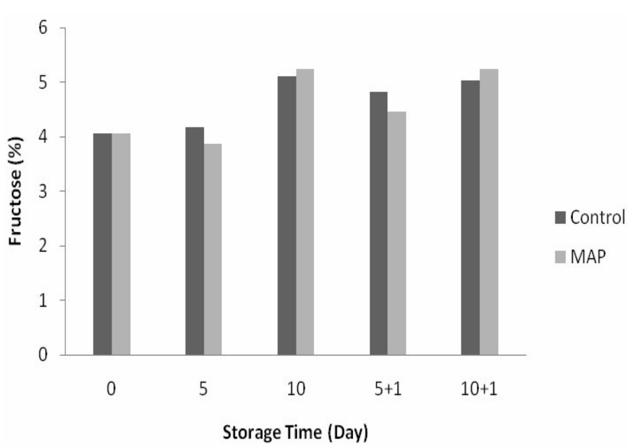

Figure 2. Changes in fructose amount during storage.

in control and modified atmospheres, without statistically significant differences between the two different packages. The higher fruit saccharose content was calculated in fruits at the beginning with 3.95% whereas the lowest was in MAP with 3.17% decreased after one day at 20℃, meaning that the during 5 days of storage. The time of storage influenced the saccharose content which was 3.51% and 3.43 in 5 and 10 days stored fruits. There were no statistically significant differences between the two different treatments and storage times during the shelf life of the berries as regards the saccharose content (Figure 3).

The modified atmosphere did not affect the hue angle (h^o), while it increased by prolonged storage time (47.84, 50.24 and 54.36°) from red to yellow. Strawberries stored for 0 days in modified atmosphere and control packaging had a smaller h^o a value which was indicated as red color. The hue increased after one day at 20℃ which means a change from red towards yellow. The same trend in respect to the day before was observed: the MAP (Tables 3 and 4).

a* coordinate values two different atmospheres did not affect this parameter, while storage time did. b* coordinate moved towards yellow direction after one day at 20℃. Neither of these coordinates was influenced by modified atmosphere packaging. As the day before, the 10+1 stored fruits had a higher b* value and therefore a higher color saturation.

Conclusions

Modified atmosphere has not affected TSS, acidity, pH, firmness, fructose saccharose and color after storing strawberries in a cold room at 0℃. Only glucose content increased in the modified atmosphere stored fruits. Fruits

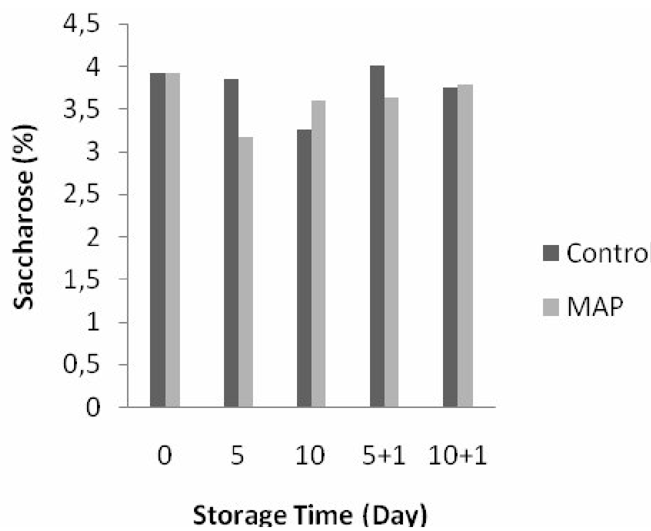

Figure 3. Changes in saccharose amount during storage.

quality changed after one day at 20°C: TSS, firmness and glucose decreased, strawberries changed color towards a higher luminance and a more intense yellow color and a less intense red color; but no differences has been recorded between the two atmospheres packaging in these parameters. MAP had a good influence on strawberries after storage, permitting considerable decrease on fruits mass loss and reducing the strawberries decay after keeping fruits at 20°C for one day also.

The storage time affected the strawberries' quality as increasing this parameter resulted in decreased TSS, acidity, glucose and saccharose levels while fructose increased. Also fruits color was affected by refrigeration time; berries colorimetric coordinates moved toward a more intense yellow color (b*) and a less intense red color (a*) as increasing storage at 0°C.

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