

Nutraceutical coating composition for postharvest conservation of 'Paluma' guava

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Abstract

This work assesses the influence of edible coating with nutraceutical properties on post-harvest conservation of guavas 'Paluma'. The experiment comprised of a completely randomized design with four replicates and three fruits per plot. Six treatments were applied combining different concentrations of agar and pomegranate seed oil (PS): T1: 1% agar and 0.1 mL/L PS oil; T2: 2% agar and 0.2 mL L⁻¹ PS oil; T3: 3% agar and 0.3 mL L⁻¹ PS oil; T4: 4% agar and 0.4 mL L⁻¹ oil; T5: 5% agar and 0.5 mL L⁻¹ oil; and T6: control (fruits without coating). After the immersion in treatment solutions, the guavas remained stored in an air-conditioned room for ten days at 10 °C and 40% RH. Fruits without coating (control) ripened faster than coated ones, so the treatments preserved fruit coloration. The treatments T4 and T5 provided the best preservation of peel color, suggesting slower ripening and maintenance of fruit quality, as their colors tended to green and opaque. The firmness of fruits without coating was decreased by 35.15% concerning the coated ones. Treatments T4 and T5 had the lowest loss of fresh mass. On the other hand, T5 showed the lowest soluble solids contents (SS)(13.46%). Titratable acidity (TA), SS/TA ratio, total sugars, and carotenoids were not affected by treatments. The edible coating with 4% of agar plus 0.4 mL L⁻¹ of pomegranate seed oil promoted the best quality traits for the post-harvest preservation of the guavas 'Paluma'.

Keywords: Conservation, *Psidium guajava* L., *Punica granatum* L., edible coating, refrigeration.

Introduction

Guava stands out among Brazilian tropical fruits due to its unmistakable aroma, unique flavor, and high nutritional value. The guava from 'Paluma' cultivar is a climacteric fruit having high rates of transpiration and loss of mass, resulting in short shelf life (Pereira et al., 2005).

Edible coatings are modern technologies used in fruit conservation, which are being propagated and analyzed as a viable means to increase the time and quality of life of fruits. They contribute significantly to the preservation of appearance, maintaining the nutritional value, and protecting against external factors (Assis and Britto, 2014).

The agar, also known as agar-agar, is a hydrocolloid extracted from several genera and species of red algae of the Rhodophyta class. This gelatin is composed of two polysaccharides (agarose and agarpectin), with about 80% of fiber. It is widely used as a basis for diets due to its satiety effect, helping to decrease the consumption of foods, and its laxative effect (Fani, 2017). In turn, pomegranate seed oil can be used as a source of substances with nutraceutical

value (Caligiani et al., 2010). This oil has high antioxidant, anticancer, and anti-lipidemic properties, which make it a supplementary compound bringing health benefits (Elfalleh et al., 2011).

The objective was to evaluate the postharvest conservation of 'Paluma' guava with different edible coatings based on pomegranate seeds and agar.

Results and Discussion

Consumers are very strict about the quality of the products they consume, and appearance comprises a relevant factor in the purchase being considered an essential attribute of quality because it affects consumer's first impression of the food. Appearance involves size, shape, texture, mass, among other features. Table 1 shows the initial characterization of guava 'Paluma' fruits used in our experiment. The fruits were in excellent condition and were considered suitable for marketing.

Coloring

After the storage period, the luminance index L^* of peels differed among the treatments. The fruits of control treatment had an average of 69.15, which were superior to the fruits treated with coatings, indicating that the fruits without coatings were shinier than the coated ones. The opacity of the fruits increased with the concentration of the coatings (Table 2). Chromaticity index C^* differed among treatments. The control fruits presented higher values (46.94) than the other treatments. The T5 treatment obtained the lowest values (39.56), followed by T4 (42.01), indicating little variation in the color intensity of the fruit peels after storage (Table 2). The fruits of the T5 treatment showed a small reduction in the θ_h index compared to the values in the initial characterization, with an average of 107.94, indicating a yellow-green coloration. On the other hand, the control fruits had the lowest mean (93.32), representing the yellow coloration typical from fruits in the stage of advanced maturation (Table 2). The brightness indexes L^* , chromaticity C^* , and angle hue (θ_h) of the pulp did not differ statistically among treatments, suggesting that the concentrations of agar and oil of the pomegranate seed do not affect these variables (Table 2).

Fresh mass loss

The fruits without coating had a higher loss of fresh mass, presenting an average of 16.71%, a higher value than the coated fruits. This result implies greater respiration in fruits without coatings, losing more water, which was reflected in the weight of the fresh mass. The T4 treatment showed lower loss of fresh mass than the other treatments (8.06%), suggesting that this treatment may have affected respiratory activity, reducing fruit evapotranspiration (Table 3). According to Forato et al. (2015), which evaluated the quality of fresh and cut guavas coated with cashew gum and carboxymethylcellulose coating, the samples without coating have faster degradation, whereas the covered fruits guarantee a smaller loss of fresh mass, improving conservation.

Firmness of the fruits

The fruits of T5 treatment obtained better conservation of the firmness (33.72 N), which indicates that these fruits had a less advanced maturation than the others. The fruits without coating had the lowest values, 16.79 N on average (Table 3). According to Bessa et al. (2015), studying the effect of starch and starch/zeolite coatings applied to guava preservation, firmness decreases more markedly in uncoated fruits, while the coatings contribute to maintaining firmness over time.

Fruit Appearance

The results concerning the subjective visual grading scale (Table 5) are based on the color of the fruit peel and pulp. The treatments T4 and T5 did not differ statistically from each other, and showed the best averages for the external and internal appearance, indicating green to beginning of yellowing peels and beginning of pink pulps. The remaining treatments presented higher values, indicating that the fruits were more yellowish, in a stage of more advanced

maturation. This difference suggests that the coating as a viable alternative in maintaining the post-harvest quality of guavas.

Soluble solids (SS)

The soluble solids content (SS) decreased as the coating concentration increased. The control treatment obtained the lowest mean (Table 4). According to Onias et al. (2018), in a paper about the effect of *Spirulina platensis* biodegradable coating on the post-harvest conservation of guava 'Paluma', the soluble solids contents decrease during storage. The control group also showed the lowest mean in the experiment of these authors.

Titratable acidity (TA)

The coated fruits had the highest values of titratable acidity (TA), ranging from 0.92 to 0.81, while the control had the lowest average (0.75). According to Aquino et al. (2015), guavas coated with cassava starch and chitosan showed the highest values of titratable acidity compared to uncoated guavas.

Ratio (SS/AT)

The SS/TA ratio did not differ among treatments, ranging from 16.88 to 20.58, but was higher than the initial characterization (11.60). A high SS/TA ratio is desirable for the marketing of fresh and processed fruits because it indicates the consumer's receptivity to fruit flavor (Manica et al., 2001).

Hydrogen potential (pH)

There was little oscillation in the pH variable. The fruits had average values between 3.35 and 3.87. Onias et al. (2018) observed that the pH values of guavas 'Paluma' coated with a biodegradable coating based on *Spirulina platensis* also had a small variation in pH, ranging from 3.80 to 4.0. The pH influences oxidative darkening of plant tissues. Its decrease leads to a reduction in the darkening speed of the fruit (Freitas, 2010).

Ascorbic acid content

The ascorbic acid content of guavas after storage (55.20% to 95.73%) was higher than in the initial characterization (45.92%). The coatings may have affected the ascorbic acid content, but this acid may also be influenced by several factors such as variety, saturation, growth media, season and acidity (Costa et al., 2010). Thus, this difference may be the result of the choice of the fruits used in the experiment.

Total sugars and carotenoids

The analysis of total sugars of the initial characterization obtained a mean of 12.01 mg 100 g⁻¹, while the treatments did not differ statistically, ranging from 8.93 mg 100 g⁻¹ to 12.58 mg 100 g⁻¹. The carotenoid values of the treatments also did not differ among treatments and ranged from 0.74

Table 1. Initial characterization of guava 'Paluma' fruits, peel and pulp color analysis, titratable acidity (TA), pH, soluble solids (SS), SS/TA ratio, firmness, external and internal appearance, carotenoids, and total sugars.

Color	Mean ± SD
Peel	
L*	59.69 ± 3.86
C*	41.56 ± 2.65
°h	110.71 ± 2.47
Pulp	
L*	61.49 ± 2.87
C*	32.70 ± 2.17
°h	35.36 ± 3.18
Physical-Chemical Characteristics	
Titratable Acidity (% Citric Acid)	0.93 ± 0.20
pH	3.62 ± 0.01
SS (SS %)	12.19 ± 1.25
SS/TA ratio	11.60 ± 2.28
Ascorbic Acid (% Ascorbic Acid)	45.92 ± 14.18
Firmness (N)	61.62 ± 28.73
External Appearance	2 ± 0
Internal Appearance	2 ± 0
Carotenoids (mg 100 g ⁻¹)	0.99 ± 0.42
Total Sugars (mg 100 g ⁻¹)	10.58 ± 2.97

Table 2. Color variables (h°, C*, L*) of guava 'Paluma' peel and pulp treated with edible coatings.

Coatings*	Peel			Pulp		
	°h	C*	L*	°h	C*	L*
T1	100.56 c	46.49 ab	65.91 ab	35.03 a	37.44 a	59.91 a
T2	99.94 c	44.12 abc	65.26 ab	36.89 a	39.47 a	58.88 a
T3	101.67 bc	45.98 ab	65.23 ab	37.51 a	38.07 a	59.71 a
T4	106.32 ab	42.01 bc	61.21 bc	36.89 a	36.66 a	60.83 a
T5	107.94 a	39.56 c	58.28 c	36.55 a	38.32 a	58.59 a
T6	93.32 d	46.94 a	69.15 a	36.91 a	40.05 a	57.34 a
Mean	101.63	44.18	64.17	36.63	38.34	59.21
CV(%)	2.45	4.69	4.22	4.54	4.33	2.70

*Means followed by the same letter in the column do not differ statistically according to the Tukey test at the 5% probability level. T1: 1% agar and 0.1 mL/L oil; T2: 2% agar and 0.2 mL/L oil; T3: 3% agar and 0.3 mL/L oil; T4: 4% agar and 0.4 mL/L oil; T5: 5% agar and 0.5 mL/L oil; and T6: control (fruits without coating).

Table 3. pH, fruit firmness, loss of fresh mass (LFM), and vitamin C of guava 'Paluma' treated with edible coatings.

Coatings*	pH	Firmness (N)	LFM (%)	Vit. C (mg.100 ⁻¹)
T1	3.74 a	22.81 ab	16.02 a	95.40 a
T2	3.78 a	19.97 b	11.65 b	86.88 a
T3	3.66 a	23.63 ab	11.33 b	81.00 a
T4	3.35 b	29.33 ab	8.06 c	84.00 a
T5	3.57 ab	33.72 a	9.11 bc	55.20 b
T6	3.87 a	16.79 b	16.71a	95.73 a
Mean	3.66	24.37	12.15	83.03
CV(%)	3.72	24.73	9.84	13.78

*Means followed by the same letter in the column do not differ statistically according to the Tukey test at the 5% probability level. T1: 1% agar and 0.1 mL/L oil; T2: 2% agar and 0.2 mL/L oil; T3: 3% agar and 0.3 mL/L oil; T4: 4% agar and 0.4 mL/L oil; T5: 5% agar and 0.5 mL/L oil; and T6: control (fruits without coating).

Table 4. Soluble solids (SS), titratable acidity (TA), SS/TA, total sugars (TS), and carotenoids guava 'Paluma' treated with edible coatings.

Coatings*	SS	TA	SS/TA	TS (mg/100g)	Carotenoids (mg/100g)
T1	16.89 a	0.92 a	18.27 a	12.58 a	1.22 a
T2	16.29 ab	0.86 a	19.38 a	11.61 a	1.12 a
T3	15.47 abc	0.76 a	20.58 a	10.65 a	1.13 a
T4	15.05 abc	0.84 a	18.12 a	10.51 a	1.03 a
T5	13.46 bc	0.81 a	16.88 a	10.11 a	1.08 a
T6	13.25 c	0.75 a	17.77 a	8.93 a	0.74 a
Mean	15.07	0.82	18.49	10.73	1.05
CV(%)	8.96	14.27	13.63	17.62	31.07

*Means followed by the same letter in the column do not differ statistically according to the Tukey test at the 5% probability level. T1: 1% agar and 0.1 mL/L oil; T2: 2% agar and 0.2 mL/L oil; T3: 3% agar and 0.3 mL/L oil; T4: 4% agar and 0.4 mL/L oil; T5: 5% agar and 0.5 mL/L oil; and T6: control (fruits without coating).

Table 5. External appearance (EAP) and Internal appearance (IAP) of guava 'Paluma' treated with edible coatings.

Coatings*	EAP	IAP
T1	5.48 a	5.48 a
T2	5.39 a	5.62 a
T3	4.75 b	4.75 b
T4	3.50 c	3.75 c
T5	3.25 c	3.25 c
T6	5.69 a	5.69 a
Mean	4.68	4.75
CV(%)	5.48	4.90

*Means followed by the same letter in the column do not differ statistically according to the Tukey test at the 5% probability level. T1: 1% agar and 0.1 mL/L oil; T2: 2% agar and 0.2 mL/L oil; T3: 3% agar and 0.3 mL/L oil; T4: 4% agar and 0.4 mL/L oil; T5: 5% agar and 0.5 mL/L oil; and T6: control (fruits without coating).

mg 100 g⁻¹ to 1.22 mg 100 g⁻¹, which are close to the content found in the initial characterization.

Materials and methods

The fruits were collected in a four years old orchard, located in the Várzeas de Sousa, Paraíba, Brazil. Guavas from 'Paluma' cultivar were harvested manually early in the morning. A first selection in the field eliminated the fruits with injuries. Afterward, the fruits were transported to the Post-harvest Technology Laboratory at the Federal University of Campina Grande, Pombal-PB campus, where the selection for color and size uniformity was performed. The fruits were washed with 1% neutral detergent solution and, after rinsing, sanitized with sodium hypochlorite solution at 100 ppm chlorine for fifteen minutes and dried in the open air.

The experiment was carried out in a completely randomized design with four replicates and three fruits per plot. The treatments (T) comprised different formulations of agar and pomegranate seed oil, as follows: T1: 1% of agar and 0.1 mL/L of oil; T2: 2% of agar and 0.2 mL/L of oil; T3: 3% agar and 0.3 mL/L oil; T4: 4% agar and 0.4 mL/L oil; T5: 5% agar and 0.5 mL/L oil; and T6: Control (without coating).

The coatings were prepared from the complete dilution of the agar Culinary (Vovó Nize) concentrations in water at 70°C under constant stirring. After cooling the solutions to 30°C, the pomegranate seed oil was added, also under continuous stirring. The fruits were immersed in their due treatments for 15 seconds. After drying in the open air, the fruits were placed in styrofoam trays and stored in an air-conditioned room at 10°C and 40% RH for ten days.

After storage, the following characteristics were analyzed in each fruit. Color of the peel and pulp was measured in the L*,a*,b* system by reflectometry using a colorimeter (Konica Minolta, model Chroma Meter CR-400). The calibration of the instrument was performed on a standard whiteboard, following the manufacturer's instructions. The color parameters measured with respect to the standard plate were: luminosity (L*), which varies from black (0) to white (100); a*, which varies from green (-60) to red (+60); and b*, ranging from blue (-60) to yellow (+60). From the values L*, a*, b*, the hue angle was calculated, with $^{\circ}h = \arctan(a*/b*)(-1)+90$ for a negative a* and $^{\circ}h = 90 - \arctan(a*/b*)$ for a positive a*, and the chroma saturation index, C*, $(C* = a^{*2} + b^{*2})^{1/2}$.

The loss of mass (%) was measured by gravimetry using the difference between the initial weight of the fruit and that obtained after storage, and the results were expressed as a percentage. The firmness of the pulp (N) was obtained using

a digital penetrometer (Instrutherm, model PTR-300), with two samplings in the equatorial region of the fruit, after removal of the peel with an 8 mm blade according to AOAC (2006).

The external and internal appearance was measured through a subjective visual scale of notes based on the color of the peel and the pulp, with the cooperation of three volunteer evaluators. The following scale was adopted for peel: 1 - totally green; 2 - transition from green to the beginning of pigmentation; 3 - beginning of yellow pigmentation; 4 - predominant green pigmentation with yellow traces; 5 - predominant yellow pigmentation with green traces; 6 - predominant yellow; 7 - yellow with advanced maturation, sign of senescence. For the pulp, the same scale was used but varying to red, which is typical of the 'Paluma' cultivar (Venceslau, 2014).

The following parameters were analyzed in the juice homogenized by the processing of the fruits in a domestic blender. Soluble solids (SS; %) were determined by direct reading with a digital refractometer brand Digital Refractometer (AOAC, 2006). The titratable acidity (TA; % citric acid) was measured taking 1 mL of juice diluted in 50 mL of distilled water, plus two drops of the 1% phenolphthalein indicator, and titrating with NaOH at 0.1 M (Ial, 2008). The ratio between the two variables provided the SS/TA ratio. The pH was obtained by direct reading in the juice with a digital bench pHmeter (Digimed DM-22) (Ial, 2008). The ascorbic acid content (% ascorbic acid) was measured by stirring 1 ml of diluted juice in 49 ml of oxalic acid, and titrating with DCPIP solution according to the method of Tillmans (AOAC, 2006).

The total sugars (mg/100g) were obtained through of anthrone method by diluting 0.2 g of guava in 100 mL of distilled water. From this solution, a 0.15 mL aliquot was taken in a tube along with 0.85 mL of water and adding 2 mL of anthrone reagent under stirring. The solution was kept in a water bath at 100°C for 5 minutes. After cooling, the readings were done in a spectrophotometer at the wavelength of 620 nm (Yemm & Willis, 1954). Carotenoids (mg/100g) were determined by maceration of 0.2 g of guava and adding 0.2 g of calcium carbonate and 5 ml of 80% acetone. The solution was centrifuged for 10 minutes at 3000 rpm. The reading was carried out using the supernatant in a spectrophotometer at three wavelengths (470 nm, 663 nm, and 646 nm) (Lichtenthaler, 1987).

The data were analyzed through analysis of variance (F test) and Tukey's test at the 5% probability level using SISVAR software version 5.6 (Ferreira, 2011).

Conclusion

The edible coating produced with agar at 4% and pomegranate seed oil at 0.4 mL/L provided the best quality characteristics for post-harvest preservation of guava 'Paluma' after ten days of storage at 10 °C and 40% RH.

References

- Aoac, Association of Official Analytical Chemists (2006) Official methods of Analysis. 18 ed. Washington DC USA.
- Aquino AB, Blank AF, De Aquino Santana LCL (2015) Impact of edible chitosan–cassava starch coatings enriched with *Lippia gracilis* Schauer genotype mixtures on the shelf life of guavas (*Psidium guajava* L.) during storage at room temperature. *Food Chem.* 171: 108-116.
- Assis OBG, Britto D (2014) Revisão: Coberturas comestíveis protetoras em frutas: fundamentos e aplicações. *Braz J Food Technol.* 87-97.
- Bessa RA, de Oliveira LH, Arraes DD, Batista ES, Nogueira DH, Silva MS, Loiola AR (2015) Filmes de amido e de amido/zeólita aplicados no recobrimento e conservação de goiaba (*Psidium guajava*). *Rer Virtual Quim.* 7(6): 2190-2201.
- Caligiani A, Bonzanini F, Palla G, Cirlini M, Bruni R (2010) Characterization of a potential nutraceutical ingredient. Pomegranate (*Punica granatum* L.) seed oil unsaponifiable fraction. *Plant Foods Hum Nutr.* 65: 277-283.
- Costa FB, Menezes JB, Alves RE, Nunes GHS, Maracajá PB (2010) Armazenamento refrigerado do mamão Havaí 'Golden' produzido na Chapada do Apodi–RN-Brasil. *Rev Verde Agroec Desenvol Sust.* 5(4): 37-54.
- Elfalleh W, Ying M, Nasri N, Sheng-Hua H, Guasmi F, Ferchichi A (2011) Fatty acids from Tunisian and Chinese pomegranate (*Punica granatum* L.) seeds. *Int J Food Sci Nutr.* 62(3): 200-206.
- Fani M (2017) Ágar: Geletificante Natural Com Múltiplas Aplicações. *Rev Food Ingreds Br.* 19(41).
- Ferreira DF (2011) Sisvar: um sistema computacional de análise estatística. *Ciênc Agrotec.* 35(6): 1039-1042.
- Forato LA, de Britto D, de Rizzo JS, Gastaldi TA, Assis OB (2015) Effect of cashew gum-carboxymethylcellulose edible coatings in extending the shelf-life of fresh and cut guavas. *Food Packaging Shelf.* 5: 68-74.
- Freitas IR (2010) Goma xantana como carreadora de solução conservadora e cloreto de cálcio aplicado à maçã minimamente processada. Monografia (Especialização em Ciência dos Alimentos). Universidade Federal de Pelotas, Pelotas, Brasil.
- Ial (2008) Normas Analíticas do Instituto Adolfo Lutz: Métodos físico-químicos para análise de alimentos. Disponível em: < <http://www.ial.sp.gov.br> > Acesso em 20 mar 2018.
- Lichtenthaler HK (1987) Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. In: *Methods in Enzymology.* Academic Press. 34: 350-382.
- Manica I, Icumá IM, Junqueira NTV, Salvador JO, Moreira A, Malavolta E (2001) Goiaba: do plantio ao consumidor. Porto Alegre: Cinco Continentes, 32.
- Onias EA, Teodosio AEM, Bomfim MP, Rocha RHC, Lima JF, de Medeiros, ML (2018) Revestimento biodegradável à base de *Spirulina platensis* na conservação pós-colheita de goiaba 'Paluma' mantida sob diferentes temperaturas de armazenamento. *Rev Cienc Agrár.* 41(3): 281-290.
- Pereira T, Carlos LA, Oliveira JG, Monteiro AR (2005) Chemical composition and physical characteristics of guava cv. Cortibel (*Psidium guajava*) stored at 8°C and packed with X-tend film. *Alim Nutr.* 16(1): 11-16.
- Venceslau WCD (2013) Maturação, conservação e capacidade antioxidante em goiabas 'Paluma'. Dissertação (Mestrado em Sistemas Agroindustriais). Universidade Federal de Campina Grande, Centro de Ciências e Tecnologia Agroalimentar. 2(1): 151.
- Yemn EW, Willis AJ (1954) The estimation of carbohydrate in plant extracts by antrone. *The Biochem J.* 57(3): 504–514.