Acta Scientiarum
http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8664
Doi: 10.4025/actascitechnol.v40i1.31074
SCIENCE, FOOD TECHNOLOGY AND FOOD ENGINEERING

Propolis extract from different botanical sources in postharvest conservation of papaya

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ABSTRACT. This study evaluated the physical and chemical characteristics of the papaya 'Solo' cv. 'Golden' (*Carica papaya* L.) coated with propolis extract drawn from various botanical sources, during storage at room temperature. Papayas underwent three types of dip coating propolis extract, in 2.5% (w v^{-1}) concentration ('aqueous extract' and 'hydroalcoholic extract of propolis wild type', 'hydroalcoholic extract of the propolis green rosemary'), at ambient temperature and two controls (without coating, one at 'ambient temperature' and the other 'refrigerated'). The variables weight loss, firmness, soluble solids (SS), titratable acidity (TA), maturation index ratio (SS/TA) and hydrogen potential (pH) were evaluated, at three day intervals for twelve storage days. Sensory analyses of the papayas were performed on days three and six of storage, by acceptance testing. Coatings with hydroalcoholic extract of propolis wild type and green rosemary controlled weight loss and firmness in papayas. The coatings showed no effect on the variable SS. Fruit coated with hydroalcoholic extract of rosemary green propolis showed satisfactory results evaluating AT, SS/TA and pH, as well as sensory analysis. Thus, the coating formulated with propolis extract can be used as an alternative to extend the shelf life of papaya fruits.

Keywords: *Carica papaya* L., coating, storage, acceptance, shelf life.

Extrato de própolis de diferentes fontes botânicas na conservação pós-colheita do mamão

RESUMO. O trabalho objetivou avaliar as características físico-químicas de mamão 'Solo' cv. 'Golden' (*Carica papaya* L.), revestido com extrato de própolis de diferentes fontes botânicas armazenado à temperatura ambiente. Mamões (156 frutos de mamoeiro) foram submetidos a três formas de revestimentos por imersão em extrato de própolis com concentração de 2,5% (m v^{-1}) ('extrato aquoso' e 'extrato hidroalcoólico de própolis tipo silvestre', 'extrato hidroalcoólico de própolis tipo verde alecrim'), mantidos à temperatura ambiente e dois controles (sem revestimento, 01 mantido à temperatura ambiente e outro refrigerado). As variáveis perda de massa, firmeza, sólidos solúveis (SS), acidez titulável (AT), índice de maturação (SS/AT) e potencial hidrogeniônico (pH) foram avaliadas em intervalos de três dias por 12 dias de armazenamento. Realizou-se a análise sensorial dos mamões aos três e seis dias de armazenamento, por meio do teste de aceitação. As coberturas com extrato hidroalcoólico de própolis, tipo silvestre e verde alecrim, controlaram a perda de massa e a firmeza nos mamões. Os revestimentos não interferiram na variável SS. Frutos revestidos com extrato hidroalcoólico de própolis verde alecrim apresentaram resultados satisfatórios nas avaliações de AT, SS/AT e pH, bem como na análise sensorial. Desta forma, o extrato de própolis pode ser utilizado para revestir o mamão, como alternativa para estender sua vida útil.

Palavras-chave: *Carica papaya* L., revestimento, armazenamento, aceitação, vida útil.

Introduction

Papaya (*Carica papaya* L.) of the *Caricaceae* family, is one of the most popular fruits. As it is a climacteric fruit, rapid maturing of the physiologically ripen fruit occurs after harvest, stimulated by ethylene production and enhanced respiratory rate (Martins, Barbosa, & Resende, 2014), resulting in a storage period of seven to twenty days (El-Ramady, Domokos-Szabolcsy, Abdalla, Taha, & Fári, 2015). The postharvest losses of papaya are caused mainly by mechanical, physiological and pathogenic damage (Madani, Mirshekari, &Yahia, 2015).

Extension of the storage period of papaya is possible by minimizing its transpiration and respiration rates (Kader, 2002; Ali, Muhammad, Sijam, & Siddiqui, 2011). Biodegradable coatings are an effective strategy, and they may assist in maintaining the physicochemical and sensory quality of the fruit, with the advantage of being safer for the consumer and the environment (Mattiuz et al., 2015).

These coatings provide a very thin coverage on the fruit surface enabling a higher CO_2 concentration from the respiration of the fruit itself, and the same reduction in the O_2 intensity, slowing down the metabolism, and lengthening the useful life of the fruit (Sánchez-González, Cháfer, Hernández, Chiralt, & González-Martínez, 2011). Biodegradable coating can also reduce pathogen prevalence, if it is effective against bacteria and fungi (Sánchez-González et al., 2011; Torlak & Sert, 2013; Ali, Pheng, & Mustafa, 2015; Madani et al., 2015; Mattiuz et al., 2015). Coatings in papaya can be composed of several substances like sodium alginate and cellulose acetate (Silva et al., 2014), chitosan (Ali et al., 2011; Torlak & Sert, 2013), carrageenan (Hamzah, Osman, Tan, & Ghazali, 2013), gum arabic (Ali, Cheong, & Zahid, 2014), essential oils, as lemongrass, thyme and lime essential oils (Bosquez-Molina, Jesús, Bautista-Baños, Verde-Calvo, & Morales-López, 2010; Ali et al., 2015) and propolis extract combined with polymers (Torlak & Sert, 2013; Ali et al., 2014).

Propolis is a composite mixture occurring in hives, containing resinous and balsamic substances. It is collected by Africanized bees, *Apis mellifera* L. from various plant exudates (Park, Paredes-Guzman, Aguiar, Alencar, & Fujiwara, 2004). The components of propolis are directly linked with the chemical composition of the resin of plant of origin.

Bankova (2005) showed that the tropical propolis samples, from Brazil in particular, are different in chemical composition, when compared with propolis from other countries. This fact has triggered great interest in research, with respect to the diversity of propolis. The objective of the present study was to analyze the effects of propolis extract coatings, with different botanical origins, on the physicochemical characteristics of papaya 'Solo' cv. 'Golden', storaged at room temperature.

Material and methods

Propolis extracts produced by the Africanized bee (*Apis mellifera* L.), using various wild plant exudates (wild propolis) and *Baccharis dracunculifolia* (green rosemary propolis), were obtained from the partnership with the Industry and Apiary Centro Oeste Ltda/ Natucentro, in Bambuí, state Minas Gerais, Brazil.

The hydroalcoholic propolis extracts (wild rosemary and green) with 11% concentration of propolis (w v^{-1}) were dissolved in 70% grain alcohol solution to achieve a final concentration of 2.5%. The aqueous extract 2.5 % was prepared from the wild propolis extract and a concentration of 11% propolis (w v^{-1}), diluted with distilled water.

Solo papaya cv. 'Golden' obtained at the Central Supply of Minas Gerais S/A - CEASA Regional Patos de Minas, state Minas Gerais, were chosen based on skin color showing 15-25% yellow peel surface area. They were randomly segregated into five groups and subjected to postharvest treatments as follows:

1. Control - fruit without coating; 2. Aqueous - fruit coated with the aqueous extract of wild type propolis 2.5% (w v^{-1}); 3. Wild - fruit coated with hydroalcoholic extract of wild type propolis 2.5% (w v^{-1}); 4. Green - fruit coated with hydroalcoholic extract of green rosemary propolis 2.5% (w v^{-1}); 5. Refrigerated - fruit uncoated and refrigerated at 7 ± 1°C.

The fruits were coated by individually immersion in the solutions defined, for 5 s. Then the fruits were placed horizontally on 'nylon' screens to drain off the excess liquid for about 5 min. They were then arranged on counter tops in a completely randomized design, according to the related postharvest treatments, at ambient temperature (18 ± 5°C and 51 ± 5% RH). The fruits subjected to the 'refrigerated' postharvest treatment were stored at a temperature of 7 ± 1°C and relative humidity of 80 ± 2% (within the critical range). The Security Minimum Temperature (SMT) for papaya ranges from 7 to 13ºC at a relative humidity of 85 ± 5% (El-Ramady et al., 2015). The fruits were evaluated prior to the application of the postharvest treatment (at time 0) and then at three, six, nine and twelve days of storage.

The experimental units were analyzed for 1- weight loss (non destructive group), 2- firmness, 3- soluble solids (SS), 4- titratable acidity (TA), 5- maturation index ratio (SS/TA) and 6- hydrogen potential (pH) (destructive group), following the recommendations of the Association of Official Analytical Chemists (AOAC, 2012).

Weight loss analysis was performed in a completely randomized design in the factorial split plot scheme 5 x 4, with plots of the postharvest treatments (control, aqueous, wild, green and refrigerated) and the subplots of evaluation times (three, six, nine and twelve days of storage), with six replicates. The analysis was done utilizing a semi-analytical electronic balance (BL-320H model;

Splabor – Presidente Prudente, state Paraná, Brazil), with 0.001 g sensitivity, by subtracting the initial and final weight of the fruits and expressing the results in percentage.

The variables from the destructive group were determined in a completely randomized design in the factorial split plot scheme 5 x 4+1, and the postharvest treatments of the plots (control, aqueous, wild, green and refrigerated). It also included the subplots, time of evaluation (three, six, nine and twelve days of storage) and an additional analysis done at time zero, with six replicates.

To determine the firmness, the digital penetrometer (PTR-300 model; Instrutherm – state São Paulo, Brazil) was used, with a 5 mm nozzle diameter. The firmness was measured at two opposite points, on the equatorial belt of the fruit. A small piece of the peel was sliced with a blade. The results express the force in Newtons (N). Soluble solids (SS) were measured directly with a digital refractometer (PAL-1 model; Atago – Ribeirão Preto, state São Paulo, Brazil), having automatic temperature compensation to 20°C. These results were given in percentage. The titratable acidity (TA) was determined using the titration method. Pulp tissues (5.0 g) were homogenized with 50 mL of distilled water. The mixture with two to four drops of phenolphthalein 1%, used as indicator, was titrated using 0.01 mol L^{-1} NaOH to reach an endpoint pink (pH 8.1). The results were expressed as the percentage of citric acid, the predominant acid in papaya. The maturity index was calculated as the ratio between SS and TA. The results were expressed by the absolute value recorded. The pH was ascertained using a digital pH meter (MPA-210 model; Tecnopon – Piracicaba, state São Paulo, Brazil). The glass electrode was immersed directly in the papaya pulp, and the results were expressed by the absolute value found.

The papayas were submitted to sensory analysis to determine which postharvest treatment was more accepted by the panelists during six days of storage, and to observe if there was anaerobic respiration in the coating fruit. Firstly, this study was approved for its ethical and methodological aspects by the Ethics Committee on Human Research of the Federal University of Viçosa, by the production of an appreciation for ethical No. 32222114.8.0000.5153. The papayas Solo cv. 'Golden', were evaluated in the afternoon on days three and six of storage, between 14h00 and 16h00. The tasters were between eighteen to sixty one years old, were selected based on their papaya consumption habits and also on their availability and interest on being a participant.

Sixty untrained panelists participated in the sensorial analysis. They tasted all the five papaya samples (control, aqueous, wild, green and refrigerated). Each taster was served 30 g of each sample in white plastic cups coded with three digit numbers, in a randomized complete block design (Lawless & Heymann, 2010). The panelists were also given a glass of water at room temperature to drink and cleanse the palate after tasting each sample. The samples were evaluated on a hedonic scale of nine points, ranging from 'extremely liked' (nine) to 'dislike extremely' (one), based on the methodology of Lawless and Heymann (2010).

The data were submitted to the tests of homogeneity of variances (Hartley test) and normality of residuals (Jarque-Bera test). Transformations were performed in the weight loss analysis and firmness to allow the ANOVA (Analysis of variance) assumptions. The weight loss transformation was determined by log (x+1). For firmness, the transformation was $\sqrt{x}$. The influence exerted by the factors (postharvest treatments and storage period) and their interactions with the responses were subjected to factor analysis of the split plot. After the split of ANOVA, the means of the postharvest treatments were compared using the Student-Newman-Keuls test (SNK), a 5% probability. The postharvest means of the treatments over time were submitted for regression analysis. Adjustment of the data to models was sought with up to two dependent factors. The models described that the equations are significant at 5% and the F test showed no significant lack of fit.

For the sensory analysis the experimental design selected was randomized blocks, with sixty repetitions. The record classification was transformed into numerical values for easy analysis, and the ANOVA was applied at 5% of significance using the variance ratio F to identify the significant differences. Analysis was done on days three and six of storage. For the factors having significant F values in the 5% level of probability, the Newman-Keuls means test was applied at 5% probability.

Results and discussion

The weight loss of papaya 'Solo' cv. 'Golden' showed significant effects on the postharvest treatments and storage periods ($p < 0.05$), which were observed in the interaction among the factors (Table 1).

Table 1. Weight loss (%) of papaya 'Solo' cv. 'Golden' coated and uncoated with the propolis extract sourced from different plant origins, during storage period.

Treatments	3 days	6 days	9 days	12 days	Means	Adjusted model	R^2
Control	2.09 *A*	4.75 *A*	7.90 *A*	14.15 *A*	7.22	Log(y+1) = 0.278+0.075x	0.995
Aqueous	2.13 *A*	5.09 *A*	8.79 *A*	16.83 *A*	8.18	Log(y+1) = 0.262+0.082x	0.996
Wild	1.31 *B*	2.87 *B*	4.86 *B*	8.75 *B*	4.45	Log(y+1) = 0.159+0.069x	0.998
Green	1.29 *B*	2.84 *B*	4.87 *B*	10.03 *B*	4.76	Log(y+1) = 0.130+0.074x	0.994
Refrigerated	0.82 *C*	1.60 *C*	2.75 *C*	4.85 *C*	2.55	Log(y+1) = 0.085+0.056x	0.999
Means	1.53	3.43	5.87	10.90		CV: 7.2 %	

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$).

Ten percent of weight loss makes the fruit unfit for consumption, according to Kader (2002). Keeping this value in mind and the weight loss adjustment equations as a function of time (Table 1), the fruit of the postharvest treatment 'control' would be unfit for consumption after 10 days. The papaya coated with hydroalcoholic propolis extract type 'wild' would be unfit for consumption after 13 days, an increase of 26% in postharvest life time. The fruit coated with the hydroalcoholic extract of green rosemary propolis would be unfit for consumption after 12 days, representing an increase of 21% in the postharvest lifetime. This factor has been proven to be critical to fruit preservation, because a great loss of mass in relation to the initial weight will detract from its appearance, caused by loss in cell turgor (Hamzah et al., 2013).

The weight loss reduction reported in papaya was similarly seen in papaya and dragon fruit (pitaya) coated with ethanol extract of propolis, according to Ali et al. (2014) and Zahid, Ali, Siddiqui, and Maqbool (2013), respectively. The papayas coated with a concentration of 1.5% ethanol extract of propolis revealed approximately 7% weight loss when stored at 13°C ± 1 and 80-90% RH for 28 days storage (Ali et al., 2014); however, the pitayas coated with 0.5% ethanol extract of propolis showed a 13% weight loss when stored at 20 ± 2°C and 80 ± 5% RH for 20 days of storage (Zahid et al., 2013).

The weight loss percentage in papaya depends upon the peel; surface thickness, which in turn is dependent on the growth and maturity of the fruit at harvest (Ong, Forney, Alderson, & Ali, 2013). Paull and Chen (1989) explained that the thickness of the papaya cuticle does not change until the fruit turns mature green to half yellow, but decreases after. Therefore, the weight loss increases as the fruit ripens during storage. In this study, the rate of weight loss appears constant as the fruit ripens. This may be due to the constant water permeability of cuticle influenced by the type of postharvest treatments and days of storage.

Significant differences in the postharvest treatments were observed with respect to the firmness of the papaya 'Solo' cv. 'Golden' and the days of storage ($p < 0.05$), with no interaction ($p > 0.05$) among the factors (Table 2).

A decrease in the firmness was noted in all the postharvest treatments over the 12 days storage period. Postharvest treatments that ensured better resistance to mechanical damage and better fruit durability were limited to the 'refrigerated', 'green', wild' and 'aqueous' treatments, which showed no significant difference from each other ($p > 0.05$).

The hardening of papayas during the storage period after the postharvest 'green', wild' and 'aqueous' treatments can be justified by the presence of propolis in the coating, that can be given to the insolubility pectic material, which inhibits the degradation of pectin by pectin methylesterase (PME) and polygalacturonase (PG) (enzymes responsible for softening of fruit). The propolis hydroalcoholic extract coating enhances firmness retention and concurs with the results of Ali et al. (2014) and Zahid et al. (2013). The papaya and dragon fruit, respectively, appeared firmer than the postharvest control treatment during the duration of storage.

Table 2. Firmness (N) of papaya 'Solo' cv. 'Golden' coated and uncoated with propolis extract sourced from different plant origins, during storage period.

Treatments	3 days	6 days	9 days	12 days	Means	Adjusted model	R^2
Control	2.09 *A*	4.75 *A*	7.90 *A*	14.15 *A*	7.22	Log(y+1) = 0.278+0.075x	0.995
Aqueous	2.13 *A*	5.09 *A*	8.79 *A*	16.83 *A*	8.18	Log(y+1) = 0.262+0.082x	0.996
Wild	1.31 *B*	2.87 *B*	4.86 *B*	8.75 *B*	4.45	Log(y+1) = 0.159+0.069x	0.998
Green	1.29 *B*	2.84 *B*	4.87 *B*	10.03 *B*	4.76	Log(y+1) = 0.130+0.074x	0.994
Refrigerated	0.82 *C*	1.60 *C*	2.75 *C*	4.85 *C*	2.55	Log(y+1) = 0.085+0.056x	0.999
Means	1.53	3.43	5.87	10.90		CV: 7.2 %	

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$).

Papaya being a climacteric fruit, exhibits increased respiratory rate and high ethylene production, leading to common reactions to maturity, among which are the increased activity of pectin methylesterase (PME) and polygalacturonase (PG) (Hamzah et al., 2013). These hydrolytic enzymes PME and PG disturb the structural carbohydrates, leading to fruit firmness loss (Annegowda & Bhat, 2016). The softening occurs during ripening, making it the ideal fruit for consumption. However, the advance of the softening leads to a drop in the textural qualities of the fruit, including peel wrinkling or wilting.

A minimum reduction in the soluble solids was observed depending on the duration of storage. No significant variations with respect to this parameter were noted among the postharvest treatments (Table 3).

Climacteric fruit contain starch reserves in their cellular construction. When this carbohydrate is hydrolyzed it produces one of the obvious changes of ripening (Annegowda & Bhat, 2016). However, in regard to papaya starch, it occurs in no significant quantity (representing less than 1% to be hydrolyzed). This causes negligible variation in the total soluble solids during the postharvest (Gomez, Lajolo, & Cordenunsi, 2002).

Significant differences were noted for TA for the postharvest treatments, during the duration of storage ($p < 0.05$) as well as the interaction among the factors. However, a single regression equation could not be adjusted between the storage periods (Table 4).

The TA increased slightly in the postharvest treatments 'green' and 'refrigerated' at day three of storage, but did not differ significantly from each other ($p > 0.05$); however, significant differences ($p < 0.05$) were observed compared with the other postharvest treatments. As the maturing process advances it caused a slight increase in the TA that can be associated with the increased galacturonic acid content, due to the hydrolysis of pectin by enzymes like pectin methylesterase (PME) and polygalacturonase (PG) and the increased respiratory rate. These result in the production of organic acids (Annegowda & Bhat, 2016).

At the culmination of the duration of storage, the postharvest treatments 'control' and 'wild' showed high TA, differing significantly ($p < 0.05$) from the other postharvest treatments. Reduction of the TA in the end of the storage period in the postharvest treatments 'aqueous', 'green' and 'refrigerated' can be explained by the increase in the consumption of organic acids by the respiratory process and conversion to simple sugars (El-Ramady et al., 2015). Significant variations in the maturation index ratio (SS/TA) among the postharvest treatments and the duration of storage ($p < 0.05$) were found to occur in the interaction between the factors (Table 5).

Table 3. Soluble solids concentration (%) of papaya 'Solo' cv. 'Golden' coated and uncoated with propolis extract sourced from different plant origins, during storage period.

Treatments	0 day	3 days	6 days	9 days	12 days	Means	Adjusted model	R^2
Control	12.42	12.25	11.92	12.33	11.83	12.08 *A*		
Aqueous		12.17	12.75	12.67	11.50	12.27 *A*		
Wild		11.67	12.08	12.00	10.33	11.52 *A*		
Green		12.42	12.08	11.92	10.83	11.81 *A*		
Refrigerated		12.33	11.92	12.00	11.58	11.96 *A*		
Means		12.17	12.15	12.18	11.22	CV: 7.4 %	$y = 12.506-0.080x$	0.661

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$).

Table 4. Titratable acidity (%) of papaya 'Solo' cv. 'Golden' coated and uncoated with propolis extract sourced from different plant origins, during storage period.

Treatments	0 day	3 days	6 days	9 days	12 days	Means	Adjusted model	R^2
Control	0.035	0.032 *B*	0.036 *A*	0.025 *A*	0.036 *A*	0.03	*	
Aqueous		0.031 *B*	0.025 *B*	0.029 *A*	0.028 *B*	0.03	*	
Wild		0.035 *B*	0.027 *AB*	0.022 *A*	0.036 *A*	0.03	*	
Green		0.043 *A*	0.030 *AB*	0.028 *A*	0.027 *B*	0.03	*	
Refrigerated		0.048 *A*	0.032 *AB*	0.029 *A*	0.024 *B*	0.03	*	
Means		0.04	0.03	0.03	0.03	CV: 20.3 %		

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$). *Models with two dependent factors could not be fitted.

Table 5. Maturation index ratio of papaya 'Solo' cv. 'Golden' coated and uncoated with propolis extract sourced from different plant origins, during storage period.

Treatments	0 day	3 days	6 days	9 days	12 days	Means	Adjusted model	R^2
Control	367.7	399.7 *A*	342.6 *B*	500.1 *AB*	338.0 *BC*	395.1	*	
Aqueous		410.7 *A*	529.6 *A*	453.9 *B*	426.8 *AB*	455.2	$y = 357.6+37.3x-2.66x^2$	0.734
Wild		338.6 *AB*	465.2 *AB*	578.1 *A*	289.7 *C*	417.9	*	
Green		298.5 *AB*	410.4 *B*	418.3 *B*	422.4 *AB*	387.4	$y = 337.6+7.64x$	0.481
Refrigerated		266.4 *B*	370.6 *B*	391.8 *B*	487.6 *A*	379.1	$y = 348.2-17.46x+2.47x^2$	0.816
Means		342.8	423.7	468.4	392.9		CV: 20,6%	

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$). *Models with two dependent factors could not be fitted.

Variations in the maturation index ratio were seen during the storage period and among postharvest treatments. The postharvest 'refrigerated' treatment showed significant difference ($p < 0.05$) compared to postharvest treatments 'control' and 'aqueous' at three days of storage. Both postharvest treatments had higher SS/TA, due to lower TA values. This indicates that the papaya fruit postharvest treatments 'control' and 'aqueous' matured early, considered a variable maturity index (Kader, 2002).

The postharvest treatment 'wild' showed a lower maturation index ratio at twelve days of storage, and revealed no significant difference ($p > 0.05$) compared to postharvest treatment 'control'. This fact is confirmed by the drop in the SS value, resulting from the increased utilization of the fruit sugars reserves, and the increased value of TA due to the fungal proliferation.

A greater increase was observed in maturation index ratio at days six and nine of storage, and papaya postharvest treatment 'aqueous' increased this variable over storage. This implies that the climacteric peak for papaya was between the sixth and ninth day of storage, along with the threshold of maximum maturation and early senescence. The coating with the aqueous extract of propolis induced a higher metabolic activity in the fruit.

A significant difference was noted in the pH values in relation to the days of storage and interaction among the factors ($p < 0.05$); however, no significant difference was observed among the postharvest treatments ($p > 0.05$) (Table 6).

No variation was seen in the means of the pH values among the postharvest treatments, ranging from 5.60 to 5.84. Quadratic behavior was noted for the treatment 'control' with a pH rise and subsequent fall towards the culmination of the storage period. The drop in the pH values at the end of the storage period is caused by alterations in the structure of the pectins, due to the pectic enzymes, which result in fruit softening. This increase in the concentration of the organic acid produced by enzymatic hydrolysis of the pectins, could be the probable reason for the lowered pH (Azene, Workneh, & Woldetsadik, 2014). These authors propose that the tendency for the increase in the pH value observed in postharvest treatment 'green' during storage period is due to the fact that when fruit maturation continues, the organic acids decrease. Thus, coating the fruit with hydroalcoholic extract of the green rosemary type propolis may have slowed down the ripening process of the papaya. Azene et al. (2014) found that the pH of the papaya 'Solo' ranges from 5.0 to 5.8. The fruit analyzed showed pH in the range which corresponds to the results obtained by the authors.

Table 7 shows the results of the sensory analysis of papayas with and without the coating of the propolis extract sourced from different botanical origins, stored at room temperature.

At day three of storage the postharvest 'aqueous' treatment revealed a significant difference ($p < 0.05$), but when compared with the other postharvest treatments it did not differ significantly ($p > 0.05$) from the postharvest treatment 'green'. The latter showed no difference from the other postharvest treatments with a hedonic note related to the expression 'like moderately'. The tasters reported that the papaya samples coated with the aqueous and green rosemary extract of propolis showed a more intense orange color and sweeter flavor. The sweet taste perceived in the sample referred to is related to the latex disappearing, a characteristic of the green fruit (Gomez et al., 2002); it were also related to alterations in the concentrations of the phenolic compounds which enhance the flavor (Annegowda & Bhat, 2016).

At the 6th day of storage, postharvest treatment 'aqueous' showed significant difference ($p < 0.05$) compared with the other postharvest treatments, reducing the mean value under the hedonic term 'indifferent' not significantly different ($p > 0.05$) postharvest treatment 'green'. The other postharvest treatments revealed corresponding similarity between the hedonic terms 'liked slightly' and 'liked moderately'.

El-Ramady et al. (2015) stated that the coatings induce changes in the gas exchange between the product and the environment, which could trigger some reduction in the production of the volatile substances accountable for the sensory characteristics.

Table 6. Hydrogen potential of papaya 'Solo' cv. 'Golden' coated and uncoated with propolis extract sourced from different plant origins, during storage period.

Treatments	0 day	3 days	6 days	9 days	12 days	Means	Adjusted model	R^2
Control	5.52	5.74 A	5.80 A	5.88 A	5.60 A	5.76	$y = 5.512 + 0.102x - 0.008x^2$	0.899
Aqueous		5.52 A	5.60 A	5.89 A	5.69 A	5.68	*	
Wild		5.50 A	5.76 A	5.77 A	5.67 A	5.67	$y = 5.530+0.019x$	0.492
Green		5.67 A	5.64 A	5.73 A	5.79 A	5.71	$y = 5.555+0.019x$	0.860
Refrigerated		5.58 A	5.63 A	5.91 A	5.76 A	5.72	$y = 5.522+0.027x$	0.675
Means		5.60	5.69	5.84	5.70	CV: 3 %		

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$). *Models with two dependent factors could not be fitted.

Table 7. Assessment grades for the sensory characteristics of papaya 'Solo' cv. 'Golden' coated and uncoated with propolis extract sourced from different botanical origins.

Treatments	Storage days	
	3 days	6 days
Control	6.721 *B*	7.033 *A*
Aqueous	7.525 *A*	5.967 *B*
Wild	6.574 *B*	6.836 *A*
Green	7.147 *AB*	6.525 *AB*
Refrigerated	6.688 *B*	6.852 *A*
Means	6.931	6.642

Letters in the columns indicate the significant differences among the postharvest treatments (SNK test, $p < 0.05$).

Conclusion

The postharvest treatments 'wild' and 'green' resulted in lowest weight loss and increased firmness of papaya during 20 days of storage at room temperature. The coatings with propolis extract did not interfere on contents of SS. Coating with hydroalcoholic extract of green rosemary type propolis had a positive influence on the TA variables, maturation index ratio and pH of papaya. Also, fruit coated with hydroalcoholic extract of green rosemary type propolis resulted in satisfactory sensory characteristics. The coating with hydroalcoholic extract of green rosemary type propolis can limit the preservation costs incurred in papaya storing.

Acknowledgements

To *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq - Brazilian Ministry of Education) for granting the research fellowships, and Natucentro to the supply of propolis extracts for the research.

References

Ali, A., Cheong, C. K., & Zahid, N. (2014). Composite effect of propolis and gum arabic to control postharvest anthracnose and maintain quality of papaya during storage. *International Journal of Agriculture & Biology, 16*(6), 1117-1122.

Ali, A., Muhammad, M. T. M., Sijam, K., & Siddiqui, Y. (2011). Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. *Food Chemistry, 124*(2), 620-626.

Ali, A., Pheng, T. W., & Mustafa, M. A. (2015). Application of lemongrass oil in vapour phase for the effective control of anthracnose of 'Sekaki' papaya. *Journal of Applied Microbiology, 118*(6), 1456-1464.

Annegowda, H. V., & Bhat, R. (2016). Composition of papaya fruit and papaya cultivars. In M. S. J. Simmonds, & R. P. Preedy (Eds.), *Nutritional composition of fruit cultivars* (p. 497-516). Salt Lake, UT: Academic Press.

Association of Official Analytical Chemists [AOAC]. (2012). *Official methods of analysis* (19nd ed.). Arlington, TX: AOAC.

Azene, M., Workneh, T. S., & Woldetsadik, K. (2014). Effect of packaging materials and storage environment on postharvest quality of papaya fruit. *Journal of Food Science and Technology, 51*(6), 1041-1055.

Bankova, V. (2005). Recent trends and important developments in propolis research. *Evidence-Based Complementary and Alternative Medicine, 2*(1), 29-32.

Bosquez-Molina, E., Jesús, E. R., Bautista-Baños, S., Verde-Calvo, J. R., & Morales-López, J. (2010). Inhibitory effect of essential oils against *Colletotrichum gloeosporioides* and *Rhizopus stolonifer* in stored papaya fruit and their possible application in coatings. *Postharvest Biology and Technology, 57*(2), 132-137.

El-Ramady, H. R., Domokos-Szabolcsy, E., Abdalla, N. A., Taha, H. S., & Fári, M. (2015). Postharvest management of fruits and vegetables storage. In E. Lichtfouse (Ed.), *Sustainable agriculture reviews* (p. 65-152). New York City, NY: Springer International Publishing.

Gomez, M. L. P. A., Lajolo, F. M., & Cordenunsi, B. R. (2002). Evolution of soluble sugars during ripening of papaya fruit and its relation to sweet taste. *Journal of Food Science, 67*(1), 442-447.

Hamzah, H. M., Osman, A., Tan, C. P., & Ghazali, F. M. (2013). Carrageenan as an alternative coating for papaya (*Carica papaya* L. cv. Eksotika). *Postharvest Biology and Technology, 75*(1), 142-146.

Kader, A. A. (2002). *Postharvest technology of horticultural crops* (3nd ed.). Oakland, CA: University of California.

Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: principles and practices* (2nd ed.). New York City, NY: Springer.

Madani, B., Mirshekari, A., & Yahia, E. (2015). Effect of calcium chloride treatments on calcium content, anthracnose severity and antioxidant activity in papaya fruit during ambient storage. *Journal of the Science of Food and Agriculture, 16*(1), 1-6.

Martins, D. R., Barbosa, N. C., & Resende, E. D. (2014). Respiration rate of Golden papaya stored under refrigeration and with different controlled atmospheres. *Scientia Agricola, 71*(5), 345-355.

Mattiuz, B. H., Ducamp-Collin, M. N., Mattiuz, C. F. M., Vigneault, C., Marques, K. M., Sagoua, W., & Montet, D. (2015). Effect of propolis on postharvest control of anthracnose and quality parameters of 'Kent' mango. *Scientia Horticulturae, 184*(1), 160-168.

Ong, M. K., Forney, C. F., Alderson, P. G., & Ali, A. (2013). Postharvest profile of a Solo variety 'Frangi' during ripening at ambient temperature. *Scientia Horticulturae, 160*(1), 12-19.

Park, Y. K., Paredes-Guzman, J. F., Aguiar, C. L., Alencar, S. M., & Fujiwara, F. Y. (2004). Chemical constituents in *Baccharis dracunculifolia* as the main botanical origin of southeastern Brasilian propolis. *Journal of Agricultural and Food Chemistry, 52*(5), 1100-1103.

Paull, R. E., & Chen, N. J. (1989). Waxing and plastic wraps influence water loss from papaya fruit during storage and ripening. *Journal of the American Society for Horticultural Science, 114*(1), 937-942.

Sánchez-González, L., Cháfer, M., Hernández, M., Chiralt, A., & González-Martínez, C. (2011). Antimicrobial activity of polysaccharide films containing essential oils. *Food Control, 22*(8), 1302-1310.

Silva, D. A., Oliveira, J. K., Santos, C. M., Bery, C. C. S., Castro, A. A., & Santos, J. A. B. (2014). The use of sodium alginate-based coating and cellulose acetate in papaya post-harvest preservation. *Acta Scientiarum. Technology, 36*(3), 569-573.

Torlak, E., & Sert, D. (2013). Antibacterial effectiveness of chitosan–propolis coated polypropylene films against foodborne pathogens. *International Journal of Biological Macromolecules, 60*(1), 52-55.

Zahid, N., Ali, A., Siddiqui, Y., & Maqbool, M. (2013). Efficacy of ethanolic extract of propolis in maintaining postharvest quality of dragon fruit during storage. *Postharvest Biology and Technology, 79*(1), 69-72.

Received on February 23, 2016.
Accepted on August 18, 2016.