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Functional potential and food safety of fresh-cut 'Paluma' guava under edible coatings

Potencial funcional e segurança alimentar de goiaba 'Paluma' minimamente processada sob recobrimentos comestíveis

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Highlights

Coating with chitosan (Q) maintained the bioactive compounds in guava slices.
Antioxidant activity (TAA) was superior when coated with Q, $CaCl_2$ (CC) and CC + Q.
Slices coated with Q were those with safe microbial counts.
Slices with Q have higher TAA than control and are microbiologically safe.

Abstract

Guava is a fruit rich in antioxidants and its value can be enhanced by fresh-cut processing, which increases convenience for consumption. The objective of this study was to evaluate the changes in bioactive compounds, total antioxidant activity (TAA) and microbial quality in slices of fresh-cut (FC) 'Paluma' guava coated with chitosan at 2% (Q), calcium chloride at 1% (CC), calcium chloride at 1% + sodium alginate at 1% (CC + A), calcium chloride at 1% + chitosan at 2% (CC + Q), and control (T - without coating). Coated slices were packed in trays, wrapped with PVC film and kept at 3 ± 1 °C and 75 ± 4% RH for 12 days and evaluated for ascorbic acid, lycopene, β-carotene, total extractable polyphenols (TEP), and TAA by $ABTS^{+-}$ and DPPH . Ascorbic acid content of slices did not differ by coatings, but TEP was higher in slices coated with Q. The TAA by DPPH was higher in slices coated with Q, however, by $ABTS^{+-}$ it was higher in those coated with Q, CC and CC + Q. No thermotolerant coliforms or *Salmonella* were detected in FC guava from

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any treatment. However, slices coated with Q showed the lowest counts of total coliforms and molds and yeasts. Therefore, the application of Q coating provided microbiological safety to FC guava, still maintaining the levels of bioactive compounds and TAA superior to the control slices, which can characterize this as a healthy FC product, with superior functional potential.
Key words: Modified Atmosphere. $ABTS^{+-}$. β-carotene. DPPH. Lycopene. PET. Sodium alginate. Microbial quality.

Resumo

Goiaba é um fruto rico em antioxidantes e pode ser potencializado pelo processamento mínimo, que aumenta a conveniência ao consumo. Assim, o objetivo deste trabalho foi avaliar as mudanças nos compostos bioativos, atividade antioxidante total (AAT) e qualidade microbiológica de goiaba 'Paluma' minimamente processada (MP) em fatias e recobertas com quitosana a 2% (Q), cloreto de cálcio a 1% (CC), cloreto de cálcio a 1% + alginato de sódio a 1% (CC + A), cloreto de cálcio a 1% + quitosana a 2% (CC+Q) e testemunha (T - sem recobrimento). Fatias recobertas foram embaladas em bandeja com filme de PVC de 12 µm e mantidas a 3±1 °C e 80±4% U.R durante 12 dias. As avaliações foram ácido ascórbico (AA), licopeno, β-caroteno, polifenóis extraíveis totais (PET) e atividade antioxidante total (AAT) pelos métodos $ABTS^{+-}$ e DPPH. O conteúdo de AA das fatias não diferiu entre recobrimentos, mas o de PET foi superior nas recobertas com Q. A AAT pelo DPPH foi superior em fatias recobertas com Q, entretanto, pelo $ABTS^{+-}$ foi superior nas recobertas com Q, CC e CC + Q. Não foi detectado coliformes termotolerantes nem *Salmonella* em goiaba MP de nenhum tratamento. Fatias recobertas com Q apresentaram contagens mais baixas de coliformes e bolores e leveduras. Portanto, a aplicação dos recobrimentos Q conferiu segurança microbiológica à goiaba MP, ainda mantendo os teores de compostos bioativos e TAA superiores às fatias controle, o que pode caracterizar este como um produto MP saudável, com potencial funcional superior.
Palavras-chave: Atmosfera modificada. $ABTS^{+-}$. Alginato de sódio. β-caroteno. DPPH. Licopeno. PET. qualidade microbiológica.

Introduction

Guava, belonging to the genus *Psidium* of the family Myrtaceae, is one of the most important fruit trees, and its fruit is an excellent source of nutrients and natural antioxidants (Flores, Wu, Negrin, & Kennelly, 2015). Guava is consumed mainly fresh for its excellent aroma and flavor and for being rich in lycopene (Amorim et al., 2020). Found in tropical and subtropical regions, the planting of this fruit tree has been expanded due to favorable climatic conditions (Almulaiky, Zeyadi, Saleh, & Baothman, 2018).

Fresh-cut processing brings convenience to the consumer, providing nutrients and antioxidant compounds for the diet, and can add value to a widely appreciated fruit such as guava. However, the fresh-cut operations cause stresses that increase the metabolic rate (Kalia & Parshad, 2015). This can result in losses of nutrients (eg sugars) and bioactive compounds (phenolic compounds, carotenoids, vitamins), in addition to undesirable changes in flavor, softening of the pulp, damage to tissues, release of intracellular compounds and contamination by microorganisms during manipulation and processing operation, and also to darkening

due to the oxidation of phenolic compounds and yellowing due to the loss of chlorophyll. Thus, some preservation technologies have been explored with a view to extending the shelf life, ensuring safety and maintaining the quality of products (Chumyam, Faiyue, & Saengnil, 2019; Fan, Zhang, & Jiang, 2019).

The use of modified atmosphere (MA) by flexible films for fresh-cut products (FC) is basic for maintaining quality (Fan et al., 2019; Russo et al., 2012). However, more recently MA has been associated with a wide variety of edible coatings for FC products (Kalia & Parshad, 2015; Yong & Liu, 2021). Edible coatings also modifies the atmosphere by acting as a direct physical barriers in FC products that interfere with their physiology, delaying loss of quality (Salvia-Trujillo, Rojas-Graü, Soliva-Fortuny, & Martín-Belloso, 2015) and providing food safety (Yong & Liu, 2021).

Chitosan is non-toxic, biocompatible and biodegradable and widely applied as a type of antibacterial agent. Thus, it has been used for coating various fruits to reduce the rate of quality deterioration (Tian et al., 2019). Chitosan combined with calcium chloride maintained the quality of FC melon, stabilizing the nanostructure of pectins (Chong, Lai, & Yang, 2015). In turn, alginate has been used successfully to coat FC fruits due to its non-toxicity, biodegradability, biocompatibility and low cost characteristics (Tavassoli-Kafrani, Shekarchizadeh, & Masoudpour-Behabadi, 2016).

Taking into account the functional potential of guava, the increased demand for FC products and the beneficial effects of edible coatings in maintaining quality, the present study aimed to evaluate changes in bioactive compounds, antioxidant activity and the microbiological quality of 'Paluma' guava FC into slices, kept under coatings based on chitosan and calcium chloride, and packed in expanded polystyrene trays, wrapped with PVC film for further atmosphere modification.

Material and Methods

Fruits of Paluma guava (*Psidium guajava* L.) cultivar were harvested early in the morning from a commercial orchard located at Nova Floresta - PB, Brazil. In the laboratory, fruits were washed with tap water and kept at room condition (24 ± 2 °C and 78 ± 3% RH), until reaching the mature green maturity stage (light green skin color) and pulp firmness corresponding to 15 ± 2N. The day before the fresh-cut (FC) operations, fruit were selected by size, maturity, uniformity and absence of defects, washed with 100 ppm sodium hypochlorite solution, dried in air and kept overnight at 10 °C.

The FC operations were carried out at 10 °C under Good Handling Practices. Fruit were washed with a 50 ppm sodium hypochlorite solution in cold distilled water and following cut transversely in relation to the main axis, in 10 mm thick slices (disc-pieces), rinsed with 50 ppm sodium hypochlorite distilled water solution and left to cold air dry. For coating, guava slices were dipped for 1 min in the coating solutions.

After drying, the slices were treated as following described: 1) Chitosan at 2% (w/v) (Q) - the coating solution was prepared by diluting Q in acetic acid (1%) and homogenized in distilled water for 120 min until complete dissolution, followed by adding glycerol (1% - w/v) after dilution; 2) Calcium Chloride ($CaCl_2$) at 1% (CC) - prepared by dissolving $CaCl_2$ (w/v) in distilled water; 3) $CaCl_2$ at 1% + Q at 2% (CC + Q) - slices were immersed in CC solution for

1 min and then in Q for 1 more min; To prepare the sodium alginate (A) solution (w/v), glycerol (0.5 g glycerol/g sodium alginate) was initially solubilized in 500 mL distilled water by heating with stirring to 70 °C and then the A (1%) was added, followed by cooling to 15 °C. 4) CC (1%) plus A (1%) (CC + A) - slices were first immersed in CC solution (1%) for 1 min and then in A for 1 more min to promote gelling, and 5) the control (T) slices without coating. Following, slices of all coatings were left to cold air dry.

For fresh-cut guava slices from each coating treatment, approximately 250 g were placed in expanded polystyrene trays and packed with 14µm thick polyvinyl chloride film to further modifying the atmosphere. Fresh-cut guava samples were stored at 3 ± 2 °C and 80 ± 4% RH for 12 days. For each coating treatment, evaluations were performed every two days in 4 replications of a tray.

The microbiological evaluations for total coliforms (35 °C), *Salmonella* sp., Thermotolerant coliforms (45 °C), and molds and yeasts were determined according to American Public Health Association [APHA] (2001). The ascorbic acid content was determined according to Association of Official Analytical Chemistry [AOAC] (2005); lycopene and β-carotene according to Nagata and Yamashita (1992); the total extractable polyphenols and the total antioxidant activity by the radical 1,1-diphenyl-2-picrilhhydrazyl assay ($DPPH^{\bullet}$) were determined according to Dantas, Silva, Lima, Dantas and Mendonça (2013) and total antioxidant activity through the capture of the radical $ABTS^{+\cdot}$ according to (F. V. G. Silva et al., 2012).

Data were tested by performing a two-way ANOVA ($p \leq 0.05$). For the quantitative factor (days after coating), it was applied polynomial regression analysis, testing models up to the 2nd degree and assuming the coefficient of determination (R^2) greater than or equal to 60%. The regression coefficients were evaluated by the t-test at 5% probability. For the qualitative factor (coatings), means were compared using the Tukey test with up to 5% probability. The Statistical Analysis System (SAS) software was used for these analyzes.

Results and Discussion

The application of the edible coatings maintained the appearance and clearly delayed the loss of quality (Figure 1) of fresh-cut (FC) guava slices that had been kept for 12 days at 3 °C. The most effective coatings were chitosan (Q), and calcium chloride plus Q (CC + Q) when compared to the control (T).

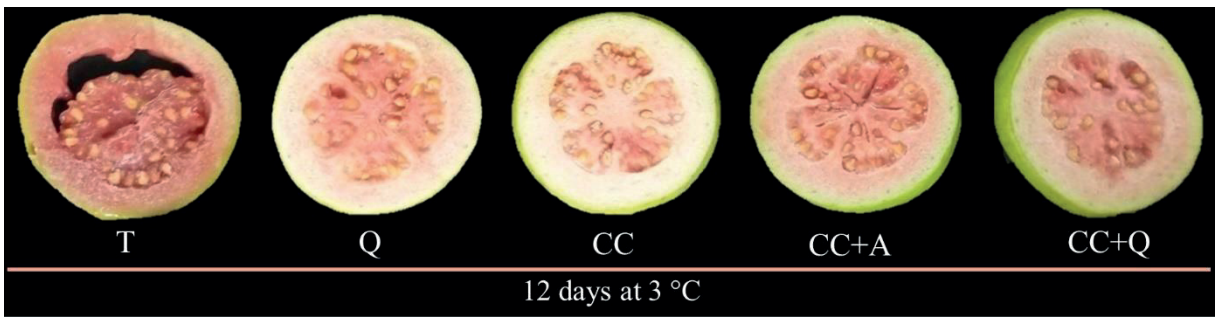

Figure 1. Fresh-cut 'Paluma' Guava coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, after 12 days at 3 ± 1 °C and 75 ± 4% RH.

The ascorbic acid (AA) content in the FC 'Paluma' guava slices did not differ between the different coatings over 12 days at 3 °C. However, gradual declines in AA from the initial content (84 mg 100 g^{-1}) were observed and losses had reached approximately 44% by the end of the storage period (Figure 2A). The AA content tends to decrease during fruit storage due to the action of oxidizing enzymes, predominantly ascorbic acid peroxidase, and its degradation may favor enzymatic browning and cause a strange taste (Salvia-Trujillo et al., 2015). In guava, the later the harvest, the higher the levels of AA, which is a result of advancing maturation (Rodrigues et al., 2018). Oliveira, Santos, Leite, Aroucha, & Silva (2018) coated 'Paluma' guavas with biopolymers hydrophobized with beeswax and observed that the coated fruits showed a reduction in AA content compared to that of the control fruits. The variation in ascorbate content is well correlated with the oxidative status (i.e., the activity of the enzyme is involved in the redox state and H_2O_2 content) of the fruit (Fenech, Amaya, Valpuesta, & Botella, 2019).

Total extractable polyphenol (TEP) content did not differ among the different coatings during storage. However, TEP content was higher in the guava slices coated with Q (166.08 mg 100 g^{-1}) compared to that of the controls (T), (152.48 mg 100 g^{-1}), and those coated with calcium chloride plus sodium alginate (CC + A) at 149.36 mg 100 g^{-1}. However, the TEP content of the slices coated with Q did not differ from those coated with calcium chloride (CC), at 158.35 mg 100 g^{-1} or those coated with CC + Q at 157.39 mg 100 g^{-1} (Figure 2B). Chitosan also maintained the TEP content of intact guavas, which was attributed to the maintenance of the redox state (W. B. Silva et al., 2018).

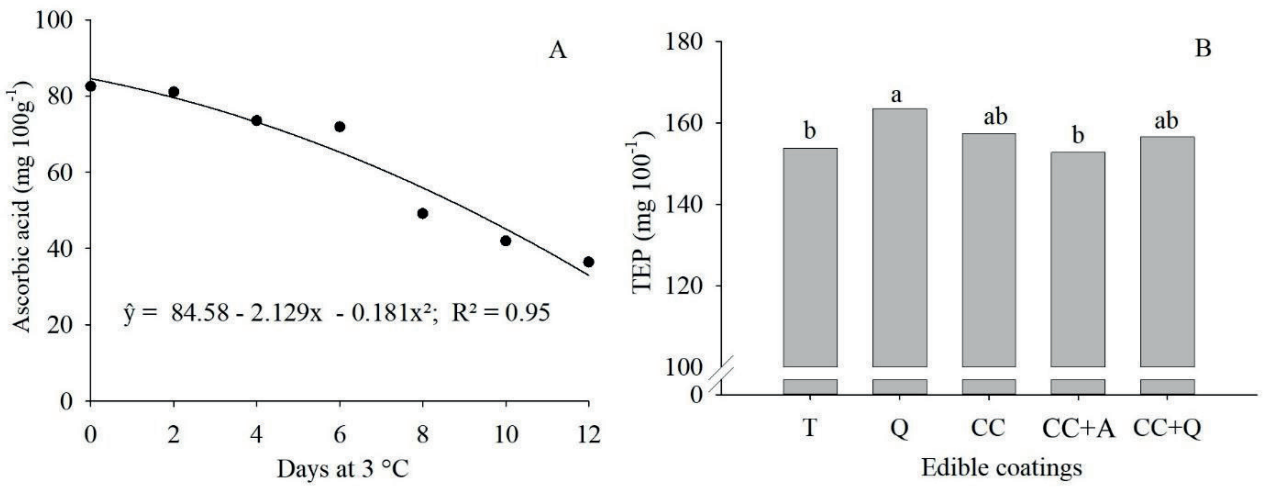

Figure 2. Ascorbic acid content of fresh-cut 'Paluma' guava stored for 12 days at 3 ± 1 ° C and 75 ± 4% R.H. (A), and total extractable polyphenols (TEP) of slices coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% CC + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, stored at 3 ± 1 ° C and 75 ± 4% RH for 12 days (B).

With regards to the β-carotene content in FC 'Paluma' guavas, there were interactions between the different coatings and the storage days (Figure 3A). β-carotene content increased in the guava slices up to the 6th day of storage and then decreased thereafter. An exception was those coated with CC + A, which increased until the 10th day of storage and then declined. The β-carotene content was higher in slices without a coating (T), followed by those coated with Q only and CC only. The lowest levels were recorded for those coated with CC + Q and CC + A, suggesting a lower metabolic rate in the slices with these coatings, which has also been reported for intact guavas coated with chitosan compositions (Rodrigues et al., 2018). β-carotene is the primary and most effective precursor of vitamin A among carotenoids and plays a crucial role in human health, protection against age-related degeneration, cardiovascular disease, certain cancers, and vitamin A deficiency (Zeng et al., 2015).

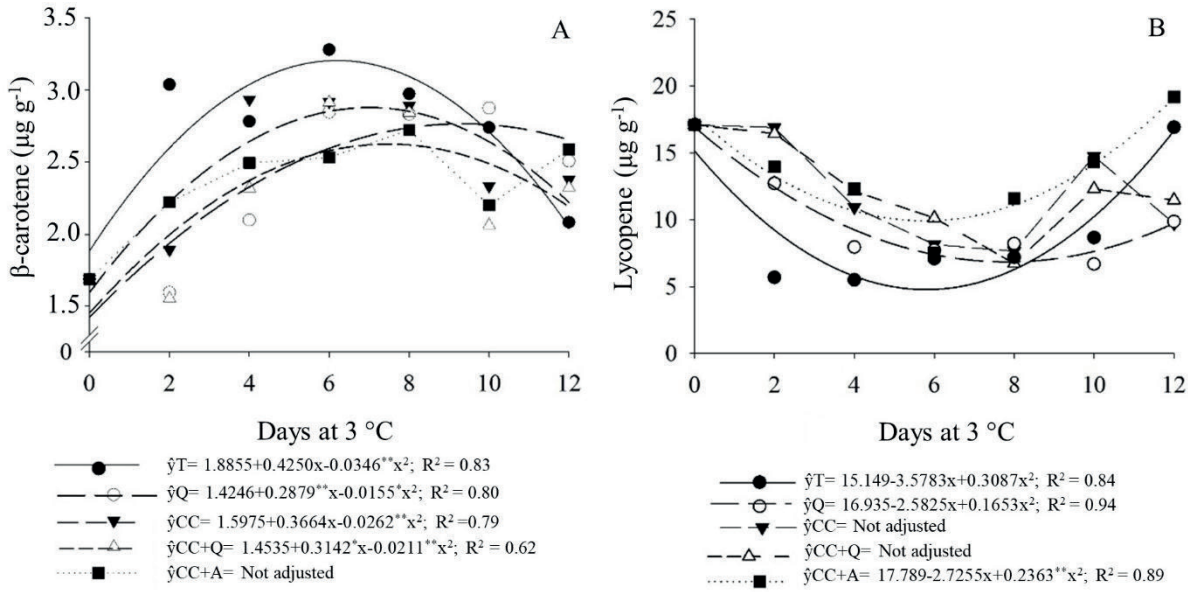

Figure 3. Content of β-carotene (A) and Lycopene (B) of fresh-cut 'Paluma' guava coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, during 12 days at 3±1 °C and 75 ± 4% RH. n=4.

The lycopene content, which provides potent anti-inflammatory properties to guava (Amorim et al., 2020), was higher than the β-carotene content in the 'Paluma' guava slices. An interaction between the coatings and the storage days was also observed for lycopene content in the FC 'Paluma' guava slices (Figure 3B). However, in contrast to that observed for β-carotene, lycopene content decreased until the 6th day of storage before increasing. Furthermore, as for β-carotene, this behavior indicates that the main changes in the FC guavas were observed from the 6th day of storage. Lycopene content was lower

in slices without a coating (T), followed by those coated with Q, while those with CC + A had the highest lycopene content. A low β-carotene content and a higher lycopene content was observed in FC slices coated with CC + A and CC + Q, further indicating that there had been a reduction in the metabolic rate. In the isoprenoid pathway, lycopene is the precursor of cyclic carotenoids, among which is β-carotene whose cyclization mechanism forms the β-ring and involves the stereospecific addition of hydrogen to the C2 carbon by lycopene β-cyclase (Zeng et al., 2015).

The total antioxidant activity (TAA) of guava slices, as determined by DPPH radicals, has been found to be close to that of pink pulp guavas (Flores et al., 2015), which confirms the high antioxidant potential of this fruit. The TAA values determined by the DPPH method, which is based on the consumption in grams (g) of the pulp necessary to react with one g of the DPPH radical, did not differ during storage among slices with the different coatings (Figure 4A), but decreased until the 4th day, indicating an increase in TAA, and stabilized until the 6th day where it decreased thereafter. The TAA of the slices coated with Q differed from those of T because they had less pulp that could react with the DPPH radical (436.83 g pulp g DPPH^{-1}) and, therefore, showed a higher TAA compared to that of the slices without a coating (521.53 g pulp g DPPH^{-1}). However, the TAA did not differ among the slices with the other coatings (Figure 4B). This reinforces the positive result that applying a coating maintains the functional potential of FC products (Yong & Liu, 2021) even when the main packaging is wrapped in a flexible film (Kalia & Parshad, 2015; Salvia-Trujillo et al., 2015), as in this study. Furthermore, these results also indicate the potential of Q in maintaining the TAA of 'Paluma' guava slices compared to that of other coatings. Murmu and Mishra (2018) evaluated the effect of edible coatings based on gum arabic, sodium caseinate, and cinnamon and lemongrass essential oils on whole guavas over 35 days storage at 4 - 7 °C and found that the coating application resulted in greater DPPH radical scavenging activity and greater AA retention.

Similar to the DPPH method, TAA determined using the ABTS^{+-} radical method did not significantly differ among slices with different coatings during storage. Coherently, as for DPPH, the TAA values increased until the 4th day, maintained their values until the 6th day, and then declined (Figure 5A). The TAA levels measured by ABTS^{+-} in the FC guava in this study were superior to that observed in whole guavas (Amorim et al., 2020). Pink pulp guava contains characteristic phenolic compounds that give them a high antioxidant activity and, possibly, other biological activities (Flores et al., 2015). Furthermore, a higher TAA determined by radical ABTS^{+-} was observed in slices coated with Q (37.86 μM trolox g^{-1}), which was consistent with the TAA determined by DPPH. However, in this case, the TAA values did not differ from those coated with CC (38.17 μM trolox g^{-1}) and CC + Q (36.93 μM trolox g^{-1}) when compared to that of the control slices, whose TAA mean was the lowest (28.87 μM trolox g^{-1}), and those coated with CC + A (34.24 μM of trolox g^{-1}) (Figure 5B). The importance of coatings in maintaining TAA is also clear, even when the product is kept under a modified atmosphere (MA) by a flexible film. Therefore, it is evident that by the two methods utilized the marked influence of Q and its combinations to maintain the TAA of FC 'Paluma' guava until the 6th day of storage at 3 °C. Furthermore, a

coating enhanced the quality of the slices, even though the product was stored under MA packaging, which characterizes edible coatings as a powerful addition to MA for FC guava. This effect in maintaining TAA may be due to the maintenance of the content of compounds with antioxidant potential in slices that have been coated (Salvia-Trujillo et al., 2015; Yong & Liu, 2021), most notably when Q was applied.

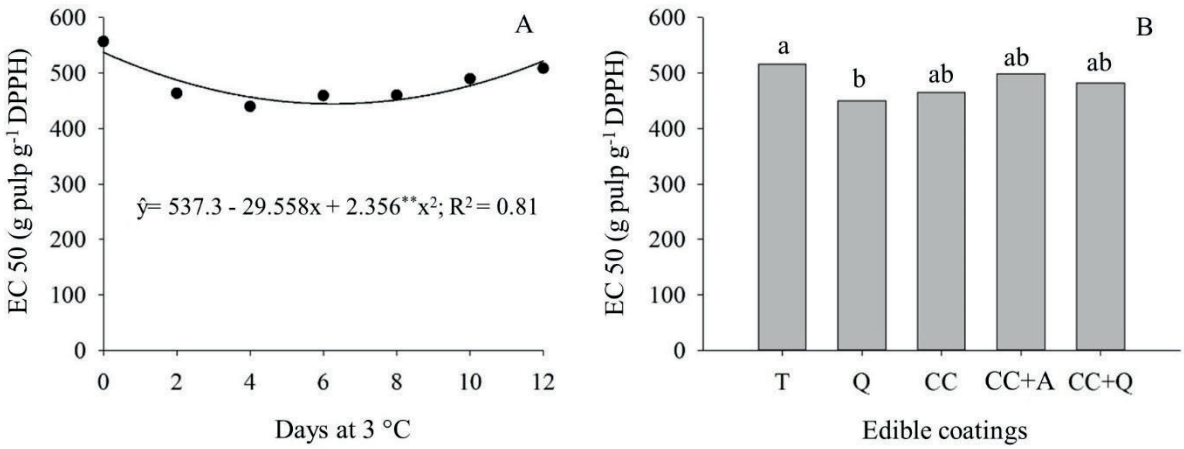

Figure 4. Total antioxidant activity (DPPH) in fresh-cut 'Paluma' guava stored for 12 days at 3 ± 1 ° C and 75 ± 4% RH (A), and coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, stored at 3 ± 1 ° C and 75 ± 4% RH for 12 days (B).

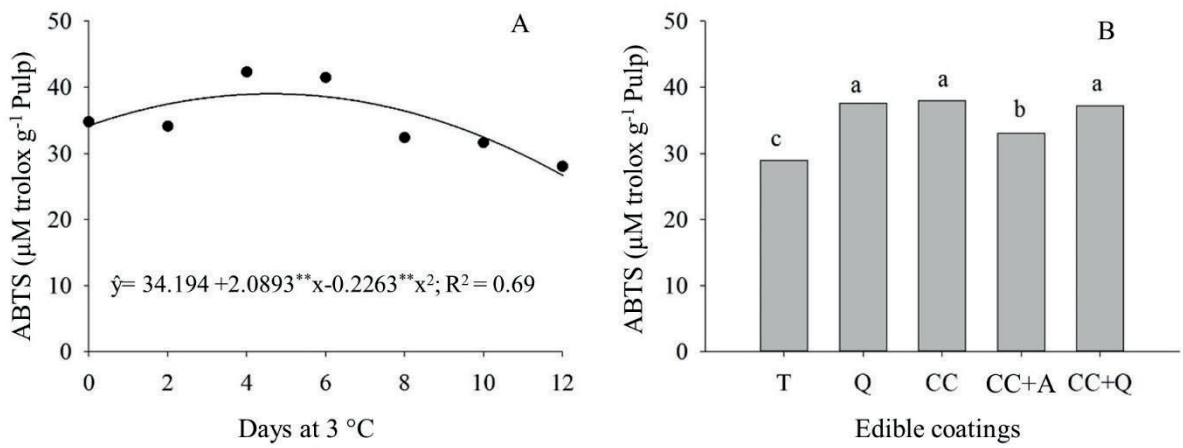

Figure 5. Total antioxidant activity (ABTS) in fresh-cut 'Paluma' guava stored for 12 days at 3 ± 1 ° C and 75 ± 4% RH (A), and coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, stored at 3 ± 1 °C and 75 ± 4% RH for 12 days (B).

The correlations between bioactive compounds and antioxidant activities determined by the two methods used were, in general, highly significant (Table 1). The correlations between antioxidant activity (TAA) using the DPPH$^{\bullet}$ method and PET (r = −0.88), AA (r = −0.66), lycopene (r = −0.61), and β-carotene (r = −0.83) were strong and negative (Table 1). However, after using the ABTS^{+-} method, lycopene showed no significant correlation with TAA, while PET, AA, and β-carotene showed a strong positive correlation (r = 0.80, r = 0.67, and r = 0.77, respectively). The correlation values between both TAA essays (DPPH$^{\bullet}$ and ABTS^{+-}) and the total extractable polyphenols, ascorbic acid, and β-carotene contents strongly suggest that these compounds contribute substantially to the antioxidant activity of FC 'Paluma' guava extracts. In fact, guava has been identified as a good source of natural antioxidants in foods (Almulaiky et al., 2018) and pharmaceutical products owing to its high capacity to eliminate free radicals (Chumyam et al., 2019). These characteristics are primarily due to the presence of AA, phenolic compounds (Flores et al., 2015), and lycopene (Amorim et al., 2020). In our study, coatings, such as Q and CC + Q, allowed the maintenance of higher levels of these compounds in the post-cut life of 'Paluma' guava, which resulted in slices with greater functional potential as they showed stronger antioxidant activity according to the DPPH$^{\bullet}$ and ABTS^{+-} results. In fresh guavas, Q coatings, or coatings in combination with Q, effectively prolong the maintenance of quality attributes due to their positive action in delaying ripening (Rodrigues et al., 2018) or by increasing the rate of antioxidant processes postharvest (W. B. Silva et al., 2018).

Table 1
Pearson correlation between bioactive compounds and total antioxidant activities in fresh-cut 'Paluma' guava coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, stored during 12 days at 3±1 °C and 75 ± 4% RH

Variable	by Variable	Correlation	Signif Prob T test	-1 0 1
DPPH	TEP	-0.8883	0.0075**	
DPPH	Ascorbic acid	-0.6623	0.0150*	
DPPH	Lycopene	-0.6063	0.0390*	
DPPH	β-carotene	-0.8326	0.0201*	
ABTS	TEP	0.7993	0.0310*	
ABTS	β-carotene	0.6731	0.0275*	
ABTS	Ascorbic acid	0.7703	0.0427*	
ABTS	Lycopene	0.5043	0.2485ns	
ABTS	DPPH	-0.6611	0.0459*	

** Significant up to 1% by T test; * significant up to 5% by the T test; ns not significant.

No thermotolerant coliforms (45 °C) or *Salmonella* were detected in the samples of slices with all coatings until the 12th day at 3 ± 2 °C. This finding characterizes these products as microbiologically safe according to the current legislation, RDC No. 12 of 2001 (ANVISA, 2001), which requires the absence of *Salmonella* and thermotolerant coliform counts of less than 5 × 10^2 NMP g^{-1} in fresh, prepared (peeled, selected, or fractionated), and chilled fruits for direct consumption. The absence of thermotolerant coliforms in FC guavas is an indication of the excellent quality of the raw material and the efficiency of the Good Manufacturing Practices adopted during processing operations. The microbiological safety of FC products is a fundamental aspect of food products (Fan et al., 2019). Paula, Vilas Boas, Rodrigues, Carvalho, & Piccoli (2009) microbiologically evaluated FC products collected in supermarket shelves in Lavras - MG, Brasília - DF, and São Paulo - SP. They detected contamination by thermotolerant coliforms, and in 50% of cases, contamination was caused by isolates of *Escherichia coli.* Furthermore, they suggested that this contamination could have come from inadequately sanitized raw materials or from the handlers.

The total number of coliforms (35 °C) increased during storage, with maximum counts on the 12th day of storage in slices coated with CC only (240 NMP g^{-1}). Slices coated with Q only showed counts for total coliforms on the 12th day of storage (6.2 NMP g^{-1}), which was the lowest count detected (Table 2). Slices coated with Q + CC showed total coliform counts only after the 8th day of storage, confirming the antimicrobial effect of Q (Salvia-Trujillo et al., 2015; Yong & Liu, 2021). There are no maximum limits established by legislation for the acceptable values of total coliforms and counts of bacteria, molds, and yeasts (ANVISA, 2001). However, it is recommended that foods containing counts of approximately 104 - 105 UFC g^{-1} are unfit for human consumption due to the loss of nutritional value, organoleptic changes, deterioration risks, and/or the presence of pathogens (Paula et al., 2009).

Table 2
Total coliforms (35 °C) in fresh-cut 'Paluma' guava coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q), and the control (T), slices without coating, stored during 12 days at 3±1 °C and 75 ± 4% RH

Storage days	T	Q	CC	CC + A	CC + Q
0	0	0	0	0	0
4	0	0	0	0	0
6	3	0	3	15	0
8	6.1	0	3	23	0
10	75	3.6	7.2	75	21
12	150	6.2	240	150	36

Values expressed in MPN g^{-1} (most probable number per gram).

For molds and yeasts in FC guava with different coatings (Table 3), slices coated with Q exhibited the lowest counts by the 12th day of storage (6×10^4 CFU g^{-1}), which, in general, confirmed the action of Q in keeping the slices microbiologically safe. The largest populations of molds and yeasts (4×10^8 CFU g^{-1}) were detected in slices coated with CC + A. Fruits with water activities greater than 0.98 are more susceptible to deterioration by bacteria, fungi, and yeasts (Kalia & Parshad, 2015). A high population of molds and yeasts is undesirable because these microorganisms can produce a variety of enzymes that deteriorate the quality of fruits and, in addition, many molds can produce toxic metabolic substances in food (Fan et al., 2019).

Table 3
Mould and yeast counts (CFU g-1) in fresh-cut 'Paluma' guava coated with 2% Chitosan (Q), 1% Calcium Chloride (CC), 1% Calcium Chloride + 1% Sodium Alginate (CC + A), 1% Calcium Chloride + 2% Chitosan (CC+Q) and the control (T), slices without coating, stored during 12 days at 3±1 °C and 75 ± 4% RH

Storage days	T	Q	CC	CC + A	CC + Q
0	63	63	63	63	63
4	3×10^2	72	3×10^2	6×10^3	81
6	8×10^4	2×10^2	2×10^2	1×10^4	2×10^3
8	1×10^5	2×10^2	4×10^4	9×10^4	7×10^3
10	4×10^5	3×10^4	5×10^4	2×10^5	3×10^5
12	6×10^5	6×10^4	3×10^5	4×10^8	1×10^6

Values expressed in CFU g^{-1} (colony forming units per gram).

Conclusions

For fresh-cut 'Paluma' guava slices kept with edible coatings at 3 °C in packages wrapped with PVC film:

The application of coatings contributes substantially to maintain the levels of bioactive compounds and antioxidant activity, and can be a powerful ally to the modified atmosphere by flexible film in FC guava;

No thermotolerant coliforms or Salmonella were detected in slices of any coating, but the counts of total coliforms and molds and yeasts were lower in slices coated with chitosan.

Together, the chitosan coating in 'Paluma' guava slices maintains the bioactive compounds levels, mainly PET, lycopene and β-carotene and the antioxidant activity, which gives the product greater functional potential, in addition to be a food safe for consumption.

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