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Impact of cassava starch-alginate based coatings added with ascorbic acid and elicitor on quality and sensory attributes during pineapple storage

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Pineapple is a tropical fruit of great consume demand. However, due to its high perishability at room conditions, there is noticeable loss of quality postharvest in a short period. In this context, the use of biodegradable coatings is a promising alternative for maintaining postharvest quality. Thus, the aim of this study was to evaluate the use of cassava starch-alginate based biodegradable coatings added with ascorbic acid and an elicitor on postharvest quality and conservation of 'Pérola' pineapple. Fruits were coated with: Cassava starch 1.5% + alginate 0.5%; cassava starch 1.5% + alginate 0.5% + ascorbic acid 0.18 %; cassava starch 1.5% + alginate 0.5% + elicitor, each added of 0.5% of glycerol as a plasticizer, and the control (uncoated fruits), following storage at room conditions (23 ± 1°C, 88 ± 2% RH). Pineapples coated with cassava starch-alginate associated with the elicitor (SE) or ascorbic acid (SA) kept lower levels of reducing and total sugars as well as better appearance and general acceptance (GA) during room storage for 18 days. According to the panelists, the determining factors for higher GA of 'Pérola' pineapple under these coatings were the sweetness, fresh like characteristics of taste and odor, and better appearance. Overall, the use of SE and SA coatings had a marked impact in maintained the quality during 18 days and did not adversely affect the sensory characteristics of 'Pérola' pineapple stored at room conditions.

Key words: *Ananas comosus, Manihot esculenta,* biodegradable coating, sugars, sensorial acceptance.

INTRODUCTION

Pineapple (*Ananas comosus* var. comosus) stands out as one of the most important fruit crops in tropical and subtropical countries (Paull and Chen, 2003), especially in Brazil where it is widely cultivated, producing 1,762,938 fruits in 2014, ranking among the three largest world producers (IBGE, 2016). Despite its extensive production in Northeastern Brazil, the pineapple chain has several critical constraints that have limited its expansion to new markets, even inside the country (Martins et al., 2012). In this context, postharvest losses are the main concern, which are related to its high perishability that contributes to its short postharvest life (Silva et al., 2010), and especially those related to physiological disorders such as internal browning (Luengwilai et al., 2016). Additionally, exposure to oscillating ambient conditions during marketing results in decreasing its overall quality, indicating that the pineapple fruit chain demands more innovation (Dantas et al., 2015) in order to maintain postharvest fruit quality and acceptance by consumers (Hounhouigan et al., 2014). This is especially true in the context of the production systems in the Northeastern Brazil, which are characterized by low income producers and conventional practices of crop management (Dantas Junior et al., 2009).

Pérola cultivar is the most consumed pineapple in Brazil (Dantas et al., 2015). However, it presents a short postharvest life (Martins et al., 2012). Some efforts have been directed to extend postharvest conservation using cold storage and associated technologies such as plant regulators (Zhang et al., 2015), modified atmospheres (Chiumarelli and Hubinger, 2014), and polysaccharide-based coating (Lima et al., 2012). However, these approaches need to be optimized in terms of improving the barrier properties of the coatings (Dhall, 2013).

The use of biodegradable coatings have been reported as a way to prolong the postharvest life of whole fruit (Azerêdo et al., 2016) and fresh-cut products (Bitencourt et al., 2014). Due to their specific properties, coatings act as good barriers to gases (Hamzah et al., 2013), resulting in decreased respiratory rate (Chiumarelli et al., 2011), and reduced water loss (Lima et al., 2012). Furthermore, incorporating active compounds in the polymer matrix such as essential oil found in chitosan (Aloui et al., 2014) and in starch-based coating (Oriani et al., 2014), can assist in controlling diseases and reducing metabolic rate, thus enhancing postharvest life and adding value to the product through exploiting safe, sustainable, and affordable local raw material.

More recently, the development of functional coatings has been discussed, which depend on the intrinsic properties of the matrix and the embedded materials, as well as the type of fruit regarding its postharvest life and quality maintenance. However, an important aspect to be noted is that the use and application of coatings are ruled by the laws of the country in which it is being applied, and/or the country to which the fruits are to be exported (Dhall, 2013). Thus, incorporating active components in coatings has attracted the attention of researchers, since it is supposed to modulate either the fruit's physiology or be adjusted to the matrix, changing its properties. In this context, elicitors are compounds which activate chemical defense in plants and have been used for disease control (Thakur and Sohal, 2013), and can be useful for postharvest applications. Different types of elicitors have been characterized, including inorganic compounds, carbohydrate polymers, lipids, glycopeptides, and glycoproteins (Terry and Joyce, 2004). However, many more studies are needed about the impact of coatings composed of widely available raw material such as cassava starch on postharvest quality of pineapple, in which the matrix is embedded with functional ingredients (Ghidelli et al., 2014).

Starch from cassava (*Manihot esculenta*) seems to be a promising raw material to develop coatings due to its physical properties and workability, allowing combining with other components to improve its mechanical properties and form stable emulsions if lipids and hydrocolloids are combined (Santos et al., 2014). In this context, alginate has been successfully used as a component of the polymeric matrix of coatings (Chiumarelli et al., 2011), and glycerol as a plasticizer (Dhall, 2013). In addition, edible coatings and films may also act as food additive carriers, including antioxidants and antimicrobial compounds (Jiménez et al., 2012). Even though the pineapple has an irregular surface, application of a polysaccharide-based coating may be an affordable option to reduce its postharvest losses and maintain quality under room conditions. Thus, the aim of this study was to evaluate the use of cassava starch-alginate based biodegradable coatings added with ascorbic acid and elicitor in the postharvest conservation of 'Pérola' pineapple.

MATERIALS AND METHODS

Fruit harvest

Fresh pineapple (*Ananas comosus* var. comosus) fruits were harvested in the commercial maturity (beginning of yellow pigmentation at the fruit base) from an orchard located at the municipality of Santa Rita, State of Paraíba, Brazil. Fruits were selected with weight ranging between 0.9 and 1.2 Kg, presenting uniform size and regular shape without visible defect. Pineapples were transported to the Postharvest Biology and Technology laboratory of the Centro de Ciências Agrárias, of the Universidade Federal da Paraíba, Brazil, to be evaluated. Fruits were manually washed, then immersed in a 200 mg/L sodium hypochlorite solution for 5 min, and immersed in distilled water for 2 min. After drying at room conditions, pineapples were separated into four groups for the application of coatings.

Preparation and coatings application

Three coating polymeric matrixes were designed. Initially, 1.5%

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Table 1. Formulations for cassava starch-alginate based coatings applied in 'Pérola' pineapple harvested at the commercial maturity.

Coating code	Cassava starch (%)	Sodium alginate (%)	Glycerol (%)	Additive
C	-	-	-	-
SA	1.5	0.5	0.5	Ascorbic acid (0.18 %)*
SE	1.5	0.5	0.5	Elicitor (0.4 %)
S	1.5	0.5	0.5	-

*Ghidelli et al. (2014).

cassava starch dispersion was prepared by gelatinization of the starch, which consisted of heating the solution to 70°C under constant stirring (Lima et al., 2012). Following the gelatinization of the cassava starch, the additional components and additives were added under constant stirring until the complete homogenization (Table 1). All coating dispersions were added with 0.5% sodium alginate (Sigma-Aldrich) and 0.5% glycerol (Sigma-Aldrich), as a plasticizer. The formulation cassava starch-alginate + ascorbic acid (SA), was added with 0.18% ascorbic acid (Sigma-Aldrich). The formulation cassava starch-alginate + Elicitor (SE) was added with 0.4% of the elicitor. Uncoated pineapples were the control treatment (C).

Pineapples were immersed in each cassava starch-alginate based coating for 1 min under a fruit smooth rotation for better adherence of dispersion. Then, coated fruit was kept at room conditions until complete drainage. Afterward, pineapples were placed in styrofoam trays and stored under room conditions (23 ± 1°C and 88 ± 5% RH) for 18 days. The elicitor was composed by bioflavones, phytoalexins, and polyphenols (1.66 g/100 mL), ascorbic acid (1.65 g/100 mL), lactic acid (0.95 g/100 mL), citric acid (1.30 g/100 mL), and vegetable glycerin (6.60 g/100 mL) (Ecolife® QUINABRA - Química Natural Brasileira Ltda., Sao Paulo, Brazil).

Experimental design

The experiment was performed in a completely randomized design in a 4 × 4 factorial scheme, combining 4 coatings (S, SA, SE, and C) and 4 evaluation periods (0, 6, 12, and 18 days), using four replications, consisting of 6 pineapples each. However, the sensory analysis had a randomized block design, with the same factorial scheme, where the 24 trained panelists were considered the replications.

Physical and physiochemical evaluations

Firmness was measured with digital penetrometer (Magness Taylor Pressure Tester, Canada) at two equational regions of each fruit at different storage time using a 6 mm diameter probe and results were expressed in Newton-N. Weight loss was measured by recording the fruit weight during the storage time. The percentage of weight loss was relative to the initial value (taken as 0%) (Martins et al., 2012).

The following physicochemical characteristics were determined according to AOAC (2012): The content of soluble solids was determined with a digital refractometer with automatic temperature compensation (model ATAGO N1) and expressed as percentage; acidity was determined by titration with 0.1 M NaOH and was expressed as gram of citric acid per 100 g of fresh weight (fw); SS/TA *ratio* was obtained by the relation between the soluble solids and titratable acidity; pH was measured from the acidity extract before titration with a pH-meter; the reducing, non-reducing, and total sugars (g/100 g fw) were determined by titration with Fehling's solution.

Sensory evaluations

For the sensory characteristics evaluation, twenty four panelists, regular pineapple consumers, were selected between 18 and 40 years old. The panelists were trained based on the perception of the acidity (AC), sweetness (SW), characteristic taste (CT), characteristic odor (CO) of the samples based on 5-point hedonic scales (9-very intense, 7-intense, 5-moderate, 3-light, and 1-absent). For the off odor (OO) and off taste (OT), a structured scale varying from 1 to 6 (6 = Absent; 3 = Moderate; 1 = Strong) was used to express the degree of unacceptability (Mascarenhas et al., 2010). The 5-point hedonic scale for color (CL), considering the fruit skin color, was 1 (100% green and 0% yellow), 2 (75% green and 25% yellow), 3 (50% green and 50% yellow), 4 (25% green and 75% yellow) and 5 (0% green and 100% yellow). The hedonic structured scale varying from 1 to 9 (9 = Liked very much; 5 = not like or dislike; 1 = Disliked very much) was used to express the degree of acceptability for appearance (AP) and general acceptance (GA) (Miguel et al., 2010). Sensory tests were carried out in morning sessions at sensory laboratory equipped with individual sensory cabinets. The panelists used water and salted cracker as palate cleanser between one sample to another, respecting a 1 min rest time among the samples evaluations. The samples for taste proofs were placed in plastic cups at room conditions (23 ± 1°C and 88 ± 5% RH), codified with three-digit number codes, and in a randomized and balanced order of sample presentation. Scores and comments of the panelists were recorded on scorecards.

Statistical analysis

Data were submitted to analysis of variance by F test ($p \leq 0.05$). For the storage period (days), the polynomial regression analysis was applied, testing up to cubic level and coefficient of determination higher than $R^2 > 0.5$. Additionally, treatments (coatings) were individually analyzed by the Tukey test ($p \leq 0.05$) for each day at room storage when regression did not meet the required criterions. Multivariate analysis, such as principal components analysis (PCA) and Ward's clustering were performed to correlate the variables that have been more affected by the applied coatings during storage. Statistical analysis were performed with the Sisvar 5.6 software (Ferreira, 2008) and JMP v10.0.0 (SAS©, 2012).

RESULTS

Firmness decreased during storage, but was maintained higher for 15 days in coated pineapples. For uncoated pineapples, firmness reduced nearly 25% by the 12th day of storage (Figure 1A). In fact, uncoated pineapples (C)

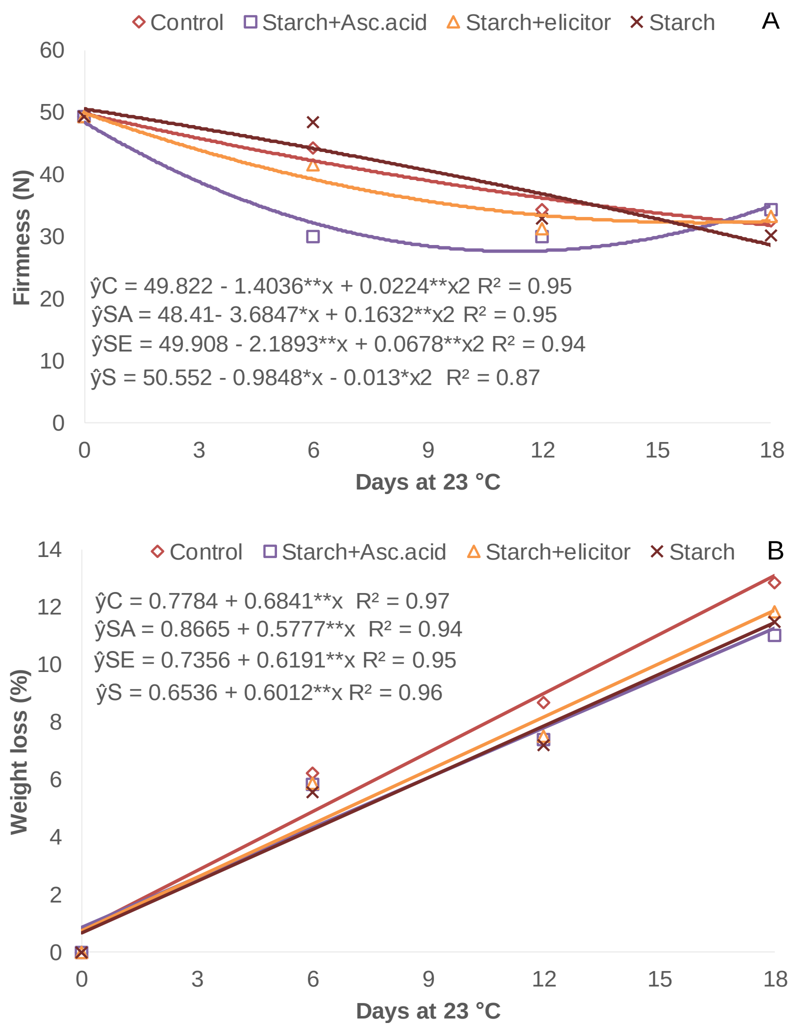

Figure 1. Firmness (A) and weight loss (B) in 'Pérola' pineapple, coated with cassava starch-alginate (S), cassava starch-alginate + ascorbic acid (SA), cassava starch-alginate + elicitor (SE), and uncoated fruit (C), during 18 days storage at room conditions (23 ± 1°C and 88 ± 5% RH). n=4.

had the highest weight loss during storage with 12.86% at 18 days of storage. In turn, starch-alginate based coatings (S, SA, and SE) presented lower weight losses (Figure 1B). Indeed, the highest slope was obtained for pineapples from the Control group (0.68). Soluble solids (SS) content was affected by the application of cassava starch-alginate based coatings. SS content was higher for the uncoated pineapples (C) and lower in pineapples coated with cassava starch-alginate (S) throughout storage (Table 2). In turn, fruits coated with starch-alginate + ascorbic acid (SA) and starch-alginate + elicitor (SE) showed intermediate levels for SS during the 18 days of storage, indicating a lower metabolic rate provided by these coatings to 'Pérola' pineapples, mainly for the SA. Titratable acidity (TA) in 'Pérola' pineapples did not differ among coatings until the 12th day of storage. However, pineapples coated with cassava starch-alginate (S) showed a decline in the TA content afterward (Table 2), which was followed by a higher pH. However, the pH of the pulp of pineapples from other coatings did not differ much throughout the 18 days of storage. The observed decline in TA in S-coated pineapples during the storage provided the highest values for the SS/AT ratio.

The initial mean content of reducing sugar (RS) was 2.27 g/100 g, which declined during the 18 days of storage. This reduction in the RS was much faster for S-coated pineapple until the 15th day of storage. In turn, pineapples coated with starch-alginate + elicitor (SE) and starch-alginate + ascorbic acid (SA) showed the highest RS content throughout storage (Figure 2A). Non-reducing sugar (NRS) content declined until 9 days of storage, and increased thereafter, regardless of the coating applied to the pineapples (Figure 2B). However, this decline was much lower for uncoated pineapples (C), and, in turn, faster for coated pineapples, mainly for the S-coated ones. After 9 days of storage, pineapples coated with

Table 2. Soluble solids (SS), titratable acidity (TA), SS/TA ratio, and pH in 'Pérola' pineapple coated with cassava starch-alginate (S), cassava starch-alginate + ascorbic acid (SA), cassava starch-alginate + elicitor (SE), and uncoated fruit (C) during 18 days storage under room conditions (23 ± 1 °C and 88 ± 5% RH).

Days		Soluble solids (%)	Titratable acidity ($g.100g^{-1}$)	SS/AT Ratio	pH
0	C	11.17^{a}	0.75^{a}	14.89^{a}	3.76^{a}
	SA	11.17^{a}	0.75^{a}	14.89^{a}	3.76^{a}
	SE	11.17^{a}	0.75^{a}	14.89^{a}	3.76^{a}
	S	11.17^{a}	0.75^{a}	14.89^{a}	3.76^{a}
6	C	12.83^{a}	0.85^{a}	15.09^{a}	3.74^{b}
	SA	11.50^{b}	0.79^{a}	14.57^{a}	3.85^{ab}
	SE	12.25^{a}	0.85^{a}	14.43^{a}	3.89^{a}
	S	10.50c	0.82^{a}	12.86^{b}	3.85^{ab}
12	C	12.33^{a}	0.84^{b}	14.62^{a}	3.72^{a}
	SA	12.75^{a}	0.91^{a}	13.96^{a}	3.75^{a}
	SE	12.58^{a}	0.82^{b}	15.33^{a}	3.73^{a}
	S	11.67^{b}	0.80^{b}	14.63^{a}	3.77^{a}
18	C	13.00^{a}	0.87^{a}	14.88^{ab}	3.84^{b}
	SA	11.73^{b}	0.84^{a}	14.02^{b}c	3.83^{b}
	SE	11.33^{b}c	0.86^{a}	13.23c	3.94^{ab}
	S	10.97c	0.68^{b}	16.08^{a}	4.05^{a}

Means followed by the same letter in the column do not differ by Tukey's test ($p \leq 0.05$).n=4.

only cassava starch-alginate (S) had the lowest levels of sugars (4.47 g/100 g), which were kept lower throughout storage. Total sugar (TS) content decreased until the 12th day of storage. However, regarding NRS, TS was higher for uncoated (8.66 g/100 g) and lower for S-coated pineapple (4.45 g/100 g) from the 12th day of storage (Figure 2C).

Sensory attributes of 'Pérola' pineapple under the different coatings are shown in Table 2. According to the panelists, pineapple acidity (AC) is a characteristic feature of the acceptance of this cultivar, and was reduced over time; mainly for the S-coated pineapples from the 12th day onward. During the 18 days of storage, perception of acidity was reduced by 65%, which negatively impacted general acceptance. In turn, the sweetness (SW) perception of pineapple pulp did not differ ($p \leq 0.05$) among the coatings applied throughout storage.

Scores for characteristic taste (CT) decreased during storage, notably for S-coated pineapple, with the lowest score of 3.47 (light) during the 18 days of storage. In turn, the characteristic odor (CO) was maintained until the 12th day, regardless of the coating applied. However, the CO decreased for uncoated and S-coated pineapples during the room storage. The off taste (OT) was not reported by the panelists until the 12th day. However, the OT later reached the acceptance limit (score 4) for uncoated pineapples as well as for S-coated fruits, which was reported by the panelists as tasteless. The same pattern was observed for the off odor (OO), where uncoated pineapples reached 4.33 (close to the limit of acceptance) and S-coated pineapples reached 3.75 (below the acceptance limit) during the 18 days of storage. This was described by the panelists as presenting a fermented fruit smell, negatively impacting the CO, CT and, consequently, the GA. In turn, OT or OO were not reported for SA- or SE-coated pineapples by the panelists during the 18 days of room storage, with scores much above the acceptance limit, and without significant difference between these two coating formulations (Table 2).

The pineapple color evolved from green to orange during storage (Table 3; Figure 3), mainly for uncoated fruits, indicating the impact of coatings on retaining color development. However, SA- and SE-coated pineapples had the highest scores for appearance by the panelists, which characterized the fruits as fresh-like and with a turgid surface, while also presenting low brightness and a yellow color, absence of blemishes or diseases, severe damage and/or rot during the 18 days of storage. In turn, 'Pérola' pineapples coated with only starch (S) and the uncoated pineapples (C) had lower appearance scores than SA and SE after 12 days, being below the acceptable limit (5 – moderate). For uncoated pineapples (C), the observed decline in appearance during the 18 days of storage coincided with the color development and the transition from green (score 2) to yellow (score 5) (Table 3).

The general acceptance (GA) scores decreased during storage. However, they were kept higher for SA- and SE-coated pineapples during the 18 days of room storage. In turn, S-coated and uncoated pineapples (C) had scores

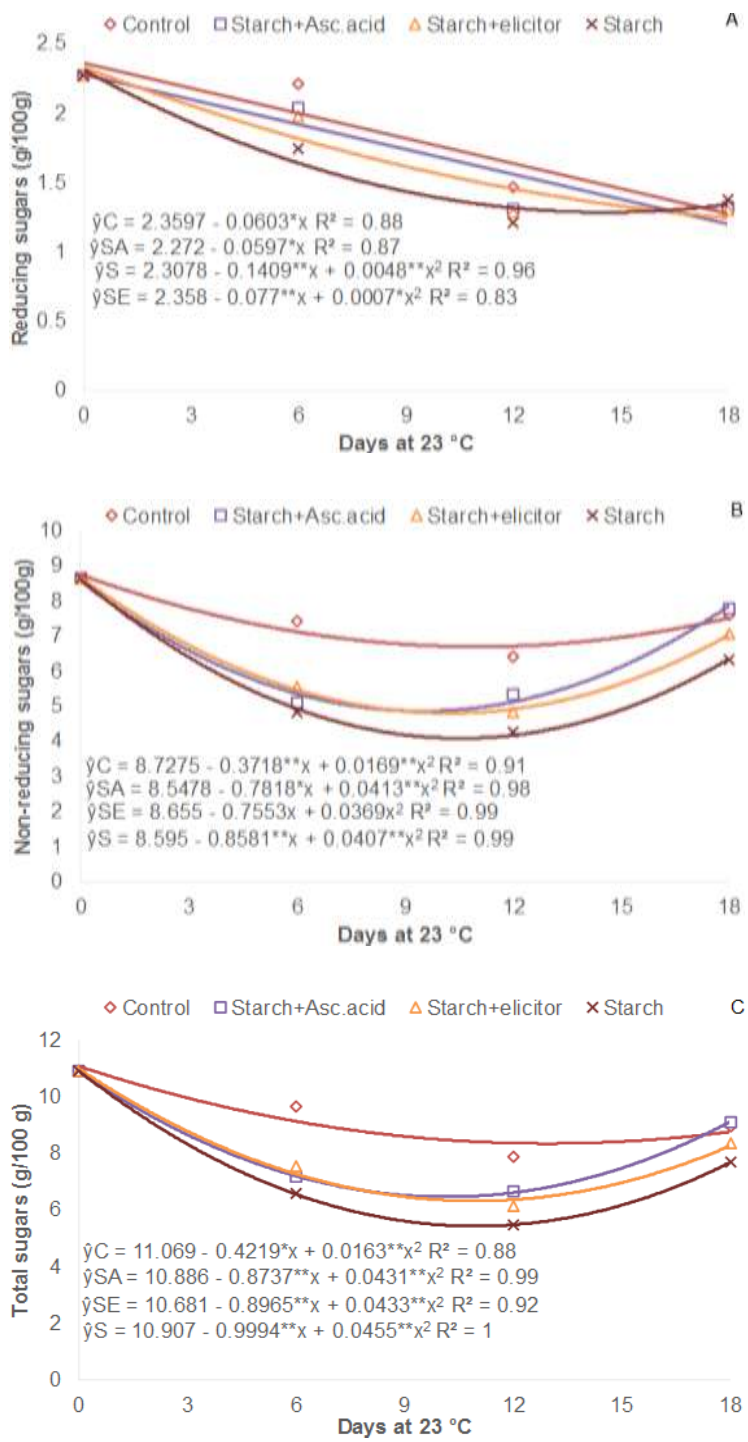

Figure 2. Reducing (A), non-reducing (B) and total sugars (C) in 'Pérola' pineapple coated with cassava starch-alginate (S), cassava starch-alginate + ascorbic acid (SA), cassava starch-alginate + elicitor (SE), and uncoated fruit (C) stored for 18 days under room conditions (23 ± 1°C and 88 ± 5% RH). n=4

below the general acceptance limit of 5.0 (5 - neither liked nor disliked). SA- and SE-coated pineapples presented good appearance, low shriveling and a suitable color at the end of the storage at room conditions (Figure 3).

Principal component analysis (PCA) covered 88.41% of

Table 3. Sensorial attributes for 'Pérola' pineapple (pulp and whole fruit) coated with cassava starch-alginate (S), cassava starch-alginate + ascorbic acid (SA), cassava starch-alginate + elicitor (SE), and uncoated fruit (C) stored for 18 days under room conditions (23 ± 1 °C and 88 ± 5% RH).

Days		Pulp						Whole fruit		
		AC	SW	CT	OT	CO	OO	CL	AP	GA
0	C	7.00^{a}	6.50^{a}	6.33^{a}	6.00^{a}	5.67^{a}	6.00^{a}	2.00^{a}	9.00^{a}	8.33^{a}
	SA	6.67^{a}	6.50^{a}	6.33^{a}	6.00^{a}	5.67^{a}	6.00^{a}	2.00^{a}	9.00^{a}	8.17^{a}
	SE	6.67^{a}	6.50^{a}	6.00^{a}	6.00^{a}	5.67^{a}	6.00^{a}	2.00^{a}	9.00^{a}	8.00^{a}
	S	6.67^{a}	6.50^{a}	5.67^{a}	6.00^{a}	5.67^{a}	6.00^{a}	2.00^{a}	9.00^{a}	8.00^{a}
6	C	6.67^{a}	6.67^{a}	7.33^{a}	5.33^{a}	6.00^{a}	6.00^{a}	3.67^{a}	6.33^{a}	7.83^{a}
	SA	6.33^{a}	6.50^{a}	6.33^{ab}	6.00^{a}	5.67^{a}	5.67^{a}	2.67^{a}	7.67^{a}	7.50^{ab}
	SE	6.67^{a}	6.83^{a}	5.67^{ab}	6.00^{a}	6.00^{a}	6.00^{a}	3.00^{a}	6.33^{a}	7.50^{ab}
	S	6.00^{a}	6.83^{a}	5.33^{b}	5.33^{a}	5.67^{a}	5.33^{a}	3.00^{a}	6.33^{a}	6.33^{b}
12	C	6.33^{ab}	6.83^{a}	5.67^{a}	4.00^{a}	6.00^{a}	5.67^{a}	4.67^{a}	5.00^{a}	6.67^{ab}
	SA	7.67^{a}	6.67^{a}	5.33^{a}	6.00^{a}	5.67^{a}	5.67^{a}	4.00^{a}	6.33^{a}	6.33^{ab}
	SE	5.67^{b}	7.00^{a}	5.67^{a}	5.33^{a}	5.00^{a}	$5,67^{a}$	4.33^{a}	6.33^{a}	7.50^{a}
	S	5.33^{b}c	7.00^{a}	4.67^{b}	5.33^{a}	5.67^{a}	5.33^{a}	4.33^{a}	5.00^{a}	6.17^{b}
18	C	6.67^{a}	6.83^{a}	5.33^{a}	4.00^{b}	3.67^{b}	4.33^{b}	5.00^{a}	4.00^{b}	4.17^{b}
	SA	4.67^{ab}	7.17^{a}	5.00^{a}	5.33^{a}	6.00^{a}	5.33^{a}	4.67^{b}	5.67^{a}	6.00^{a}
	SE	4.33^{ab}	7.33^{a}	5.00^{a}	5.00^{a}	5.67^{a}	5.00^{a}	4.67^{b}	6.33^{a}	6.50^{a}
	S	2.33^{b}	7.17^{a}	3.47^{b}	4.17^{b}	4.33^{b}	3.75c	4.67^{b}	4.00^{b}	4.00^{b}

Means followed by the same letter in the column do not differ by the Tukey's test ($p \leq 0.05$). n=24. AC, Acidity; SW, sweetness; CT, characteristic taste; OT, off taste; CO, characteristic odor; OO, off odor; CL, color; AP, appearance; GA, general acceptance. n=40. Scales: (AC, SW, CT and CO: 9-very intense, 1-absent; OO and OT: 6=absent, 1=strong; CL: 1=100% green, 5=100% yellow; AP and GA: 9=liked very much, 1=disliked very much). OF, off flavor; OT, off taste; Limit of acceptance = 4; AP, appearance; GA, general acceptance; Limit of acceptance = 5.

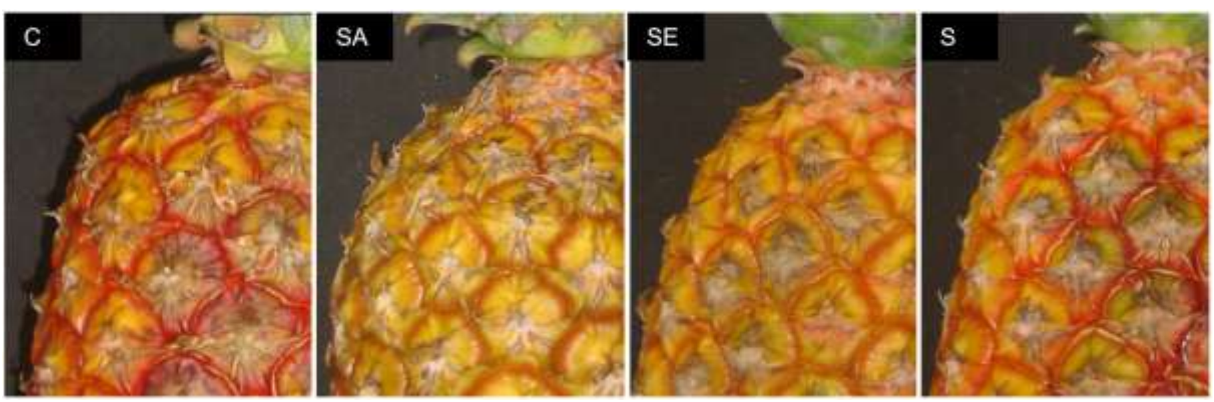

Figure 3. Appearance of 'Pérola' pineapple, coated with cassava starch-alginate (S), cassava starch-alginate + ascorbic acid (SA), cassava starch-alginate + elicitor (SE), and uncoated fruit (C), followed 18 days storage under room conditions (23 ± 1°C and 88 ± 5% RH).

the coatings variability, comprising two principal components, CP1 (61.30%) and CP2 (27.09%) (Figure 4A). The contribution of all analyzed variables regarding the two first principal components reflects the multivariate similarity of the grouped treatments, according to the overall responses of 'Pérola' pineapple to the imposed experimental conditions. Regardless of the variables SS/TA ratio, firmness, color, general appearance, and characteristic odor, which were significantly associated with PC2, all the physical, physiochemical, and sensory attributes explained the variability in PC1, meaning that the high correlation among these variables led the uncoated pineapple (Control) to differentiate itself, forming an isolated group.

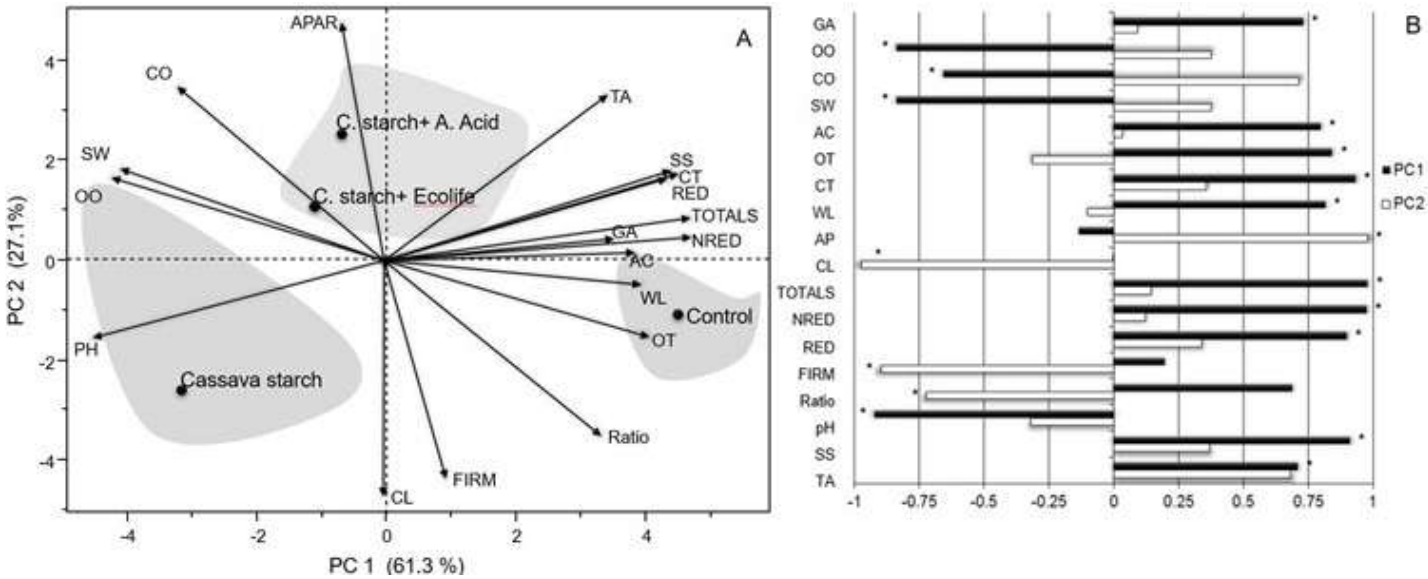

Figure 4. PCA plot of 'Pérola' pineapple quality attributes (physicochemical and sensorial) during storage and the plot of principal components correlations, PC1 and PC2. GA, General acceptance; CO, characteristic odor; OO, off odor; SW, sweetness; AC, acidity; CT, characteristic taste; OT, off taste; WL, weight loss; AP, appearance; CL, color; TOTALS, total sugars; NRED, non-reducing sugars; RED, reducing sugars; FIRM, Firmness; pH, SS/TA ratio ratio; SS, soluble solids; TA, titratable acidity of 'Pérola' pineapple coated with cassava starch-alginate S; SA, cassava starch-alginate + ascorbic acid; SE, cassava starch-alginate + elicitor; C, uncoated fruit stored for 18 days under room conditions (23 ± 1°C and 88 ± 5% RH). *The inclusion of significant variables was based on the multiplication of the highest score of each PC by 0.7, whose result was accepted as a threshold for inclusion.

Based on this, pineapple coated with cassava starch-alginate + elicitor (SE) and cassava starch-alginate + ascorbic acid (SA) were grouped together. For this group, pineapples of both coatings presented intermediate levels of titratable acidity, pH, soluble solids, reducing sugars, total sugars, and higher scores for characteristic taste and for general appearance. In turn, for starch-alginate-coated pineapple (S), the high PC scores for pH, firmness, off odor, and color separated it into another group. Interestingly, the highest PC scores for the physicochemical characteristics and the sensory attributes of off taste, acidity, low general acceptance, as well as higher weight loss led the uncoated pineapple to form a group and stay apart from the cassava starch coating group. In addition, the cassava starch-coated pineapples presented the lowest PC scores for pH and off odor perception by the panelists (Figure 4).

DISCUSSION

Reduction of firmness in pineapples was related to increased pectinesterase, polygalacturonase, and β-galactosidase activity (Rocculi et al., 2009). It has also been related to the coating composition, as polysaccharides are very hygroscopic and poor barriers to water vapor (Chiumarelli and Hubinger, 2014). Higher weight losses can also influence the water vapor transfer, resulting in increased fruit firmness in pineapples (Martins et al., 2012).

Therefore, coatings can be an alternative to minimize the weight loss of fruits and vegetables during postharvest storage (Plooy et al., 2009; Azerêdo et al., 2016), since they are able to efficiently control the gas exchange (Azarakhsh et al., 2014), being one of the main factors for increasing weight losses. Additionally, the coating components such as alginate play a noteworthy role in this effect, since they can deeply interfere with the mechanical properties of the coating (Chiumarelli and Hubinger, 2014), altering the barrier to water vapor and respiration gases (Azarakhsh et al., 2014).

The overall changes shown in the uncoated pineapples are correlated with the ambient conditions, especially temperature and humidity (Dantas Junior et al., 2009). However, there was a positive effect of the starch-alginate + ascorbic acid (SA) and starch-alginate + elicitor (SE) coatings in maintaining the soluble solids content of 'Pérola' pineapples compared with uncoated (C) or S-coated fruits, indicating that the addition of ascorbic acid or the elicitor can have an impact in reducing the metabolic rate. In general, pineapple do not present noteworthy changes in acid and sugars contents after harvested as they are a non-climacteric fruit, therefore they have no significant starch reserves that could be used in the metabolism, and then a slightly acid reduction is noticed in the postharvest (Paull and Chen, 2003).

Hong et al. (2013) reported that reducing sugar content varied between 2 and 3 g/100 g during storage of summer pineapple, responding to temperatures and time in a manner that both RS and non-reducing sugars (NRS) had their content reduced by nearly 28% over time (0 - 24 days), and by 23% at different temperatures (6, 10 and 25°C).

As already well reported, NRS were much higher than RS content in pineapple (Martins et al., 2012), which herein were found in the proportion of 1:3.6 (NRS:RS). In this direction, Hong et al. (2013) reported a proportion of glucose and sucrose in the pulp in summer pineapple around 1:4.

Soluble sugars are important components of fruit quality, especially in pineapple, which is mainly composed of sucrose, glucose, and fructose (Hong et al., 2013). Higher sugar content in the uncoated pineapples (C) is possibly due to a higher metabolic rate, which is corroborated by higher SS and weight loss as a result of water loss and a possible concentration of the sugars. Therefore, coatings may act in attenuating the metabolic rate of 'Pérola' pineapples, especially those coated with SA and SE, which kept intermediate values of NRS and TS.

Higher acidity is one of the quality features that contribute to 'Pérola' pineapple preference by Brazilian consumers, in addition to being one of the main components of the pineapple taste which is balanced by the high sugar content (Berilli et al., 2011).

The addition of ascorbic acid or the elicitor improved the characteristics of the cassava starch-alginate film, impacting on the reduced metabolism of the 'Pérola' pineapples. Positive effects on fruit quality were also reported by Chiumarelli et al. (2011) for combination of carbohydrate polymeric matrix with antioxidants, and by Azerêdo et al. (2016) with plant extracts.

On the other hand, starch-alginate + elicitor (SE) and starch-alginate + ascorbic acid (SA) coated pineapples maintained the CO throughout storage, probably due to a positive effect of the ascorbic acid or the elicitor added to the polymeric matrix. Appearance is one of the main factors that influence consumers' purchase intentions (Azerêdo et al., 2016). Thus, coatings that are able to preserve the appearance of fruits are desirable for marketing.

In turn, color development was retained for SA- and SE-coated pineapple, and the scores for appearance were higher, indicating the efficiency of these coatings in keeping the fruit quality. GA evaluation was affected by all the previous sensory attributes, and reflected the panelists' perception about the overall quality as a trained judge and a consumer of pineapple, which enabled a more realistic judgement (Miguel et al., 2010). Importantly, the use of coatings postharvest would be efficient if they do not promote the buildup of off taste or off odor in the pulp, indicating that fruit quality maintenance can be achieved without affecting the sensory characteristics (Azarakhsh et al., 2014).

For SA and SE coatings, reduced permeability to oxygen and the combinations of the polymeric matrix with ascorbic acid and flavonoid elicitor provided a reduction in the metabolic rate (Ali et al., 2013), resulting in quality maintenance, and thus increasing the postharvest life. Uncoated pineapples continued their higher metabolism at room conditions, especially using the soluble sugars (Hong et al., 2013), resulting in faster decline in quality compared with the coated ones.

Conclusion

Overall, 'Pérola' pineapples coated with cassava starch-alginate added with ascorbic acid (SA) or elicitor (SE) had preserved sensory characteristics and weight loss minimized at 23°C, extending the postharvest life from 12 to 18 days. Furthermore, fruit coated with SE and SA presented lower levels of reducing and total sugars, which indicates a delay in ripening. These effects along with better appearance and general acceptance confirm the positive impact of cassava-alginate coating associated with antioxidants as a potential alternative for maintaining quality and enhancing the postharvest life of 'Pérola' pineapples maintained at room conditions. Thus, in 'Pérola' pineapples coated with SA and SE, maintenance of good appearance and characteristic taste, as well as lower weight loss were the main factors for the higher general acceptance.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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