CHEMICAL ENGINEERING TRANSACTIONS
VOL. 75, 2019
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Sauro Pierucci, Laura Piazza

ISBN 978-88-95608-72-3; **ISSN** 2283-9216
DOI: 10.3303/CET1975081

Application of Cassava Starch Coating Prepared with Stevia Leaf-washing Water for Increasing the Postharvest Life of Strawberries

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The objective of this study was to evaluate the effect of the addition of cassava starch coating enriched or not with bioactive compounds from stevia leaf-washing water on the physical and chemical characteristics of strawberries during storage at refrigerated (4°C) or room (25°C) temperatures. The cassava starch coating was effective in increasing the postharvest life of strawberries and reduce the ripening process (decreased mass loss and maintenance of the texture, total soluble solids and color parameters). The presence of bioactive compounds from stevia leaf-washing water enhanced the coating effect, resulting in products with lower mass loss and TSS values, and higher pH. The refrigerated temperature was more effective in the maintenance of the strawberry's characteristics during storage.

1. Introduction

The strawberry (*Fragaria ananassa*) is a widely marketed fruit, mainly due to the sensory characteristics and nutritional properties (Ventura-Aguilar et al., 2018). Its postharvest life is short, due to the high sensitivity to mechanical and physiological damages, weight loss and fungal contamination (Hajji et al., 2018).

Biodegradable coatings can provide a barrier against moisture and gases, improve mechanical properties, contribute to microbial protection, and prologue the postharvest life of fruits (Divya et al., 2018). Cassava starch is one of the most interesting materials, because of its physical properties, workability, biodegradability, easiness of use and low cost (Quirino et al., 2018). The incorporation of components with antioxidant and antimicrobial activities in biodegradable coatings, such as essential oils (Aquino, Blank & Santana, 2015; Ventura-Aguilar et al., 2018) and natural antifungals (Hajji et al., 2018) is a novel way to extend the postharvest life of fruits (Hajji et al., 2018). The incorporation of bioactive compounds could protect fruits against microbiological damage and potentiate the coating action (Ventura-Aguilar et al., 2018).

Stevia is a sweetener composed of stevioside and its anomers (rebaudioside), which is extracted from the leaves of *Stevia rebaudiana* Bertoni. The processing of stevia results in a leaf-washing water, which is rich in bioactive compounds (polyphenols, chlorophylls, carotenoids, and ascorbic acid) and exhibits antioxidant and antimicrobial activity (Kovacevic et al., 2018).

The use of this water in conjunction with cassava starch could result in coatings rich in bioactive compounds and, consequently, strawberries with increased shelf life. The objective of this study was to evaluate the effect of the addition of starch coatings enriched or not with bioactive compounds from stevia leaf-washing water on the physical and chemical characteristics of strawberry during refrigerated (4°C) or room temperature (25°C).

Paper Received: 19 March 2018; Revised: 30 June 2018; Accepted: 13 September 2018

Please cite this article as: Da Rocha A., Dos Santos H., De Souza H.M., Matioli G., Barao C.E., Pimentel T., Coimbra L., Marcolino V., 2019, Application of Cassava Starch Coating Prepared with Stevia Leaf-washing Water for Increasing the Postharvest Life of Strawberries, Chemical Engineering Transactions, 75, 481-486 DOI:10.3303/CET1975081

2. Materials and Methods

2.1 Preparation of the starch solution and strawberry coating

Fruits of the '*Fragaria* sp' type, same ripening stage, no defects and good conservation status were selected. The fruits were washed with distilled water and sanitized with chlorinated water (50 ppm).

Three treatments were performed: 1A (with cassava starch coating and room temperature), 2A (with cassava starch coating enriched with bioactive compounds and room temperature), 3A (without cassava starch coating and room temperature), 1B (with cassava starch coating and refrigerated temperature), 2B (with cassava starch coating enriched with bioactive compounds and refrigerated temperature), 3B (without cassava starch coating and refrigerated temperature). The coating solution was prepared by dispersing 3 g of cassava starch in 100 mL of distilled water (1) or stevia leaf-washing water (2) and the solution was mixed for 30 min at 85°C. To increase the starch elasticity, 0.9% glycerol was added. After that, the temperature was reduced (25°C), and the strawberries were dipped in the solution for 3 min (Ventura-Aguilar et al., 2018). The fruits were stored in plastic boxes at room (25°C) or refrigerated (4°C) temperatures for 12 days. Measurements were carried out on days 1, 4, 6, 8, 10 and 12. The stevia leaf-washing water contained 86.7 mg EAG/L of total phenolic compounds and was provided by Stevita® (Maringá, Brazil).

2.2 Physical and chemical analysis

The fruits were weighed in a digital semi-analytical balance and their mass loss was determined by the difference between the initial and the final mass (Ventura-Aguilar et al., 2018). The pH was determined using a digital potentiometer (MS Tecnopon Instrumentation, mPA210, Piracicaba, Brazil). The total soluble solids (TSS) content was determined in a digital refractometer (Instruterm®, RTD model, São Paulo, Brazil) and expressed in °Brix. Prior to analysis, each fruit was macerated and homogenized.

For color instrumental evaluation (L*, a* and b*), a colorimeter (Konica Minolta, CR-400, Osaka, Japan) was used. The texture characteristics were evaluated using the Texture Analyzer TA-TX.Express (Stable Micro Systems, Extralab Brazil). The Probe Needle (P2N) was used, with penetration speeds of 2 mm/s in the pre-test phase, 1 mm/ s in the test phase and 2 mm/s in the post-test phase, and compression distance of 3 mm.

2.3 Statistical analysis

The experiment was repeated twice and followed a completely randomized design. Each treatment had 18 fruits in each replication for each day of storage. A split plot design was used to analyze the data (main treatment was the formulation and the secondary treatment was the storage time). The results were submitted to analysis of variance (ANOVA) and Tukey test (p = 5%) using the software Assistat.

3. Results and Discussion

The visual evaluation of the strawberries during the postharvest period indicated that up to the 9th day of storage all the fruits under refrigerated storage were adequate and marketable. For the products stored at room temperature, the strawberries without coating started to lose the appearance quality from the 4th day of storage, while the strawberries with starch coating had no visual changes for at least 6 days. The fruits suffered a sharp drop in their visual appearance from the 12th day, becoming non-marketable. In this way, the postharvest period considered in the present study was of 12 days, corroborating previous studies (11-17 days) (Ventura-Aguilar et al., 2018, Hajji et al., 2018).

The application of cassava starch coating resulted in a decrease in the mass loss of the strawberries stored at room temperature (1A and 2A) or under refrigeration (1B and 2B) when compared to products without coating (3A and 3B) ($p \leq 0.05$), with reductions of up to 87% (Table 1). The protective effect of the coating was more pronounced in the products stored at room temperature ($p \leq 0.05$), since the reduction in mass loss was observed from the 1st day of storage, whereas for the refrigerated products the effect was only significant from the 6th day. The protection is associated with the starch filmogenic properties, which acts as a barrier to water vapor and gas exchange, reducing water loss through transpiration (Ventura-Aguilar et al., 2018, Hajji et al. 2018).

The strawberries with cassava starch coatings made with leaf-washing wastewater had decreased mass loss ($p \leq 0.05$, 2A) after the 10th day of storage at room temperature (1A). At refrigeration temperature, the protective effect was observed only on day 10 (2B vs 1B; $p \leq 0.05$). The results indicate that the presence of bioactive compounds in the cassava starch coatings intensified the protective effect of the coatings against mass loss, mainly in the final periods of storage. In fact, antioxidants can act as additional barriers to gases, water vapor and movement of solutes, contributing to the reduction of the mass loss (Hajji et al., 2018).

Table 1: Mass loss of the strawberries

		25ºC			4ºC		
	Storage time (days)	1A	2[a]	3A	1B	2B	3B
Mass loss (%)	1	$1.42^{cB\pm0.09}$	$2.08^{dB\pm1.20}$	$10.85^{cA\pm0.66}$	$0.94^{eA\pm0.91}$	$0.81^{eA\pm0.96}$	$3.79^{eA\pm1.98}$
	4	$1.81^{cB\pm0.46}$	$3.56^{dB\pm1.57}$	$11.29^{cA\pm1.21}$	$6.86^{deA\pm0.22}$	$1.81^{eA\pm0.46}$	$6.90^{eA\pm0.38}$
	6	$16.90^{cB\pm1.00}$	$20.21^{cAB\pm2.83}$	25.11cA$^{\pm0.04}$	$7.17^{dB\pm2.29}$	$9.09^{dB\pm1.03}$	$20.53^{dA\pm0.52}$
	8	$36.50^{bB\pm6.54}$	$36.15^{bB\pm0.81}$	$51.51^{bA\pm1.03}$	$21.98^{cB\pm1.59}$	$18.59^{cB\pm2.08}$	$30.99^{cA\pm0.43}$
	10	$59.69^{aA\pm1.34}$	$45.55^{abB\pm0.86}$	$62.58^{bA\pm0.19}$	$31.86^{bB\pm0.45}$	$25.57^{bC\pm1.49}$	$42.61^{bA\pm1.88}$
	12	$64.98^{aB\pm1.17}$	$54.56^{aC\pm3.51}$	$83.18^{aA\pm3.40}$	$40.56^{aB\pm4.56}$	$43.77^{aB\pm2.88}$	$53.75^{aA\pm1.12}$

Means ± standard deviation in the same row followed by different upper-case letters indicate statistically significant differences at $p \leq 0.05$ between treatments of strawberries for the same storage day (n=36). Means ± standard deviation in the same column followed by different lower-case letters indicate statistically significant differences at $p \leq 0.05$ for each treatment affected by storage time (n=36).

The strawberries (with or without coating) behaved in a similar manner during storage, with increased mass loss with the increase in the storage period ($p \leq 0.05$). The fruits stored under refrigeration presented lower weight loss (0.81-53.7%) than those stored at room temperature (1.42-64.98%). Strawberries are fruits that present high mass loss during storage (Hajji et al., 2018).

The strawberries showed firmness (1.31 to 11.91 N), compression (160 to 2055 N) and bioyeld point (14.7 to 28.6) (Table 2) similar to previous study (Ventura-Aguilar et al., 2018). The application of cassava starch coating resulted in the maintenance of higher firmness values in the strawberries stored at room temperature (1A and 2A) or under refrigeration (1B and 2B) when compared to products without coating (3A and 3B) ($p \leq 0.05$). The protective effect of the cassava starch coating was more pronounced in the products stored under refrigeration, as higher values of firmness were observed in the whole storage period, whereas in products stored at room temperature the effect was only observed until day 8.

Regarding compression, there was oscillation in the values during the storage period at room temperature. However, in a general view, there was a protective effect of the addition of cassava starch coating ($p \leq 0.05$), observed on days 4 and 6 of storage. For strawberries stored under refrigeration, the addition of the coating resulted in products with higher values of compression ($p \leq 0.05$), indicating that the coating maintained the texture of the products for a longer period. The protection of the starch coating against the loss of firmness and compression is associated to the modification in the internal atmosphere of the products, as the starch can form semipermeable films, reducing the concentration of O_2 and increasing the concentration of CO_2, with inhibition of the enzymes responsible for the reduction of fruit firmness (Hashim et al., 2018). Thus, starch coatings can delay the degradation of components responsible for fruit stiffness, especially insoluble pectin and protopectin (Ibrahim et al., 2017).

The utilization of stevia leaf-washing water in the cassava starch coatings (2A) had no effect on the firmness, compression and bioyeld point ($p > 0.05$) of strawberries stored at room temperature (1A). For strawberries stored under refrigeration, the compression value was lower in the products made with stevia-leaf water (2B) than those with conventional coating (1B) ($p \leq 0.05$), with values closer to those of the control products (3B). The results indicate that the presence of the bioactive compounds in the cassava starch coatings had no impact on the texture characteristics of the strawberries, but maintained the initial protection exerted by the coating. During storage, the strawberries (with or without coating) behaved in a similar manner, with decreases in firmness, compression and Bioyeld Point values ($p \leq 0.05$). The loss in the texture parameters during the storage period is related to the enzymatic hydrolysis of the cell wall components, starch hydrolysis and water loss, collaborating for the fruit softening (Ventura-Aguilar et al., 2018). The fruits stored under refrigeration presented, in a general view, higher values of firmness and compression than those stored at room temperature. The conservation of fruits under low temperatures decreases the metabolic activity, reduces the enzymes activity, and reduces tissue softening (Ibrahim et al., 2017).

The strawberries presented TSS of 4.8 to 9.6 ^{o}Brix and pH of 3.2 to 3.6 (Table 3), corroborating previous studies (Ventura-Aguilar et al., 2018; Hajji et al., 2018). The application of cassava starch coating resulted in lower TSS values in the strawberries stored at room temperature (1A and 2A) or under refrigeration (1B and 2B) when compared to products without coating (3A and 3B) ($p \leq 0.05$), indicating that the coating exerted a protective effect of retarding the ripening of the fruits. The application of biodegradable coatings results in a reduction in the respiratory rate and metabolic activity of the fruits, reducing the synthesis and the use of metabolites and the hydrolysis of carbohydrates to sugars (Aquino et al., 2015).

Table 2: Texture parameters of the strawberries

	Storage time (days)	25ºC			4ºC		
		1A	2A	3A	1B	2B	3B
Firmness (N)	1	11.13$^{aA\pm1.99}$	10.74$^{aA\pm4.19}$	7.93$^{aB\pm3.08}$	11.72$^{aA\pm3.62}$	11.91$^{aA\pm3.18}$	7.25$^{aB\pm2.23}$
	4	9.78$^{abA\pm4.02}$	6.94$^{bB\pm2.14}$	6.40$^{abB\pm3.16}$	8.59bA$^{\pm2.38}$	9.90$^{bA\pm5.23}$	6.48 bB$^{\pm2.27}$
	6	7.67$^{bcA\pm3.60}$	6.96$^{bA\pm2.82}$	6.84 $^{aA\pm3.25}$	8.89$^{bcA\pm2.48}$	9.20$^{bcA\pm0.74}$	5.02$^{bcB\pm0.92}$
	8	5.40$^{cA\pm1.60}$	5.37$^{bcA\pm1.39}$	3.01$^{cB\pm1.19}$	8.66$^{cA\pm2.15}$	7.62$^{cA\pm1.00}$	3.70$^{cB\pm2.18}$
	10	5.40$^{cA\pm1.60}$	3.18$^{cdB\pm1.69}$	3.87$^{bcAB\pm2.57}$	8.72$^{cA\pm2.38}$	7.52$^{cA\pm1.61}$	2.68$^{cB\pm0.76}$
	12	1.83$^{dA\pm0.83}$	1.73$^{dA\pm1.15}$	1.99$^{cA\pm1.95}$	7.22$^{dA\pm3.18}$	7.52$^{cA\pm1.61}$	1.31$^{dB\pm0.84}$
Bioyeld Point Freshness	1	28.61$^{aA\pm5.14}$	24.90$^{aAB\pm7.20}$	26.52$^{aB\pm7.82}$	23.03$^{aAB\pm3.00}$	23.41$^{aA\pm2.81}$	25.57$^{aB\pm3.99}$
	4	25.51 $^{bA\pm5.78}$	24.62$^{bAB\pm7.93}$	19.11$^{bB\pm4.41}$	22.21$^{bAB\pm4.15}$	22.52$^{bA\pm3.64}$	21.19$^{bB\pm3.78}$
	6	20.74$^{bcA\pm4.22}$	20.87$^{bcAB\pm3.08}$	19.78$^{bcB\pm3.98}$	18.10$^{cdAB\pm4.13}$	20.13$^{cdA\pm3.30}$	17.37$^{cdB\pm3.26}$
	8	20.57$^{cA\pm4.44}$	19.61$^{cAB\pm3.39}$	17.92$^{cB\pm2.65}$	18.72 $^{cAB\pm5.27}$	20.03$^{cA\pm3.73}$	16.98$^{cB\pm2.25}$
	10	18.19$^{cdA\pm3.75}$	19.78$^{cdAB\pm4.72}$	17.47$^{cdB\pm5.06}$	17.32$^{cdAB\pm2.13}$	18.76$^{cdA\pm1.93}$	15.06$^{cdB\pm3.59}$
	12	16.85$^{dA\pm4.03}$	16.28$^{dAB\pm3.41}$	16.03$^{dB\pm2.46}$	15.99$^{dAB\pm3.03}$	18.67$^{dA\pm4.86}$	14.77$^{dB\pm2.77}$
Compression (N)	1	2054$^{aA\pm255.0}$	1462$^{aB\pm306.15}$	2098$^{aA\pm158.39}$	1840$^{aA\pm100.49}$	1717$^{aB\pm158.19}$	1500$^{aC\pm240.90}$
	4	1036$^{bA\pm435.32}$	1247$^{aA\pm135.27}$	482$^{bB\pm51.78}$	1812$^{aA\pm127.16}$	1374$^{aB\pm115.48}$	1286$^{aC\pm93.01}$
	6	924$^{bA\pm467.49}$	1281$^{aA\pm361.17}$	250$^{bB\pm48.55}$	1354$^{bA\pm124.00}$	1209$^{bB\pm118.17}$	1166$^{bC\pm51.44}$
	8	617$^{bA\pm161.20}$	446$^{bA\pm109.96}$	229$^{bA\pm50.60}$	1206$^{bA\pm160.74}$	1068$^{bB\pm59.34}$	943$^{bC\pm151.62}$
	10	544$^{bA\pm257.69}$	338$^{bA\pm6.59}$	188$^{bA\pm114.52}$	788$^{cA\pm44.20}$	798$^{cB\pm66.38}$	650$^{cC\pm55.21}$
	12	363$^{bA\pm55.05}$	326$^{bA\pm109.70}$	160$^{bA\pm52.45}$	720$^{cA\pm89.34}$	758$^{cB\pm50.15}$	520$^{cC\pm177.38}$

Means ± standard deviation in the same row followed by different upper-case letters indicate statistically significant differences at $p \leq 0.05$ between treatments of strawberries for the same storage day (n=36). Means ± standard deviation in the same column followed by different lower-case letters indicate statistically significant differences at $p \leq 0.05$ for each treatment affected by storage time (n=36).

The utilization of stevia leaf-washing water in the cassava starch coatings (2A) resulted in decreased TSS values in the strawberries ($p \leq 0.05$) stored at room temperature (1A). At refrigeration temperature, the product with coating enriched with bioactive compounds presented higher TSS values than the product added only with the coating until the 6th day of storage ($p \leq 0.05$), and similar TSS in the other evaluated periods ($p > 0.05$). The results indicate that the presence of the bioactive compounds in cassava starch coatings enhanced the protective effect of the coatings against the advance of ripening for products stored at room temperature. At refrigeration temperature, the effect was similar to the product only with cassava starch coating. During storage, the strawberries (with or without coating) behaved in a similar manner, with increase in TSS value ($p \leq 0.05$). During ripening, there are molecular changes in the cell wall structure of the polysaccharides and increases in the concentration of soluble pectin and sugars (Ventura-Aguilar et al., 2018). The pH of the strawberries presented oscillation during the storage period, however, in a general view, the application of cassava starch coatings resulted in strawberries with lower pH values ($p \leq 0.05$). Thus, although the coating addition promoted improvements in mass loss (Table 1) and texture characteristics (Table 2), it was not able to stop the pH decrease associated with the fruit ripening process. The utilization of stevia leaf-washing water in the cassava starch coatings resulted in products with higher pH values in most evaluated periods ($p \leq 0.05$). The results indicate the protection of the bioactive compounds to the strawberry ripening process, with delayed acid production (Muñoz-Labrador et al., 2018). During storage, the strawberries (with or without film) behaved in a similar manner, with a decrease in the pH values ($p \leq 0.05$). The strawberries presented L* of 21-33, a* of 5.48 to 32 and b* of 7.1 to 19.7 (dark red color, Table 4). The application of cassava starch coating resulted in higher values of L*, a* and b* regardless of the temperature ($p \leq 0.05$). In this way, the application of the coating resulted in products lighter and reddish than the products without coating. The change in L* may be related to the color of cassava starch semi-transparent films. The results indicate that there was protection of the red color (a*) with the addition of the starch coating, possibly due to the lower enzymatic activity (Muñoz-Labrador et al. 2018).

Table 3. Total soluble solids (TSS) and pH of the strawberries

		25 ºC			4 ºC		
	Storage time (days)	1A	2A	3A	1B	2B	3B
TSS	1	$5.20^{dB\pm0.17}$	$4.83^{dC\pm0.11}$	$7.66^{cdA\pm0.05}$	$4.53^{dC\pm0.05}$	$5.43^{cB\pm0.11}$	$6.03^{eA\pm0.05}$
	4	$6.46^{bcB\pm0.32}$	$5.26^{cdC\pm0.05}$	$7.30^{dA\pm0.52}$	$5.33^{cC\pm0.15}$	$5.73^{cB\pm0.05}$	$6.73^{dA\pm0.11}$
	6	$6.03^{cB\pm0.05}$	$5.66^{bcC\pm0.15}$	$7.23^{dA\pm0.28}$	$5.56^{cC\pm0.05}$	$6.80^{bB\pm0.00}$	$7.50^{cA\pm0.43}$
	8	$6.53^{bB\pm0.11}$	$5.93^{bC\pm0.05}$	$7.76^{cA\pm0.05}$	$6.66^{bB\pm0.05}$	$6.86^{bB\pm0.05}$	$7.76^{bcA\pm0.23}$
	10	$6.23^{bcB\pm0.05}$	$5.26^{cdC\pm0.05}$	$9.66^{aA\pm0.11}$	$7.00^{bB\pm0.01}$	$7.06^{bB\pm0.05}$	$8.00^{bA\pm0.01}$
	12	$7.53^{aC\pm0.05}$	$8.33^{aB\pm0.05}$	$7.66^{cdA\pm0.05}$	$7.83^{aC\pm0.05}$	$8.23^{aB\pm0.05}$	$10.36^{aA\pm0.05}$
pH	1	$3.55^{abB\pm0.03}$	$3.96^{aA\pm0.04}$	$3.66^{bB\pm0.02}$	$3.55^{aA\pm0.03}$	$3.56^{aA\pm0.02}$	$3.65^{aA\pm0.02}$
	4	$3.58^{aB\pm0.16}$	$3.42^{bB\pm0.11}$	$3.91^{aA\pm0.11}$	$3.43^{bB\pm0.02}$	$3.51^{abA\pm0.01}$	$3.64^{aA\pm0.02}$
	6	$3.45^{abB\pm0.05}$	$3.47^{bB\pm0.03}$	$3.56^{bcA\pm0.03}$	$3.53^{aB\pm0.01}$	$3.46^{bB\pm0.04}$	$3.60^{aA\pm0.01}$
	8	$3.51^{abA\pm0.04}$	$3.48^{bA\pm0.05}$	$3.57^{bcA\pm0.05}$	$3.42^{bB\pm0.01}$	$3.47^{bB\pm0.01}$	$3.63^{aA\pm0.03}$
	10	$3.41^{bB\pm0.03}$	$3.41^{bB\pm0.05}$	$3.44^{cdA\pm0.01}$	$3.30^{cA\pm0.04}$	$3.34^{cA\pm0.02}$	$3.33^{bA\pm0.04}$
	12	$3.23^{cB\pm0.01}$	$3.48^{bA\pm0.06}$	$3.32^{dAB\pm0.02}$	$3.28^{cB\pm0.04}$	$3.38^{cA\pm0.01}$	$3.36^{bA\pm0.02}$

Means ± standard deviation in the same row followed by different upper-case letters indicate statistically significant differences at p ≤ 0.05 between treatments of strawberries for the same storage day (n=36). Means ± standard deviation in the same column followed by different lower-case letters indicate statistically significant differences at p ≤ 0.05 for each treatment affected by storage time (n=36).

Table 4. Color parameters (L, a* and b*) of the strawberries*

		25 ºC			4 ºC		
	Storage time (days)	1A	2A	3A	1B	2B	3B
L*	1	$32.07^{aA\pm1.19}$	$30.72^{aB\pm1.75}$	$29.16^{aC\pm2.19}$	$33.23^{aA\pm3.57}$	$29.47^{aB\pm1.36}$	$26.82^{aC\pm1.35}$
	4	$31.04^{abA\pm3.39}$	$28.00^{abB\pm2.12}$	$28.22^{abC\pm1.48}$	$23.30^{bA\pm1.43}$	$27.64^{aAB\pm1.13}$	$25.22^{aB\pm4.26}$
	6	$30.81^{bcA\pm2.76}$	$28.63^{bcB\pm1.03}$	$25.57^{bcC\pm1.66}$	$27.50^{bA\pm2.22}$	$28.72^{aA\pm1.24}$	$24.54^{aB\pm2.94}$
	8	$29.99^{bcA\pm3.74}$	$27.14^{bcB\pm3.87}$	$25.95^{bcC\pm3.16}$	$27.77^{bA\pm2.75}$	$28.08^{aA\pm3.49}$	$24.95^{aB\pm2.88}$
	10	$27.83^{cA\pm2.04}$	$27.56^{cB\pm2.28}$	$25.36^{cC\pm3.19}$	$26.34^{bA\pm0.83}$	$21.00^{bB\pm1.67}$	$24.68^{aA\pm3.79}$
	12	$26.09^{dA\pm3.02}$	$25.37^{dB\pm2.39}$	$24.96^{dC\pm1.02}$	$25.65^{bA\pm1.92}$	$21.41^{bB\pm1.80}$	$24.15^{aA\pm3.02}$
a*	1	$32.34^{aA\pm4.17}$	$24.37^{aB\pm1.85}$	$22.69^{aB\pm2.71}$	$30.55^{aA\pm3.40}$	$24.84^{aB\pm2.29}$	$27.09^{aB\pm1.27}$
	4	$30.00^{aA\pm3.33}$	$23.68^{abB\pm1.84}$	$21.97^{aB\pm3.56}$	$30.33^{aA\pm3.47}$	$22.87^{abC\pm2.94}$	$27.25^{aB\pm1.62}$
	6	$22.47^{bA\pm1.13}$	$23.26^{abA\pm2.37}$	$21.42^{aA\pm2.13}$	$24.37^{bcA\pm1.97}$	$22.53^{abA\pm1.89}$	$23.81^{bA\pm1.70}$
	8	$22.98^{bA\pm1.44}$	$20.56^{bcAB\pm1.84}$	$19.33^{abB\pm2.14}$	$24.64^{bC\pm2.17}$	$22.43^{abA\pm1.48}$	$23.45^{bA\pm1.68}$
	10	$22.00^{bA\pm2.12}$	$18.15^{cB\pm2.37}$	$16.59^{bcB\pm2.00}$	$21.47^{cA\pm2.14}$	$22.53^{abA\pm2.49}$	$23.19^{bA\pm1.13}$
	12	$16.09^{cA\pm2.04}$	$16.84^{cA\pm1.96}$	$5.48^{cA\pm2.35}$	$21.71^{bcAB\pm2.22}$	$20.61^{bB\pm1.26}$	$23.91^{bA\pm1.47}$
b*	1	$19.71^{aA\pm1.27}$	$12.28^{aB\pm1.52}$	$11.53^{aB\pm2.00}$	$18.27^{aA\pm1.95}$	$15.88^{aB\pm1.30}$	$14.78^{aB\pm2.03}$
	4	$17.60^{aA\pm2.84}$	$10.96^{abB\pm1.90}$	$9.22^{abB\pm1.70}$	$15.05^{bcA\pm1.92}$	$13.65^{abAB\pm1.99}$	$11.88^{bB\pm1.59}$
	6	$13.43^{bA\pm1.52}$	$10.96^{abB\pm1.90}$	$9.43^{abB\pm2.61}$	$15.79^{abA\pm2.21}$	$11.99^{bcB\pm1.52}$	$9.17^{bcC\pm2.12}$
	8	$11.22^{bcA\pm2.52}$	$9.86^{abA\pm2.57}$	$9.65^{abA\pm1.33}$	$12.55^{cA\pm1.51}$	$10.60^{cdAB\pm2.19}$	$9.76^{bcD\pm1.52}$
	10	$9.07^{cdA\pm0.80}$	$9.70^{abA\pm2.03}$	$8.06^{bA\pm1.40}$	$8.85^{dA\pm1.00}$	$9.23^{dA\pm1.27}$	$8.85^{cA\pm1.17}$
	12	$8.07^{dA\pm1.14}$	$8.46^{bA\pm1.30}$	$7.17^{bA\pm1.59}$	$8.93^{dA\pm2.13}$	$8.15^{dA\pm0.86}$	$8.53^{cA\pm1.32}$

Means ± standard deviation in the same row followed by different upper-case letters indicate statistically significant differences at p ≤ 0.05 between treatments of strawberries for the same storage day (n=36). Means ± standard deviation in the same column followed by different lower-case letters indicate statistically significant differences at p ≤ 0.05 for each treatment affected by storage time (n=36).

The utilization of stevia leaf-washing water in the cassava starch coatings resulted in lower values of L*, a* and b* ($p \leq 0.05$) than those of the products added only with the coatings, similar to the control product ($p > 0.05$). The effect of the bioactive compounds may be related to the improved antioxidant capacity in the coating, acting as an oxygen barrier and limiting the action of enzymes responsible for enzymatic darkening (Romani et al., 2018).

During storage, the strawberries (with or without coating) behaved in a similar manner, with decrease in the color parameters ($p \leq 0.05$), that is, the products became darker and lost the characteristic red coloration. Enzymatic and oxidative processes associated with fruit ripening are observed during storage, resulting in darkening (Ventura-Aguilar et al., 2018) and reduction of the red color (Muñoz-Labrador et al., 2018).

4. Conclusion

The cassava starch coating (3%) was effective in increasing the postharvest life of the strawberries and reduce the ripening characteristics (decreased mass loss and maintenance of the firmness, compression, TSS and color parameters). The utilization of stevia leaf-washing water in the coating preparation enhanced the coating effect, resulting in products with lower mass loss and TSS values, and delayed acid production. It could decrease the coating cost application and is a sustainable alternative. The refrigerated temperature was more effective in the maintenance of the strawberries characteristics during storage.

Acknowledgments

To Federal Institute of Paraná, CNPq and Fundação Araucária for granting the scholarship and funds.

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