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Modified atmosphere efficiency in the quality maintenance of Eva apples

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Abstract

Modified atmosphere is a method of food preservation that provides increased lifetime, decreases deterioration losses, and facilitates marketing. The objective of this study was to evaluate the efficiency of different plastic films in modifying the atmosphere around Eva apples to assure quality maintenance during postharvest storage. The fruits were cleaned and separated into three treatment groups: polypropylene, low density polyethylene, and high density polyethylene packing with a total of 5 fruits per package for each evaluation period. A group of control apples was not submitted to atmospheric modification. After the treatment, all fruits were stored at 0.5±0.5°C (cold storage) for up to 225 days. The analyses were performed at 45, 135, and 225 days after cold storage. Respiration, ethylene production, firmness, mass loss, total pectin, soluble pectin, soluble solids, total acidity, and epidermis background color of each treatment group were evaluated. The high density polyethylene film treatment did not show a decrease in ethylene production during storage and allowed the fruits to maintain a greater firmness and smaller percentage of mass loss during the study period. Moreover, the storage of the Eva apple cultivar under modified atmosphere allowed the preservation of quality for up to seven months.

Keywords: postharvesting; conservation; polypropylene; low density polyethylene; high density polyethylene.

1 Introduction

Fruit storage conditions and postharvest conservation methods are often chosen with the aim of maintaining quality characteristics, such as color, firmness, acidity, and sugar content, focusing on maximizing postharvest life and commercial quality (Ayala-Zavala et al., 2004).

Modified atmosphere is a conservation technique that is used to expand a plant product's postharvest life and to maintain its quality (Kader, 2002). The main goal of using modified atmosphere is to create an equilibrated atmosphere inside packages that is beneficial to the product without being injurious (Zagory & Kader. 1998). Modified atmosphere have been used on many types of products (Sandhya, 2010; Rai et al., 2011). Achieving an equilibrium atmosphere inside a package of vegetables and fruits is related to the product's respiration rate, weight, storage temperature, relative humidity, and the permeability characteristics of the packaging material.

One of the most effective ways to increase fruit durability and minimize postharvest losses is low storage temperature. In the absence of cold storage, deterioration is often faster because of the production of vital heat and carbon dioxide release from respiration. Thus, cold storage is mainly used to decrease the respiratory rate, reducing losses, and retaining the product features that are associated with quality. However, the metabolic rate should remain ata minimum rateneeded to keep the product cells alive while maintaining the sensory quality during storage (Fonseca et al., 2002).

Although cold storage is widely used to slow the deterioration process, it is often necessary to combine it with another conservation method to better retain postharvest quality features. The modified atmosphere (MA) method is a good alternative because it requires low investment and technology level, and therefore it has been adopted by small and medium producers for the preservation of perishable goods (Flores et al., 2004). Moreover, this technique allows for longer term storage while maintaining product quality (Ali et al, 2004; Lurie et al., 2006; Campos et al., 2007) and provides a barrier against insect attacks (Conyers & Bell, 2007; Riudavets et al., 2009).

This preservation method leads to a reduction in the fruit respiration rate because the combination of fruit respiration and the gas permeability of the plastic film increases the CO_2 levels and decreases the oxygen (O_2) inside the package. Thus, there is a change in the metabolic processes (Hertog et al., 2001; Rocha et al., 2004) that slows fruit ripening, microbial growth (Cantwell, 1992; Caleb et al., 2012), moisture loss (Sabir et al., 2011), and enzymatic browning (Guan & Dou, 2010). Indeed, depending on the levels of fruit respiration and the film permeability, there may be an increase in the CO_2 levels that leads to anaerobic respiration, ethanol accumulation (Ares et al., 2007), and physiological injuries to the product. This process can

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result in the production of off-flavors and pulp deterioration, which result in a fruit that is unfit for consumption (Caleb et al., 2012; Pesis et al., 2002). Accordingly, studies are needed to find the best film for product quality maintenance during storage.

Eva apple cultivar was developed in 1979 from a cross between the cultivars Anna and Gala. Since it does not require cold temperatures, it is cultivated by small and medium producers in micro-regions of southeastern and northeastern Brazil. Good quality fruits that are sweet with well equilibrated acidity and weighing from 120 to 160 g have been produced in these areas (Hauagge & Tsuneta, 1999). As an early variety, Eva apple is harvested between the months of November and January, and no postharvest conservation method has proved to be efficient in the storage of fruits during the off-season to safely maintain their quality. Thus, this study aims to verify the efficiency of different films in maintaining controlled atmosphere and quality of the Eva apples during storage.

2 Materials and methods

2.1 Sample preparation

Eva apple cultivars (*Malus* sp) were grown in Barbacena, MG, southeastern Brazil, in 2009. The samples were harvested and selected for their marketable appearance and absence of injuries or diseases. They were subsequently sanitized with sodium hypochlorite (100 $mg.L^{-1}$) for 10 minutes and randomly divided into four groups.

A completely randomized design with five replicates per treatment was used; each experimental unit consisted of five fruits. The experimental treatments used were as follows: low density polyethylene (14 mm); high density polyethylene (70 mm); polypropylene (20 mm); and no packing (control). After the treatment, the fruits were stored in a cold chamber (0.5±0.5°C) with relative humidity between 90-95%. The assessments were performed at three different times (45, 135 and 225 days of storage).

Before applying the treatment, five samples of six fruits were analyzed to determine the average quality of the apples. On average, the fruits had firmness of 47.36 N (skinless), total soluble solids of 11.5°Brix, titratable acidity of 0.436%, malic acid and epidermis background color with a L* value of 77.29, chroma of 40.3°, and hue angle of up to 99.78°H, as described below.

2.2 Respiratory activity and ethylene production

During each treatment, the fruits were placed in 820 mL bottles, which were then sealed for 1 hour and kept at the same storage temperature. After this time period, respiratory activities and ethylene production were assessed with gas samples that were collected through the silicone septa of the bottles. The CO_2 content was determined directly from the bottle using a gas analyzer (PBI Dansensor Model 9900), and the results were expressed in mmol $CO2.kg^{-1}.h^{-1}$. Gas aliquots were withdrawn and injected in vacuum tubes for ethylene determination. One-milliliter samples were withdrawn from these tubes and were injected with a syringe into a gas chromatograph (model Varian Chrompack CP-3800) equipped with an ionization detector flame using the following conditions: Porapak Q packed column; injector temperature of 250°C; temperature detector of 280°C; initial column temperature of 90°C followed by a temperature increase after 4 min 30 s at the rate of 100°C per minute until reaching 220°C; nitrogen as the carrier gas (20 $mL.min^{-1)}$; and column flow pressure of 0.1 psi. The results were expressed in milliliters of $ethylene.g^{-1}.h^{-1}$.

2.3 Firmness

Firmness was individually determined in whole peeled fruits around the equatorial region using a Magness-Taylor penetrometer with a probe diameter of 5/6 inch. The results were expressed in Newtons (N).

2.4 Mass loss

Mass loss was measured by weighing the fruit in a semi-analytical balance. The results were expressed as percentages of the difference between the initial mass of each fruit and the mass measured during each experiment.

2.5 Total pectin and soluble pectin

Total and soluble pectin were extracted (McCready & McComb, 1952) and spectrophotometrically determined at 520 nm (Bitter & Muir, 1973). The results were expressed as milligrams of galacturonic acid per 100 g of pulp.

2.6 Soluble solids (SSs)

Soluble solids were determined by refractometry (Atago PR-100), according to the standard method (Association of Official Analytical Chemists, 2005) using a digital refractometer, and the results were expressed in °Brix.

2.7 Titratable acidity (TA)

Titratable acidity was obtained and expressed as a percentage of the predominant form of malic acid (Association of Official Analytical Chemists, 2005).

2.8 Color

The epidermis background color was measured on opposite sides of the fruit using a Minolta CR 400 colorimeter on CIE L *a*b* mode. The L* coordinate represents the sample lightness or darkness, and the hue angle shows the color location in a diagram, in which the angle 0° represents pure red, 90° represents pure yellow, 180° represents pure green, and 270° represents pure blue.

2.9 Statistical analysis

The results were submitted to one-way analysis of variance, and the means were compared by the Scott-Knott test at 5% probability using the R Development Core Team software (R Development Core Team, 2010).

3 Results and discussion

Respiratory activities and ethylene production are shown in Table 1. At 45 days of refrigerated storage and modified atmosphere, CO_2 was not detected, and ethylene production was observed only in fruits stored in low density polyethylene film (LDPE). At 135 days, it was observed a decrease in CO_2 over the course of the day. However, there was an increase in CO_2 levels in the polypropylene (PP) treatment during the last days of evaluation. These data can be explained by the low permeability of the film to CO_2 and/or the maintenance of fruit respiration rate during that time period. Similarly, in another study it was found that after 130 days of storage at 2°C, CO_2 concentrations inside the package doubled in Bravo Esmolfe apples that were packed in polypropylene (Rocha et al., 2004).

With regard to the ethylene production, when comparing the modified atmosphere treatments, it was verified that the high density polyethylene film (HDPE) showed the lowest ethylene production at 135 days of storage, possibly because of the higher concentrations of CO_2 inside the package than those of the other treatments. High CO_2 concentrations are able to reduce the biosynthesis of ethylene, both through the reduction of ATP availability (De Wild et al., 1999) and the inhibitions of ACC synthase and ACC oxidase (Mathooko, 1996). Thus, the HDPE film used was able to effectively delay the onset of climacteric peak. However, fruits in the control, LDPE, and PP treatment groups showed an increase in ethylene production at 135 days, followed by a decrease at 225 days, according to the climacteric behavior.

Firmness is one of the major quality attributes of apples. During storage, the treatments with modified atmosphere demonstrated similar firmness results (Table 2). However, the samples in the control treatment showed the greatest loss of firmness at 135 days and was significantly different from the other treatments until the end of the experiment. Similar results were found in another study that demonstrated the beneficial effects of modified atmosphere on apple texture (Rocha et al., 2004).

With regard to the mass loss (Table 2), the fruits that were submitted to modified atmosphere were similar in all assessments, and the control fruits had the greatest mass loss at 135 days. These data emphasize the importance of the type of plastic film for the quality of postharvest storage of fruits. Apples stored under modified atmosphere lose less weight than those stored under normal atmosphere (Rocha et al., 2004). Thus, mass loss can be one of the causes of deterioration and decrease in visual quality of fresh products over time, which can lead to dehydration, wilting, loss of firmness, loss of crispness, and nutritional quality reduction as well as senescence promotion, which reduces the enzymatic and regulatory processes of the fruit (Ben-Yehoshua & Rodov, 2003).

It is important to note that the HDPE film treatments, which showed no decrease in ethylene production during storage

Table 1. Respiration and ethylene production in Eva apples after 45, 135, and 225 days of storage (0.5±0.5°C) under modified atmosphere using high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene (PP) films. Control fruits (C) were not subjected to controlled atmosphere treatment.

Modified Atmosphere	Respiration rate (mmol CO_2 kg^{-1} h^{-1})			Ethylene production (µL g^{-1} h^{-1})		
	Days of storage			Days of storage		
	45	135	225	45	135	225
C	*ND	0.46±0.03 Ca	0.34±0.01 Ca	ND	34.13±4.1 A	ND
HDPE	ND	1.92±0.09 Aa	1.47±0.02 Bb	ND	3.95±0.3 Bb	18.05±1.5 Aa
LDPE	ND	1.62±0.04 Ba	0.47±0.03 Cb	3.92±0.5 B	45.71±5.2 Aa	4.96±0.7 Bb
PP	ND	1.36±0.03 Bb	2.63±0.04 Aa	ND	25.03±2.6 Aa	7.52±0.6 Bb

*ND = no detected; Lowercase letters within the same row indicate a significant difference and uppercase letters within the same column indicate a significant difference by the Scott-Knott test at 5% error probability.

Table 2. Firmness and mass loss in Eva applesafter 45, 135, and 225 days of storage (0.5±0.5°C) under modified atmosphere using high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene (PP) films. Control fruits (C) were not subjected to controlled atmosphere treatment.

Modified Atmosphere	Firmness (N)			Mass loss (%)		
	Days of storage			Days of storage		
	45	135	225	45	135	225
C	44.5±2.3 Aa	34.2±1.2 Bb	20.4±3.7 Cb	2.51±0.2 Ac	8.97±1.2 Ab	15.8±2.5 Aa
HDPE	42.4±2.5 Aa	39.3±3.1 Aa	32.9±5.3 Ab	1.70±0.4 Aa	3.63±0.9 Ba	4.23±1.1 Ba
LDPE	47.8±2.2 Aa	39.4±1.0 Aa	26.9±1.9 Bb	2.80±0.6 Aa	4.82±0.6 Ba	5.99±1.0 Ba
PP	46.1±0.7 Aa	40.8±2.3 Aa	25.2±1.0 Bb	4.43±0.8 Aa	6.53±2.9 Ba	7.97±2.5 Ba

Lowercase letters within the same row indicate a significant difference and uppercase letters within the same column indicate a significant difference by the Scott-Knott test at 5% error probability.

(Table 1), also produced the fruits with the highest firmness at the end of the postharvest conservation period and the lowest percentage of mass loss (Table 2) during all assessments.

Total pectin and solubility values are shown in Table 3. In general, a tendency to decrease total pectin levels was verified during the experimental period in all samples, and the control treatment was similar to the polypropylene treatments in the first two assessment times. An increase in solubility was observed over time in all treatments, and the fruits packed in HDPE film showed the lowest solubility at 135 days. Moreover, the PP group was statistically similar to the control group during the assessments. In fact, pectin plays a key role in the softening of fruits during ripening. It is known that tissue softening throughout the life cycle is caused by respiration and by ethylene, which markedly change fruit metabolism. The softening of apples during storage is a result of the enzymatic action on hemicelluloses and pectin (Hertog et al., 2001; Gorny et al., 2002).

The soluble solids (SSs) and titratable acidity results are shown in Table 4. The SSs content of the control treatment samples was similar during the postharvest conservation period and differed from the other treatments only at 225 days. In the latter assessment, the treatments that were subjected to modified atmosphere showed lower SSs values, most likely as a result of the use of this compound during the respiratory process for metabolism maintenance with considerable mass loss observed in the control treatment samples, ultimately leading to the accumulation of solids, which was also detected in another study on atemoyas (Silva et al., 2009). However, modified atmosphere showed no effect on this parameter in other studies (Rocha et al., 2004). Titratable acidity (TA) did not differ significantly during the experimental period (Table 4).

The variable L* (Table 5) represents the coefficient of brightness in a scale ranging from 0 to 100, where 0 represents black and 100 is white. It can be observed, in general, that the values of this variable decreased during storage, and it was significantly higher for LDPE and PP at 225 days. L* did not differ between treatments in the first assessment. At 135 days, the control group samples had the lowest values. During storage, the L* values followed this same trend, with the exception for the HDPE treatment, which was not significantly different from the control. During analysis, all groups showed a decrease in L* values at the end of the conservation period. This decrease in L* values may be related to fruit darkening during storage, which was confirmed in a study on atemoya (Silva et al., 2009).

As for the hue angle, the control samples and the fruits packed in LDPE film showed slightly more intense yellow color than that of the others groups after 135 days of storage, indicating fruit ripening. At 225 days, the fruits in the control group had a predominant yellow color.

Table 3. Total pectin and solubility in Eva apples after 45, 135 and 225 days of storage (0.5±0.5°C) under modified atmosphere using high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene (PP) films. Control fruits (C) were not subjected to controlled atmosphere treatment.

Modified Atmosphere	Total pectin (mg galacturonic acid.100 g^{-1})			Solubility (%)		
	Days of storage			Days of storage		
	45	135	225	45	135	225
C	393±6.3Aa	422±22.1Aa	344±7.0Ab	34.7±2.4Ac	41.2±2.7Ab	54.7±2.9Aa
HDPE	311±17.9Ca	307±5.7 BAa	346±2.2Aa	35.1±6.0Ab	32.7±1.7Bb	40.5±1.1Ba
LDPE	354±4.5Ba	261±7.4 Cb	223±19.9Bb	33.3±1.4Ab	41.8±2.3Aa	44.3±1.6Ba
PP	434±11.2Aa	373±13.3Ab	257±5.3Bc	32.8±1.3Ac	45.0±2.8Ab	50.9±0.9Aa

Lowercase letters within the same row indicate a significant difference and uppercase letters within the same column indicate a significant difference by the Scott-Knott test at 5% error probability.

Table 4. Total Soluble solids and titratable acidity in Eva apples 45, 135 and 225 days of storage (0.5±0.5°C) under modified atmosphere using high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene (PP) films. Control fruits (C) were not subjected to controlled atmosphere treatment.

Modified Atmosphere	Total Soluble solids (°Brix)			Titratable acidity (% malic acid)		
	Days of storage			Days of storage		
	45	135	225	45	135	225
C	13.2±0.2 Aa	14.8±1.0 Aa	14.3±1.5 Aa	0.576±0.01 Aa	0.402±0.1 Aa	0.469±0.06Aa
HDPE	13.0±0.5 Aa	13.2±0.6 Aa	11.5±1.0 Bb	0.535±0.05 Aa	0.424±0.03 Aa	0.469±0.1Aa
LDPE	12.8±0.9 Aa	12.8±0.3 Aa	11.3±0.3 Bb	0.554±0.04 Aa	0.469±0.06 Aa	0.402±0.06Aa
PP	12.8±0.5 Aa	13.0±0.8 Aa	12.2±0.5 Bb	0.516±0.04 Aa	0.424±0.03Aa	0.424±0.03Aa

Lowercase letters within the same row indicate a significant difference and uppercase letters within the same column indicate a significant difference by the Scott-Knott test at 5% error probability.

Table 5. The L* variable and hue angle in Eva apples after 45, 135 and 225 days of storage (0.5±0.5°C) under modified atmosphere using high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene (PP) films. Control fruits (C) were not subjected to controlled atmosphere treatment.

Modified Atmosphere	L*			Hue angle		
	Days of storage			Days of storage		
	45	135	225	45	135	225
C	75±1.0Aa	71±0.6 Ba	67.8±0.1 Bb	98±2.1Aa	99±1.3 Ba	99±1.5 Ba
HDPE	75±1.8Aa	73±1.8Aa	68.4±2.3 Bb	100±0.4Aa	103±3.2Aa	102±2.6Aa
LDPE	76±0.9Aa	75±0.4Aa	71±1.8 Ab	99±0.8Aa	100±1.2 Ba	101±0.2Aa
PP	75±1.4Aa	74±0.7Aa	70±0.5 Ab	100±1.3Aa	101±1.4Aa	103±1.8Aa

Lowercase letters within the same row indicate a significant difference and uppercase letters within the same column indicate a significant difference by the Scott-Knott test at 5% error probability.

Apples stored under modified atmosphere have a more appealing color than those stored under ambient atmosphere(Rocha et al., 2004). According these authors this might due to the change in the modified atmosphere composition, slightly improving the color of the samples. In the present study, after 7 months and 15 days of storage, the L* values and hue angles were subjected to modified atmosphere. Fruits stored under modified atmosphere have higher hue angle, which are characterized by a duller color than that of fruits that were only kept in refrigerated storage (Steffens et al., 2009). This result must be related to the lower biosynthesis and ethylene action inside the package since the change in color during storage is dependent on the action of this plant growth regulator (Argenta et al., 2003).

4 Conclusion

The use of modified atmosphere during postharvest storage of the Eva apple cultivar allowed the preservation of fruit quality stored at 0.5°C for up to seven months. High density polyethylene film with a thickness of 70 µm had the best results for most of the quality variables. This plastic film had the ability to slow climacteric respiration and provide firmer fruits with less mass loss.

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