Uningá Review

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Evaluation of the shelf life of minimally processed cassava treated with antioxidant solution and edible cassava starch-based film

Avaliação da vida de prateleira de mandioca minimamente processada tratada com solução antioxidante e película comestível à base de fécula de mandioca

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ABSTRACT

The practicality of the easy preparation of minimally processed cassava makes this market segment a viable alternative for adding value to the product. However, there is an intensification of the alterations due to physiological deterioration of the roots in storage. In light of this, the aim of this study was to evaluate cooking time, respiration rate and physicochemical properties during the shelf life of minimally processed cassava treated with preservative antioxidant solution, cassava starch-based film-forming solution and the set of antioxidant solution and film, in addition to the control treatment. All treatments were evaluated at zero, three, six, nine, 12 and 15 days of storage under refrigeration at 4 ºC. The following analyses were conducted: colorimetry, browning index, moisture, weight loss, pH, acidity, shear force, compressive force, cooking time and respiration rate. The data were submitted to analysis of variance with repeated measures and comparison of means using Tukey's test at 5% significance. It was found that the treatments with film, preservative solution and both applied to the roots of minimally processed cassava presented the same shelf life as the control treatment. However, cassava treated only with film had higher values in respiration and acidity and although the results showed a significant difference, the preservative solution showed promising results that warrant further research in view of new formulations and tests to assess quality maintenance and storage time.

Keywords: Added value. Chemical stability. Edible film. *Manihot esculenta*. Shelf life.

RESUMO

A praticidade do fácil preparo de mandioca minimamente processada torna esse segmento de mercado uma alternativa viável para a agregação de valor ao produto. Entretanto, verifica-se a intensificação das alterações por deterioração fisiológica das raízes no armazenamento. Assim, o objetivo deste estudo foi avaliar o cozimento em função do tempo, taxa de respiração e as propriedades físico-químicas durante a vida de prateleira da mandioca minimamente processada tratada com solução antioxidante conservadora, solução formadora de película à base de fécula de mandioca e o conjunto de solução antioxidante e película, além do tratamento controle. Todos os tratamentos foram avaliados nos tempos de zero, três, seis, nove, 12 e 15 dias de armazenamento sob refrigeração de 4 ºC. As análises realizadas foram: colorimetria, índice de escurecimento, umidade, perda de peso, pH, acidez, força de cisalhamento, força de compressão, tempo de cocção e taxa de respiração. Os dados foram submetidos à análise de variância de medidas repetidas e comparação das médias pelo teste de Tukey a 5% de significância. Foi possível verificar que os tratamentos com película, solução conservadora e ambos aplicados nas raízes de mandioca minimamente processada apresentaram o mesmo tempo de vida de prateleira que o tratamento controle. No entanto, as mandiocas tratadas apenas com película tiveram valores mais elevados na respiração e acidez e, embora os resultados tenham apresentado diferença significativa, a solução conservadora demonstrou resultados promissores e que ainda devem ser melhor estudados, frente a novas formulações e testes para avaliação da manutenção da qualidade e tempo de armazenamento.

Palavras-chave: Estabilidade química. *Manihot esculenta*. Revestimento comestível. Valor agregado. Vida útil.

INTRODUCTION

The practicality found in the easy preparation of minimally processed foods contributes to this market segment, providing it with a viable alternative for adding value to such products and with a significant trend for commerce. This type of processing in fruits and vegetables involves the main steps of operation, such as cleaning, sanitizing, peeling, cutting, packaging and storage (Vidigal et al., 2015; Patil, Shams & Dash, 2023).

However, there is an intensification of changes in vegetables due to physiological deterioration, mainly caused by tissue injuries from manipulation and processing, which lead to significant interaction between enzymes and substrates, causing enzymatic browning and loss of cellular compounds and moisture. These changes lead to rapid mechanisms in metabolism and, consequently, promote a decrease in product quality, interfering with shelf life (Patil et al., 2023; Wang et al., 2023).

One of the highly consumed vegetables worldwide is the cassava (*Manihot esculenta* Crantz). It may be cooked, fried or integrated into more complex dishes. Commercially, cassava is mainly found in the form of minimally processed, refrigerated, and frozen foods. However, since processed cassava has a short shelf life, this results in waste from the industry, street markets, grocery stores and consequently in loss of capital, labor, materials used in food preparation and energy. Organic waste from the disposal of food that are already in an enzymatic browning process and undergoing other undesirable post-harvest changes also imply environmental impacts and industry inefficiency (Thuppahige, Moghaddam, Welsh, Wang & Karim, 2023).

Among possible forms of post-harvest preservation, edible coatings serve as a viable and economical alternative. Edible coatings are defined as substances used on the surface of fruits and vegetables in order to protect food from physicochemical damage, microbiological contamination and exposure to light. Usually, they are developed with lipid molecules, polysaccharides, proteins, and a mixture of both (Patil et al., 2023). One must also emphasize that coatings must be safe for consumption, along with the product itself, without posing risks to consumers. And though there are several types of edible coatings, their overall goal is defined as protecting and maintaining food quality during the post-harvest period or its processing (Chettri, Sharma & Mohite, 2023).

Thus, the goal of this study was to assess the cooking time and physicochemical properties during the shelf life of minimally processed cassava submitted to treatments with edible cassava starch coating, antioxidant preservative solution and their combination.

MATERIALS AND METHODS

Reagents

The following reagents and starch were used: ascorbic acid (Synth, Diadema/São Paulo, Brazil), citric acid (Synth, Diadema/São Paulo, Brazil), calcium chloride (Dinâmica, Indaiatuba/São Paulo, Brazil), sodium chloride (Synth, Diadema/São Paulo, Brazil) and cassava starch (Zaeli, Umuarama/Paraná, Brazil).

Samples

In this study, 576-70 cassava cultivar was used, soil type: sandy texture, associated with sandstones of Caiuá Formation, harvested 22 months after planting, cultivated at Experimental Farm (-23.79105934715043 East/West longitude, -53.255664729595686 North/South longitude) of the Department of Agronomic Sciences belonging to Umuarama Regional Campus, State University of Maringá. The region is characterized by average annual rainfall of 1.400.1 – 1.600 mm, average annual temperature between 22.1 ºC and 23 ºC and average annual relative humidity of 65.1% – 70%. According to the Köppen classification, the local climate is classified as a Cfa climate (Nitsche, Caramori, Ricce & Pinto, 2019).

Harvesting was carried out in the morning, when roots were led to the processing pilot plant and sanitized. At reception, medium roots were selected and minimally processed in the following steps: peeling, sanitizing, cutting, coating application, drying and packaging.

Treatments

Only medium cuts were used, with base and tip discarded. Treatments were based on the study conducted by Fontes, Sarmento, Spoto and Dias (2008), involving: (1) control; (2) application (immersion for two minutes) of preservative solution (1% ascorbic acid, (m:v) 0.5% citric acid (m:v), 0.25% calcium chloride (m:v) and 0.7% sodium chloride (m:v) after cutting; (3) application (immersion for two minutes) of a film-forming solution (suspension of cassava starch at 3% (m:v) and heating to 70 ºC under constant vibration and, after that, solution was allowed to reach 15 ºC so it could be applied to the roots); (4) application of a preservative solution and a film-forming solution (application for two minutes in each solution), named "preservative solution + coating".

All treatments, including the control group, were dried for 30 minutes with the help of room temperature ventilation. Roots were then placed in polyethylene trays (three pieces in each tray), wrapped in PVC film (21 µm thickness) and kept under refrigeration at 4 ºC for 15 days.

Analysis

Analysis periods were at zero, three, six, nine, 12 and 15 days, involving colorimetry analyses (Bible & Singha, 1993; Palou, López-Malo, Barbosa-Cánovas, Welti-Chanes & Swanson, 1999), measuring cooking time after submerging the roots in boiling water (Lorenzi, 1994), texture – shear force and compression (Menoli & Beléia, 2007), respiration rate (Daiuto, Vieites, Tremocoldi & Russo, 2010), weight loss, moisture, pH and total acidity (IAL, 2005). For the analysis of cooking time and respiration rate, only one reading was conducted at each time and the other ones were analyzed in triplicate.

Statistical analysis

Obtained data were analyzed by variance analysis. These results were compared using Tukey's test ($p<0.05$), comparing different times x treatment and different treatments x time, in an entirely randomized design scheme. Statistical analysis was performed with *R software*, version 4.4.0 for analyses.

RESULTS AND DISCUSSION

The visual aspect of the product was assessed by color analysis. This is one of the main attributes targeted by consumers at the time of purchase. Obtained data were demonstrated for the following parameters: L^* (luminosity), ranging from zero (black) to 100 (white); a^*, ranging from green to red (positive values indicate red coloration, negative values indicate green and zero is neutral); b^*, ranging from blue to yellow (positive values indicate yellow coloration, negative values indicate blue and zero is neutral) and browning index, with all parameters presented in Table 1.

L^* parameter showed high values due to the roots' light color (Table 1). T0, T3, T6, T9, T12 and T15 analysis times did not show significant differences for L^* values between the treatments that were evaluated. Such data suggest that the color of the roots showed intensity in relationship to luminosity, probably due to environmental contact and processing (Henrique, Prati & Sarmento, 2015); this demonstrates that, regardless of the treatment, both of them, including the control one, contributed to maintaining a light color in the samples. For a^* parameter, control showed a decrease in the negative values, indicating a possible enzymatic browning. The treatments, in turn, did not show alterations (statistical differences at 5%) over time. These results (low negative values) indicate a slight green to neutral color of the roots. It is important to mention that, for each day, one package was used for evaluation, and although the roots were harvested on the same day and processed immediately, this small difference in color may be justified by these factors. In b^* parameter, the results were positive, indicating slightly yellow coloration due to plant variation. Statistically, there was variation between treatments and storage times ($p<0.05$) only for the preservative solution and for T9, correlated with treatments. The results suggest stability in view of the changes in yellow color under evaluated conditions (treatments and time).

Browning index (Table 1), calculated as a function of L^*, a^* and b^* parameters, revealed that coating treatment and preservative solution + coating showed a clearly observable difference over the course storage time. This parameter, as mentioned earlier, is an important sensory attribute at the time of purchase. The results showed that there were significant changes throughout the storage, so that roots showed an expressive conservation over the days of evaluation compared to the treatments that were used. Thus, from the point of view of color maintenance, there is an indication for the application of minimally processed cassava treatments for up to 15 days under refrigeration, especially the preservative solution.

Data from physicochemical analyses are presented in Table 2. There were statistical differences between storage times and treatments for pH, acidity, shear force and compression variables. In view of weight loss, statistically, it did not show a reduction in cassava root weight (%). Correlated with weight loss, the percentage of root moisture also did not show a decrease in mass (water). Although no difference was observed in mass loss and moisture maintenance throughout storage time compared to treatments, according to Patil et al. (2023), coatings do help in reducing moisture loss from fruits and vegetables, consequently preventing wilting and maintaining food texture. These data are in agreement with the results of this study; however, although the control also did not present a significant difference in relation to other treatments, this difference has no implications for maintaining root quality.

Table 1
Average values of L*, a*, and b* parameters and browning index by colorimetry analysis of minimally processed cassava during 15 days of storage at 4 ºC.

Variable	Time	Control	Preservative solution	Cassava-based coating	Preservative solution + Coating
L*	T0	80.6 bA ± 5.0	80.5 bA ± 5.2	84.7 aA ± 2.3	85.8 aA ± 4.4
	T3	90.1 aA ± 0.8	88.7 aA ± 1.2	85.4 aA ± 4.2	87.7 aA ± 1.5
	T6	86.3 abA ± 3.0	85.1 abA ± 2.5	84.4 aA ± 2.5	86.3 aA ± 1.7
	T9	85.4 abA ± 4.2	87.2 abA ± 1.8	84.9 aA ± 1.2	88.4 aA ± 0.3
	T12	86.2 abA ± 1.9	86.7 abA ± 3.4	85.8 aA ± 0.5	86.6 aA ± 0.7
	T15	86.7 abA ± 1.6	86.3 abA ± 0.1	85.9 aA ± 2.1	87.5 aA ± 3.3
a*	T0	-0.7 bA ± 0.2	-1.4 aA ± 0.4	-1.3 aA ± 0.4	-1.5 aA ± 0.0
	T3	-1.5 abA ± 0.1	-1.3 aA ± 0.2	-1.3 aA ± 0.0	-1.4 aA ± 0.1
	T6	-1.4 abA ± 0.2	-1.3 aA ± 0.3	-1.1 aA ± 0.5	-1.4 aA ± 0.4
	T9	-1.5 abA ± 0.2	-1.2 aA ± 0.3	-0.9 aA ± 0.8	-1.6 aA ± 0.1
	T12	-1.6 abA ± 0.9	-1.1 aA ± 0.4	-1.1 aA ± 0.3	-1.3 aA ± 0.1
	T15	-2.0 aA ± 0.4	-1.5 aA ± 0.8	-1.3 aA ± 1.0	-1.3 aA ± 0.5
b*	T0	27.3 aA ± 3.3	26.7 aA ± 2.6	26.3 aA ± 1.3	24.1 aA ± 6.1
	T3	21.1 aA ± 0.9	19.1 bA ± 1.8	21.9 aA ± 3.3	20.3 aA ± 0.5
	T6	20.8 aA ± 1.1	20.0 bA ± 0.9	19.8 aA ± 1.8	18.8 aA ± 0.6
	T9	21.5 aAB ± 0.8	18.5 bB ± 1.2	23.6 aA ± 2.7	20.2 aAB ± 1.0
	T12	20.5 aA ± 4.4	18.6 bA ± 3.2	19.9 aA ± 1.6	18.3 aA ± 1.4
	T15	23.5 aA ± 5.8	19.7 bA ± 2.3	22.8 aA ± 7.2	21.4 aA ± 0.5
Browning index	T0	39.2 aA ± 4.0	37.5 aA ± 4.8	34.8 aA ± 3.5	31.3 aA ± 10.8
	T3	24.6 bA ± 1.1	22.4 bA ± 2.6	27.8 aA ± 6.7	24.2 aA ± 0.4
	T6	25.4 abA ± 1.1	24.8 bA ± 0.7	24.9 aA ± 1.6	22.6 aA ± 0.4
	T9	26.9 abAB ± 2.6	22.1 bB ± 1.6	30.7 aA ± 4.7	23.7 aAB ± 1.4
	T12	25.2 abA ± 6.4	22.4 bA ± 4.6	24.6 aA ± 2.4	21.9 aA ± 2.0
	T15	29.2 abA ± 9.6	23.8 bA ± 2.8	29.1 aA ± 11.1	26.0 aA ± 1.2

Source: The authors.
Notes. Different lowercase letters in the same column show statistical difference of 5% between times within the same treatment; different capital letters on the same line show statistical difference of 5% between treatments within the same time. T0: day zero; T3: day three; T6: day six; T9: day nine; T12: day 12 and T15: day 15 after treatment and storage of minimally processed cassava. L* (luminosity), ranging from zero (black) to 100 (white); a*, ranging from green to red (positive values indicate red coloration, negative values indicate green and zero is neutral) and b*, ranging from blue to yellow (positive values indicate yellow coloration, negative values indicate blue and zero is neutral).

There was significant variation in the results of acidity analysis between treatments and times (Table 2), with an increase in acidity in relation to storage up to T12 and a decrease in organic acids at T15. Corroborating this data, until T12, roots were already starting to undergo degradation due to an increase in organic acid production, justifying the increase in acidity in both treatments. However, at T15, initial root senescence is suggested with degradation of compounds. Considering all treatments, control presented statistical difference compared to other treatments; however, it did not indicate a reduction in organic acids formation, without a noticeable improvement in root preservation treated with starch composite coating at 3%, preservative solution and their association.

In analyses of root shear force in the first days (Table 2), the force expressed in N was higher than in other times, with a significant difference between times and treatments. Thus, a decrease in force was observed over time, probably due to the roots' softening during shelf life. In compression, regarding the control and preservative solution treatments, a lower force exerted on them at T0 time was notable compared to the other times. Although data showed significant differences between the variables evaluated, these alterations indicate the cassava roots' resistance to cutting and this large variation in the values obtained is probably correlated with heterogeneity of cassava root composition.

Respiration rate measured in CO_2 (Figure 1) demonstrated that T0 and T3 times showed low CO_2 concentration as a function of sample mass and time, something that is justified by the fact that roots were still recently exposed to the external environment, leading to low respiration. But at T6 time, in both treatments except for the control one, roots showed a high CO_2 rate, especially in the starch treatment, showing a high rate at T6 and T12 times. A tendency for applied treatments to increase respiration rate of minimally processed cassava roots in relation to the control treatment was observed. As demonstrated in other studies, the presence of starch-based coating favored an anaerobic environment, leading to the process of root fermentation, consequently helping to increase respiration. Another relevant factor is that with increased respiration, organic substrates such as acids are consumed (Nunes, Silva, Souza, Ferrari & Germer, 2021), thus justifying the reduction of organic acids on the last day of storage under assessment.

Table 2
Average values obtained from physical and chemical analyses of minimally processed cassava during 15 days of storage at 4 °C.

Variable	Time	Control	Preservative solution	Cassava-based coating	Preservative solution + Coating
Weight loss (%)	T0	-	-	-	-
	T3	0.5 ^{aA}± 0.3	0.5 ^{aA}± 0.3	0.5 ^{aA}± 0.7	0.5 ^{aA}± 0.4
	T6	1.1 ^{aA}± 0.3	0.9 ^{aA}± 0.8	0.9 ^{aA}± 0.7	1.4 ^{aA}± 0.7
	T9	1.2 ^{aA}± 0.2	0.7 ^{aA}± 0.4	1.3 ^{aA}± 0.8	1.4 ^{aA}± 0.8
	T12	1.4 ^{aA}± 0.1	1.0 ^{aA}± 0.6	0.8 ^{aA}± 1.2	1.5 ^{aA}± 0.3
	T15	1.4 ^{aA}± 0.8	1.1 ^{aA}± 0.4	1.6 ^{aA}± 0.4	1.9 ^{aA}± 0.8
Humidity (%)	T0	49.0 ^{aA} ± 0.0	48.6 ^{aA} ± 0.0	48.6 ^{aA} ± 0.0	48.9 ^{aA} ± 0.0
	T3	46.8 ^{aA} ± 0.0	48.8 ^{aA} ± 0.1	50.1 ^{aA} ± 0.1	43.1 ^{aA} ± 0.0
	T6	47.5 ^{aA} ± 0.0	58.2 ^{aA} ± 0.2	50.9 ^{aA} ± 0.0	46.7 ^{aA} ± 0.1
	T9	50.5 ^{aA} ± 0.0	47.4 ^{aA} ± 0.0	46.5 ^{aA} ± 0.1	52.9 ^{aA} ± 0.0
	T12	46.9 ^{aA} ± 0.0	45.2 ^{aA} ± 0.1	51.4 ^{aA} ± 0.0	50.3 ^{aA} ± 0.0
	T15	46.3 ^{aA} ± 0.0	43.5 ^{aA} ± 0.0	47.9 ^{aA} ± 0.0	47.6 ^{aA} ± 0.0
pH	T0	7.2 ^{aA} ± 0.3	7.8 ^{aA} ± 0.1	7.2 ^{aA} ± 0.1	7.0 ^{aA} ± 0.4
	T3	7.3 ^{aA} ± 0.4	7.2 ^{aA} ± 0.3	7.1 ^{aA} ± 0.3	7.4 ^{aA} ± 0.3
	T6	6.8 ^{aA} ± 0.1	6.8 ^{aA} ± 0.1	6.8 ^{aA} ± 0.2	7.0 ^{aA} ± 0.5
	T9	6.7 ^{aAB} ± 0.1	7.1 ^{aA} ± 0.1	6.8 ^{aAB} ± 0.5	6.4 ^{aB} ± 0.2
	T12	7.1 ^{aA} ± 0.5	7.0 ^{aA} ± 0.6	6.5 ^{aA} ± 0.2	6.6 ^{aA} ± 0.2
	T15	7.0 ^{aA} ± 0.5	7.5 ^{aA} ± 0.7	6.7 ^{aA} ± 0.6	6.8 ^{aA} ± 0.4
Titratable acidity (mL of NaOH mol L^{-1})	T0	8.8 ^{bcA}± 5.2	8.3 ^{bcA}± 3.6	5.6 ^{bA}± 1.8	12.6 ^{abA}± 2.4
	T3	5.3 ^{cA}± 2.0	11.1 ^{abA}± 0.6	5.2 ^{bA}± 0.2	8.8 ^{bcA}± 4.2
	T6	12.2 ^{bcAB}±2.0	11.2 ^{abAB}± 1.1	18.2 ^{aA}± 5.9	7.5 ^{bcB}± 0.9
	T9	16.6 ^{bA}± 0.9	16.0 ^{aA}± 0.7	15.3 ^{aA}± 1.2	16.4 ^{aA}± 1.2
	T12	32.9 ^{aA}± 6.4	14.1 ^{aB}± 2.9	12.4 ^{abB}± 4.0	11.2 ^{abB}± 0.7
	T15	6.2 ^{cA}± 1.1	4.3 ^{cAB}± 0.2	5.7 ^{bAB}± 1.2	3.4 ^{cA}± 0.8
Shear force (N)	T0	107.5^{aA}± 18.4	101.4 ^{aA}± 10.3	67.3 ^{abB}± 34.6	102.7 ^{aA}± 13.9
	T3	51.1 ^{bA}± 12.0	80.7 ^{aA}± 28.3	58.7 ^{abA}± 28.3	72.3 ^{abA}± 37.3
	T6	80.5 ^{abA}± 13.7	75.8 ^{aAB}± 33.4	69.3 ^{abAB}± 21.9	45.4 ^{bcB}± 12.0
	T9	47.1 ^{abA}± 8.5	71.9 ^{aA}± 10.2	44.5 ^{cA}± 1.0	51.0 ^{bcA}± 12.0
	T12	55.0 ^{bA}± 28.9	70.5 ^{aA}± 34.4	70.4 ^{abA}± 33.8	37.1 ^{cA}± 12.5
	T15	81.7 ^{abA}± 35.8	86.2 ^{aA}± 19.6	99.4 ^{aA}± 19.6	46.5 ^{bcA}± 13.1
Compressive force (N)	T0	69.1^{bcC}±13.3	95.8 ^{abBC}±45.5	161.9 ^{aA}±32.0	123.7 ^{aAB}±30.6
	T3	114.4 ^{aA}±20.5	120.8 ^{aA}±29.8	104.0 ^{bA}±23.6	124.4 ^{aA}±34.0
	T6	106.9 ^{abA}±29.9	83.5 ^{abA}±29.5	125.6 ^{abA}±32.1	91.0 ^{abA}±30.1
	T9	111.3 ^{aA}±27.8	115.5 ^{abA}±13.3	91.3 ^{bA}±24.9	94.0 ^{aA}±33.6
	T12	113.7 ^{aAB}±22.8	126.7 ^{aA}±29.4	84.1^{bB}±29.8	88.0 ^{abB}±15.5
	T15	55.7 ^{cA}± 27.6	69.5 ^{bA}±33.4	81.2 ^{bA}±38.3	45.9 ^{bA}±19.0

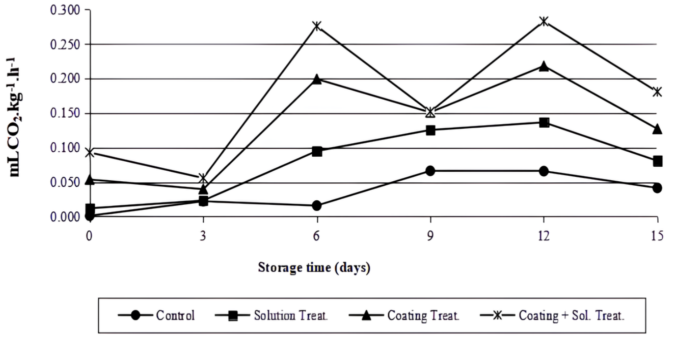
Source: The authors.
Notes. Different lowercase letters in the same column show a statistical difference of 5% between times within the same treatment; different capital letters on the same line show a statistical difference of 5% between treatments within the same time. T0: day zero; T3: day three; T6: day six; T9: day nine; T12: day 12 and T15: day 15 after treatment and storage of minimally processed cassava.

Lastly, cooking time evaluated by the minute (Figure 2) at T3, T6, T9 and T12 times showed an increase in cooking time for the roots. At T0 and T15 times, cooking time was shorter, so that at T0 time roots were collected and analyzed on the same day, indicating the shortest time after harvest and less time required for cooking. However, at T15 time, the cassava was entering a degradation state, which explains how easy it was to cook it.

According to a study conducted by Henrique, Prati and Sarmento (2010), with the use of edible coatings on minimally processed cassava with and without a vacuum, such as cassava starch and a previous treatment with ascorbic acid (5%), evaluated at a temperature of 30 ºC (estimated room temperature) during the storage period, it was found that the cassava showed physiological deterioration and apparent enzymatic browning. Visually, the use of ascorbic acid did not reduce enzymatic browning, a fact also observed in this study when preservative solution and starch + preservative solution treatments were evaluated.

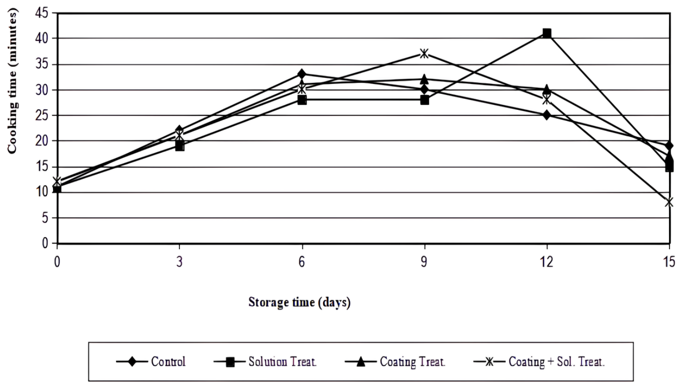
Cassava starch consists of an edible coating widely used as biopolymers, especially for its low cost and applications in food industry and packaging. Amylum, which contains starch in its composition, enables the development of colorless coatings that possess characteristics similar to synthetic ones (Patil et al., 2023). Although the results of this study were not promising regarding food preservation in relation to the control treatment, edible coatings are important in food science and technology, aiming at economy, easy preparation, microbiological and physiological safety, delay of enzymatic browning and quality maintenance, such as texture, appearance, flavor and aroma. There is an ever-growing demand for practical and healthy foods and, in turn, techniques and ways of preparing food aim to contribute to this practicality and also to reducing the use of synthetic and non-biodegradable packaging, which negatively affect the environment (Patil et al., 2023).

Figure 1
Respiration rate of minimally processed cassava with different treatments during storage of 15 days at 4 °C.



Source: The authors.

Figure 2
Cooking time (minutes) of minimally processed cassava with different treatments during storage of 15 days at 4 °C.



Source: The authors.

CONCLUSION

Treatments with starch coating, preservative solution and starch + preservative solution applied to minimally processed cassava roots showed the same shelf life compared to the control treatment. Although these results have showed a significant difference, cassava treated only with cassava starch-based coating had an increase in respiration and acidity values, emphasizing that this coating did not present benefits in post-harvest conservation and maintenance, although colorimetric evaluation presented satisfactory results. The preservative solution, in turn, showed promising results that should be studied further in view of new formulations and tests to assess quality maintenance and storage time.

COMPETING INTERESTS
The authors declare that there are no conflicts of interest.

FUNDING ACKNOWLEDGMENTS
The authors declare that they have no financial interests.

AUTHOR CONTRIBUTIONS
Conceptualization: J. C. C., J. S., C. M. F. M. *Data curation*: J. C. C. *Formal analysis*: J. C. C. *Investigation*: J. C. C. *Methodology*: J. C. C., M. G. P., R. C. H., J. S., C. M. F. M. *Project administration*: J. C. C., J. S., C. M. F. M. *Resources*: M. G. P., R. C. H., J. S., C. M. F. M. *Software*: J. C. C. *Supervision*: J. S., C. M. F. M. *Validation*: J. C. C., J. S., C. M. F. M. *Visualization*: J. C. C., N. S. P., A. L. C. F., A. B. S. *Writing the initial draft*: J. C. C., C. M. F. M. *Revision and editing of writing*: J. C. C., N. S. P., A. L. C. F., A. B. S., J. S., C. M. F. M.

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