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The use of sodium alginate-based coating and cellulose acetate in papaya post-harvest preservation

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ABSTRACT. This study aimed to evaluate the ripening of papaya fruit (*Carica papaya* L.) at room temperature (± 25°C) and 10°C with 80% relative humidity, coated with edible film based on sodium alginate (1%) and cellulose acetate film (3%) by dipping the fruit in the suspensions for 1 min. On the application of the treatment and every three days during 12 days of storage, fruit were evaluated for weight loss, firmness, total carotenoid content, lycopene content and vitamin C content of the pulp. The cellulose acetate film extended the shelf-life of papayas, without affecting their quality. This treatment delayed fruit ripening, whose changes in all the parameters analyzed were significantly slower than fruit treated with sodium alginate-based coating. The coating with cellulose acetate at 3% was more effective in the preservation of papaya stored for 12 days under both temperatures.

Keywords: coating, ripening, storage.

Uso de película à base de alginato de sódio e acetato de celulose na conservação pós-colheita de mamão

RESUMO. Este estudo teve como objetivo avaliar o amadurecimento de mamão (*Carica papaya* L.) à temperatura ambiente (± 25°C) e a 10ºC, com 80% de umidade relativa, revestido com filme comestível à base de alginato de sódio (1%) e película de acetato de celulose (3%) por meio de imersão dos frutos nas suspensões durante 1 min. Na aplicação do tratamento e a cada três dias, durante 12 dias de armazenamento, os frutos foram avaliados quanto à perda de peso, firmeza, concentração total de carotenoides, licopeno e teor de vitamina C da polpa. O filme de acetato de celulose estendeu o prazo de validade do mamão, sem afetar a sua qualidade. Este tratamento retardou o amadurecimento dos frutos, cujas alterações em todos os parâmetros analisados foram significativamente mais lentas que os frutos tratados com revestimento à base de alginato de sódio. O revestimento com acetato de celulose a 3% foi mais eficaz na preservação do mamão armazenado por 12 dias sob as duas temperaturas.

Palavras-chave: revestimento, amadurecimento, armazenamento.

Introduction

The fruit of papaya (*Carica papaya* L.) grows in most of Brazil, especially in the states of Bahia, Espírito Santo and Paraíba, which make up about 90% of national production (MARTINS et al., 2007).

A restriction to the postharvest preservation of papaya is the rapid deterioration, result from high amount and respiratory rate, therefore, with high heat output and soft structure, easily damaged. Due to this high deterioration, ripening control is critical for the increase in lifespan, aiming domestic and foreign markets. The main factors that reduce the postharvest quality of papaya are the rapid softening and high incidence of rotting (JACOMINO et al., 2003).

There are several techniques to extend the shelf life of tropical fruit. The use of modified atmosphere has been widespread because it is a simple technique for storage, in which plastic films are usually employed, which limits the gas exchange and the water loss to the environment by reducing the metabolism of the product and extending their shelf-life (CHITARRA; CHITARRA, 2005). However, environmental concerns associated with the wide variety of plastics have facilitated the research of alternative solutions to replace the common plastic, especially for the biodegradability of these materials (CEREDA; OLIVEIRA, 2003). In recent years there has been growing interest in the use of edible coatings applied to the surface of perishables (CHITARRA; CHITARRA, 2005). Coating is formed from a suspension of a thickening agent, which after application on the product forms a film that acts as a barrier to gas exchange and water loss by modifying the atmosphere and slowing fruit ripening. Sodium alginate is one of the agents that can be used to form edible coatings, whose characteristics are good transparency and good resistance to gas exchange. Alginates are linear polymers comprising residues of α-L-guluronic (G) and β-D-mannuronic (M) present in variable proportions and sequences in the cell wall and intercellular space of brown algae. The gelling mechanism is an ion exchange process wherein the sodium alginate is replaced by calcium present in the gelling medium through a chemical bond between two carboxyl groups present in adjacent polyguluronic acid residues. Cellulose-based films have also been an alternative to extend the shelf life of fruit, applied as non-edible coatings, with high efficiency as a barrier to gas exchange. The ethyl cellulose is one of cellulose derivatives of great commercial importance.

Material and methods

Fruit of papaya (*Carica papaya* L.) were obtained from Central Supply of the State of Sergipe S/A (CEASA) in the Aracaju city, Sergipe State, Brazil. Fruit were selected according to the size and maturity stage (peel with the first signs of yellowing, corresponding to the maturity stage 1), free of infection and physical defects. They were then washed with a chlorine solution (200 ppm) and dried for 10 minutes at room temperature (± 25°C). After drying, they were divided into groups and immersed in the solutions of 1% sodium alginate (10 g 1 L^{-1}) and 3% cellulose acetate (30 g cellulose acetate $1L^{-1}$ acetone) for one minute and then dried at room temperature. Fruit were analyzed after storage at room temperature of 10 and 25°C, 80% RH for 12 days. Six types of samples were analyzed, control fruit stored at room temperature (CTA), chilled fruit control (CTR), fruit with sodium alginate film at room temperature (ALTA), chilled fruit with sodium alginate film (ALTR) fruit with cellulose acetate film at room temperature (ACT) and chilled fruit with cellulose acetate film (ACTR).

Quality indicators were evaluated every three days at times zero, three, six and twelve days. Weight loss (%) was evaluated with an electronic balance accurate to 0.001 g. The fruit firmness was analyzed in a texturometer Brookfield, model CT3. Pulp penetration test was carried out in a whole fruit using a cylindrical probe of 4 mm diameter at a penetration rate of 2 mm s^{-1} and distance of 20 mm depth. Measurements were made at three equidistant points from the central region of each fruit, obtaining an average value of the maximum penetration force (N), which expresses the resistance of the pulp to penetration. Carotenoids extraction was performed with 2 g sample macerated with 80% acetone. Spectrophotometer readings were taken in Micronal-B582 spectrophotometer. Levels of carotenoids, expressed in g g^{-1} were calculated by the method of Lichtenthaler (1987). Lycopene determination was carried out according to the method of Rodriguez-Amaya (1993) and expressed in g/g. The amount of ascorbic acid was determined by the AOAC (1984) method modified by Benassi and Antunes (1988), using oxalic acid as extractant. The experimental design was completely randomized in a 5 × 6 factorial arrangement. Variables studied were the treatments: uncoated fruit, fruit coated with 1% sodium alginate and fruit coated with 3% cellulose acetate, under room and chilling temperatures, and the storage time (0, 3, 6, 9 and 12 days). Three replicates per treatment were considered, each consisting of three fruits.

Results of physical and chemical analyses were subjected to analysis of variance and mean values compared by a Tukey's test at 5% probability using the software Assistat 7.6 beta, 2011.

Results and discussion

Weight loss

It was verified a gradual weight loss over the storage period in all treatments. A higher weight loss was verified in the treatment with sodium alginate at 1% (high) with a loss of 28% in the 12th day of storage in environmental conditions, that is: at room temperature (± 25°C) and 10°C with 80% RH. Pereira et al. (2006) analyzed the ripening of Formosa papaya coated with edible cassava starch film (1%) with 12 days of storage at room temperature and 27% and 70% RH, and verified a weight loss of 4.27%. Moreover, Santos et al. (2008) developed a research with Formosa papaya in bulk transportation (EMB 1), wooden crates (EMB 2), corrugated cardboard boxes (EMB 3) and plastic boxes wrapped in bubble wrap (EMB 4), and concluded that the packaging procedure promotes changes in postharvest qualities, resulting in an index rise of the peel color, firmness flesh decrease, high loss of fresh weight, increased respiratory rate and higher percentages of injured peel area, in both color stages studied.

However the lowest loss was observed in the treatment with cellulose acetate stored at 10°C with 2.77% (Table 1). The weight loss is an important factor in fruit conservation, a high weight loss in relation to the initial weight, damages the fruit aspect, which shows a wrinkled surface (CASTRO et al., 2011). The papaya is commercialized per unit of weight, and the weight loss results in a lower productivity. Cenci et al., (2002) noted that a weight loss above 5% is sufficient for the papaya depreciation and the loss is frequently neglected in the marketing chain (Table 1).

Firmness

Table 2 shows a decrease in fruit firmness over the days after treatments, but in fruit coated with cellulose acetate (3%) at chilling temperature, this decrease was slower and fruit remained firmer than those coated with 1% sodium alginate film and control fruit.

Lopes et al. (2005) cited by Santos et al. (2008) observed a positive correlation between papaya fruit weight loss and papaya texture pulp. So, the greater the fruit weight loss the lower the texture values. In the present work, a correlation between these two variables was detected, wherein an increase in the percentage of weight loss led to a reduction in fruit firmness in all treatments.

Pereira et al. (2006) with papaya coated with 1, 2 and 3% of cassava starch and stored at 27°C and 70% RH, found that all fruit after the 12th day had a firmness near 20N considered ideal for papaya consumption as Bron et al. (2003) for the papaya 'Golden'. The greater fruit firmness registered with the use of cellulose acetate film ensures a better resistance to mechanical damage during handling. Therefore, a longer durability as stated by Pereira et al. (2006).

The use of cellulose acetate combined with low temperatures has prolonged the fruit firmness. Fruit softening is related to the ripening process, which involves a series of enzymatic reactions triggered by the increase in climacteric respiration and reduction of ethylene. Ethylene is involved in accelerated ripening and senescence of climacteric fruits such as papaya. At a certain stage of maturity, ethylene binds to its receptor on the cell and triggers a series of events that culminate with the fruit ripening and senescence. Bell peppers covered with PVC and cassava starch films at 4 and 4.5% have differed significantly from the control, presenting a firmer texture at the 8th day of storage (HOJO et al., 2007).

Carotenoids

An increased was observed in the content of carotenoids after the 6th storage day in all treatments (Table 3), which was expected as the fruit were in a ripening stage. However, a loss in the content of carotenoids after 12 days of storage was observed in almost all treatments except for the ACTR that remained nearly constant.

Cellulose acetate coating was more effective in controlling the appearance of orange color of the fruit, because carotenoids concentration remained virtually constant from the 3rd to 12th days after treatment.

Besides, Castro et al. (2011) examined the papaya preservation associated with edible coating tapioca-based starch application at 2% in a temperature of ± 25°C with 82% RH and cooled to 8°C, and observed a carotenoids increase after the 6th day of storage, up to a level above 20 mg g^{-1}.

Papaya is a climatic fruit that ripens after the harvest period. During the ripening, the green pigment chlorophyll is degraded and carotenoids are synthetized. Carotenoids particularly lycopene and β-carotene represent the basic ripe fruit pigmentation components that are responsible for ripe tomato color giving them an orange shade.

Table 1. Values of weight loss (%) of papaya according to treatments and storage time.

Treatment	Time (days)				
	0	3	6	9	12
CTA	0 ± 0.54^{aE}	4.34 ± 1.25^{bD}	9.49 ± 0.28^{bC}	16.30 ± 0.32^{bB}	26.04 ± 0.08^{bA}
CTR	0 ± 0.54^{aE}	1.16 ± 0.095^{eD}	2.28 ± 0.75^{eC}	3.66 ± 0.09^{eB}	5.51 ± 0.06^{eA}
ALTA	0 ± 0.54^{aE}	6.98 ± 1.23^{aD}	13.40 ± 0.38^{aC}	20.03 ± 0.08^{aB}	28.06 ± 0.17^{aA}
ALTR	0 ± 0.54^{aE}	1.39 ± 1.47^{dD}	3.12 ± 0.17^{dC}	4.85 ± 0.17^{dB}	6.68 ± 0.12^{dA}
ACTA	0 ± 0.54^{aE}	3.66 ± 1.71^{cD}	6.64 ± 0.12^{cC}	12.4 ± 0.15^{cB}	16.68 ± 0.07^{cA}
ACTR	0 ± 0.54^{aE}	0.63 ± 0.98^{fD}	1.43 ± 0.09^{fC}	2.37 ± 0.05^{fB}	2.77 ± 0.05^{fA}

Mean values followed by the same letter, lowercase on the column and uppercase on the row, do not differ by Tukey's test at 5% probability. CTA = control at room temperature; CTR = control at chilling temperature; ALTA = sodium alginate at room temperature; ALTR = sodium alginate at chilling temperature, ACTA = cellulose acetate at room temperature; ACTR cellulose acetate at chilling temperature.

Table 2. Values of firmness (N) of papaya according to treatments and storage time.

Treatment	Time (days)				
	0	3	6	9	12
CTA	64.07 ± 0.41^{aA}	48.16 ± 1.71^{cB}	10.30 ± 2.38^{cC}	6.69 ± 1.06^{cC}	5.67 ± 1.06^{cC}
CTR	64.07 ± 0.41^{aA}	60.22 ± 1.92^{aAB}	57.09 ± 3.97^{aB}	30.19 ± 1.52^{bC}	26.00 ± 1.68^{bC}
ALTA	64.07 ± 0.41^{aA}	54.16 ± 1.09^{bB}	44.24 ± 3.27^{bC}	9.19 ± 0.98^{cD}	7.10 ± 0.90^{cD}
ALTR	64.07 ± 0.41^{aA}	59.66 ± 8.07^{abA}	44.16 ± 2.24^{bB}	27.58 ± 1.41^{bC}	26.88 ± 2.31^{bC}
ACTA	64.07 ± 0.41^{aA}	57.14 ± 3.50^{abB}	47.32 ± 2.93^{bC}	11.36 ± 0.51^{cD}	8.73 ± 1.13^{cD}
ACTR	64.07 ± 0.41^{aA}	61.38 ± 1.14^{aAB}	58.74 ± 1.4^{aABC}	56.71 ± 3.2^{aBC}	55.23 ± 3.57^{aC}

Mean values followed by the same letter, lowercase on the column and uppercase on the row, do not differ by Tukey's test at 5% probability. CTA = control at room temperature; CTR = control at chilling temperature; ALTA = sodium alginate at room temperature; ALTR = sodium alginate at chilling temperature, ACTA = cellulose acetate at room temperature; ACTR cellulose acetate at chilling temperature.

Table 3. Carotenoid content (μg g^{-1}) of papaya according to treatments and storage time.

Treatment	Time (days)				
	0	3	6	9	12
CTA	32.84 ± 0.84^{aC}	34.11 ± 0.27^{aB}	35.59 ± 0.40^{aA}	28.57 ± 0.25^{eD}	20.86 ± 0.22^{fE}
CTR	32.84 ± 0.84^{aC}	32.58 ± 0.07^{bcC}	33.94 ± 0.08^{cB}	35.78 ± 0.12^{aA}	28.42 ± 0.32^{dD}
ALTA	32.84 ± 0.84^{aC}	34.08 ± 0.10^{aB}	35.67 ± 0.12^{aA}	30.94 ± 0.09^{dD}	23.69 ± 0.09^{eE}
ALTR	32.84 ± 0.84^{aC}	32.18 ± 0.12^{cD}	34.77 ± 0.15^{bA}	33.66 ± 0.38^{cB}	30.22 ± 0.06^{cE}
ACTA	32.84 ± 0.84^{aC}	33.15 ± 0.09^{bB}	34.21 ± 0.06^{bcA}	34.10 ± 0.17^{bcA}	32.06 ± 0.08^{bC}
ACTR	32.84 ± 0.84^{aC}	32.91 ± 0.05^{bC}	33.05 ± 0.08^{dC}	34.33 ± 0.05^{bB}	34.96 ± 0.17^{aA}

Mean values followed by the same letter, lowercase on the column and uppercase on the row, do not differ by Tukey's test at 5% probability. CTA = control at room temperature; CTR = control at chilling temperature; ALTA = sodium alginate at room temperature; ALTR = sodium alginate at chilling temperature, ACTA = cellulose acetate at room temperature; ACTR cellulose acetate at chilling temperature.

Content of lycopene

According to Table 4, after 12 days stored at room temperature CTA and ALTA led to a reduction in lycopene content 48.8 and 39% respectively, while cellulose acetate treatments caused an increase at the 9th days of storage.

It was noticed a decrease from the 9th day of storage for fruit coated with sodium alginate film, while fruit coated with cellulose acetate film stored at room temperature showed lower values only on the 12th day. On the other hand, fruit coated with acetate film stored under refrigeration presented almost constant values from the beginning to the end of the evaluation period, maintaining thus the levels of lycopene. Lycopene has no vitamin A activity, but contribute to papaya pulp reddish color.

Tomatoes are considered a good source of lycopene, with average ranging from 3.0 to 5.0 mg 100 g^{-1} fresh pulp. Researches have shown that the consumption of food products containing tomatoes reduce the possibility of developing several types of cancer, which has been associated to higher blood lycopene levels (SHI; MAGUER, 2000). Lycopene levels in papaya fruit are close to that of tomatoes. Thus this fruit can also be considered a good source of this carotenoid.

Vitamin C

A significant increase was detected for ascorbic acid on the 3rd day of evaluation in fruit coated with cellulose acetate film at both temperatures, and in those coated with sodium alginate film at chilling temperature. Control fruit and those coated with alginate at room temperature showed statistically lower levels in the same period (Table 5).

There was an increase of vitamin C on the 3rd day of storage and a decrease in the values at the 12th day in all treatments. Differently from observed for most fruits, in papaya there is a gradual increase in vitamin C by the complete ripening of the fruit. This increase is noted in the literature on papaya so that the ascorbic acid content increase aims to protect the fruit against aerobic metabolism oxidative damage (SMIRNOFF, 1996). It is suggested that the ascorbic acid precursors can occur due to the cell wall polysaccharides degradation (SMIRNOFF et al., 2001, GODOY et al., 2010).

Table 4. Lycopene content (μg g^{-1}) of papaya according to treatments and storage time.

Treatment	Time (days)				
	0	3	6	9	12
CTA	25.45 ± 0.40^{aB}	26.14 ± 0.18^{abcB}	28.01 ± 0.10^{aA}	20.74 ± 0.56^{dC}	13.05 ± 0.41^{fD}
CTR	25.45 ± 0.40^{aB}	25.22 ± 0.20^{cdB}	25.90 ± 0.26^{dB}	28.72 ± 0.22^{aA}	21.93 ± 0.08^{dC}
ALTA	25.45 ± 0.40^{aB}	26.82 ± 0.43^{aA}	26.71 ± 0.16^{cdA}	23.87 ± 0.29^{cC}	15.55 ± 0.31^{eD}
ALTR	25.45 ± 0.40^{aB}	24.33 ± 0.42^{dC}	26.99 ± 0.96^{bcA}	26.74 ± 0.36^{bA}	23.45 ± 0.20^{cC}
ACTA	25.45 ± 0.40^{aC}	26.70 ± 0.33^{abB}	27.96 ± 0.17^{abA}	28.72 ± 0.20^{aA}	25.09 ± 0.27^{bC}
ACTR	25.45 ± 0.40^{aB}	25.79 ± 0.17^{bcB}	26.10 ± 0.34^{cdB}	27.64 ± 0.10^{bA}	27.54 ± 0.21^{aA}

Mean values followed by the same letter, lowercase on the column and uppercase on the row, do not differ by Tukey's test at 5% probability. CTA = control at room temperature; CTR = control at chilling temperature; ALTA = sodium alginate at room temperature; ALTR = sodium alginate at chilling temperature, ACTA = cellulose acetate at room temperature; ACTR cellulose acetate at chilling temperature.

Table 5. Values of Vitamin C (mg AA 100 g^{-1}) of papaya according to treatments and storage time.

Treatment	Time (days)				
	0	3	6	9	12
CTA	51.41 ± 1.04^{aC}	72.32 ± 0.44^{aA}	64.02 ± 3.81^{bB}	61.11 ± 3.85^{cB}	40.02 ± 8.07^{cD}
CTR	51.41 ± 1.04^{aBC}	57.88 ± 1.46^{bcAB}	63.66 ± 3.71^{bA}	64.60 ± 1.54^{bcA}	45.22 ± 2.41^{cC}
ALTA	51.41 ± 1.04^{aC}	62.08 ± 1.59^{bAB}	65.26 ± 0.88^{bA}	65.40 ± 0.51^{bcA}	55.50 ± 3.9^{bBC}
ALTR	51.41 ± 1.04^{aC}	51.51 ± 1.99^{cC}	77.41 ± 2.21^{aA}	64.93 ± 3.33^{bcB}	44.42 ± 0.67^{cC}
ACTA	51.41 ± 1.04^{aC}	54.89 ± 3.47^{bcC}	81.60 ± 0.96^{aA}	71.41 ± 0.67^{bB}	67.41 ± 1.88^{aB}
ACTR	51.41 ± 1.04^{aC}	62.34 ± 3.80^{bB}	80.98 ± 1.30^{aA}	86.16 ± 1.30^{aA}	56.20 ± 1.9^{bBC}

Mean values followed by the same letter, lowercase on the column and uppercase on the row, do not differ by Tukey's test at 5% probability. CTA = control at room temperature; CTR = control at chilling temperature; ALTA = sodium alginate at room temperature; ALTR = sodium alginate at chilling temperature, ACTA = cellulose acetate at room temperature; ACTR cellulose acetate at chilling temperature.

Conclusion

The cellulose acetate film has extended the shelf-life of papaya fruit, without affecting their quality. This treatment delayed fruit ripening, whose changes in weight loss, firmness, total carotenoid, lycopene and vitamin C were significantly slower than fruit treated with sodium alginate-based coating. The cellulose acetate film at 3% proved to be more effective in preserving papaya stored for 12 days at both temperatures studied.

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