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# Effect of cassava starch biofilm with diffusion of silver nanoparticles on the conservation of banana 'prata'

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**Abstract:** Brazil is now the world's fourth-largest banana producer in the world with an annual production of 6.953,747 tons per year. In Brazil, the banana (*Musa* spp.) stands out, not only because it is the most widespread, but also because it is the most consumed by all social classes. Cassava is a renewable, almost unlimited resource and one of the most abundant substances in nature. It is one of the most important starchy root crops of the tropics used for food and industrial purposes. The present study aimed to evaluate the use of biofilms based on cassava starch with the diffusion of silver nanoparticles (AgNP) on the conservation of banana 'Prata'. Initially, filmogenic solutions were produced using the casting technique for five treatments. Additionally, transparency**,** thickness, grammage, and, subsequently, the biofilms were applied in the film-forming solution for 1 min and suspended for further drying at room temperature. After this process, were evaluated the fresh mass loss and total soluble solids. This study revealed the efficiency of cassava starch biofilm with gelatin addition to reduce the enzymatic browning rate and increase the shelf life of bananas (*Musa* Subgroup Prata). However, no significant results were observed with the addition of commercial silver nanoparticles.

**Keywords:** enzymatic browning, shelf life, biofilms, food security.

**Adherence to the BJEDIS' scope:** This paper presents Tukey's test to analyze all the variables obtained. In addition to using regressions to determine the behavior of fresh mass loss as a function of the two biofilms during 12 days of the experiment.

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## 1. INTRODUCTION

Brazil is now the world's fourth-largest banana producer globally, with 6,953,747 tons per year (1).

Among the countless varieties of fruit produced globally, the banana stands out because it is the most widespread and because it is the most consumed by all social classes. The banana, the world's most widely produced and commercialized fruit, is grown in all tropical regions of the world, being intensely present in local businesses and subsistence crops serving as an essential source of nutrients for the poorest populations (2).

In Brazil, the banana (*Musa* spp.) stands out because it is the most widespread and consumed by all social classes (3). Biodegradable packaging, also known as biofilms, is developed by polymers from natural sources, such as corn, cellulose, and cassava.

The degradation occurs by microorganisms in weeks or months under favorable conditions of biodegradation (4). Although there are many processing possibilities for fruits, there is an increasing search for methods that less alter these foods' physical-chemical and sensory characteristics. One way to preserve the original characteristics of fruits and vegetables and increase shelf life is to apply minimal processing.

Minimally processed vegetables undergo only physical changes, maintaining their state of freshness, including operations such as selection, washing, sanitizing, peeling, cutting, centrifugation, packaging, freezing storage (5).

Despite guaranteeing a food closer to natural, minimal processing still lacks a longer shelf life. There are, however, some possibilities for mild treatments that can increase the shelf life of minimally processed vegetables and fruits. Among them, edible coatings or biofilms, bleaching, various forms of refrigeration, and the use of substances for protecting food can be highlighted (6). The present study aimed to evaluate the use of biofilms based on cassava starch with the diffusion of silver nanoparticles (AgNP) on the conservation of bananas'.

## 2. MATERIALS AND METHODS

### 2.1 Production of the film starch solution

Filmogenic solutions were developed using the casting technique, according to (7), with adaptations. Five treatments were used, as shown in table 1.

**Table 1.** Treatments for the preparation of filmogenic solution.

| Treatments | |
|---|---|
| T1 | (2,6% starch (m/v) + 0.0% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water) |
| T2 | (2,6% starch (m/v) + 0.1% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water) |
| T3 | (2,6% starch (m/v) + 0.5% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water) |
| T4 | (2,6% starch (m/v) + 1.5% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water) |
| T5 | (2,6% starch (m/v) + 3.0% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water) |

Initially, the starch was gelatinized to approximately 85 °C under constant agitation for 25 min. The gelatin was diluted with 20 mL water and added from 70°C through a drip.

### 2.1 Transparency

The transparency test was performed via analysis of the blue channel of the RGB system. The samples were photographed, opened in the freeware Gimp 2.10, from where their histograms were collected. Blue values and their respective standard deviations were noted. The average value of the standard sample's Blue channel was taken as 100% transparent. The other transparency values are proportional to the average value of the corresponding Blue channel, compared to the one of the standard sample.

### 2.2 Thickness

Biofilms' thickness was measured using a DIGIMESS micrometer with a scale from 0 to 0.25 mm with an accuracy of 0.001 mm. The final thickness corresponded to the arithmetic average of five random points from each sample (8).

### 2.3 Grammage

Grammage (G), the ratio between the solution amount by the area occupied film's area, was calculated according to the literature (9). The Equation 1 gives the weight,

$$G = 10000 * p / \alpha \qquad (1)$$

where G is the weight expressed in g/cm$^2$ p is the sample mass, and α is the sample area. With that, the result was given in g/cm$^2$.

### 2.4 Application of biofilm in fruits

The protective properties of the biofilm were tested following the treatments described in item 2.1. A negative control group (without the biofilm) was also used (10). A completely randomized design was adopted, with three replications by treatment. The fruit chosen for the covering was the chunky banana (Musa Subgroup Prata) because it is a climacteric fruit (11). They were selected by format, color, and degree of ripeness, without damage or presence of rot, all from the same bunch, purchased at a grocery in Rio de Janeiro / Brazil. The fruits were cleaned by immersion, for five minutes, in sodium hypochlorite solution (2%), followed by rinsing by immersion in freshwater before processing (12). The fruits were immersed in the film-forming solution for 1 min and suspended for further drying at room temperature.

### 2.5 Fresh mass loss

The fresh mass loss is the difference between the weight of the fruits before and after determined time intervals, equal to 3, 6, 9, and 12 days. The results are expressed as a percentage (13).

### 2.6 Totals soluble solids

The content of total soluble solids was determined using a portable refractometer, model RCZ, with a reading of the 0 a 32 ºBrix, after extracting a sample of the pulp from the central region of each fruit, the result being expressed in ° Brix (13,14).

## 3. STATISTICAL ANALYSIS

The variables' averages were compared using Tukey's test at 5% probability using the SigmaPlot 12.5 software.

## 4. RESULTS AND DISCUSSION

The biofilms synthesized by the casting technique presented an excellent aspect. They are transparent, homogeny, and flexible. Figure 1 shows the biofilms after removing them from the Petri dish.

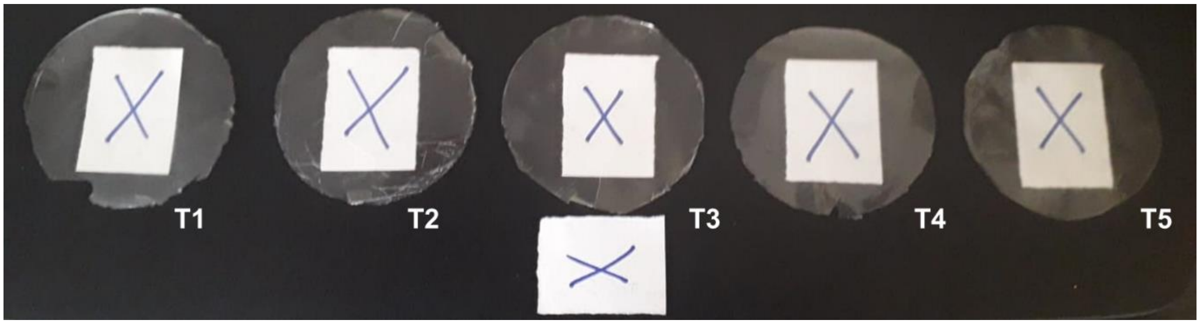


**Figure 1.** Visual aspect and transparency of cassava starch biofilms. T1 (2,6% starch (m/v) + 0.0% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water); T2 (2,6% starch (m/v) + 0.1% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water); T3 (2,6% starch (m/v) + 0.5% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water); T4 (2,6% starch (m/v) + 1.5% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water); T5 (2,6% starch (m/v) + 3.0% of AgNP (v/v) + 2.5 g of gelatin + 300 mL of distilled water).

The AgNP increase in the film's composition produced a slight change in the transparency of the materials. The average values of the Blue channel (RGB), the transparency, and their respective confidence limits with 95% probability are shown in Table 2. These values are also presented in Figure 2 as a function of the AgNP content.

**Table 2**. Blue channel values, transparency, and amount of pixels per analysis.

| Sample | Blue Scale (RGB) | Transparency (%) | Pixels (number) |
|---|---|---|---|
| Control | 0.931±0.002 | 100.0±0.2 | 7904 |
| T1 | 0.917±0.002 | 98.5±0.2 | 7904 |
| T2 | 0.923±0.002 | 99.1±0.2 | 7904 |
| T3 | 0.904±0.002 | 97.1±0.2 | 7904 |
| T4 | 0.847±0.002 | 91.0±0.2 | 7904 |
| T5 | 0.720±0.001 | 77.7±0.2 | 7904 |

Figure 2 shows that the Blue channel average values and transparency ones are linearly dependent on the AgNP concentration. The greater the amount of AgNP, the opaquer the material. The films' opacity and more yellowish appearance as a function of the AgNP amount are phenomenons known for decades due to the natural reaction between these nanoparticles and gelatin (15, 16). Therefore, the transparency results entirely agree with the increasing amounts of AgNP inserted in the film's base material.

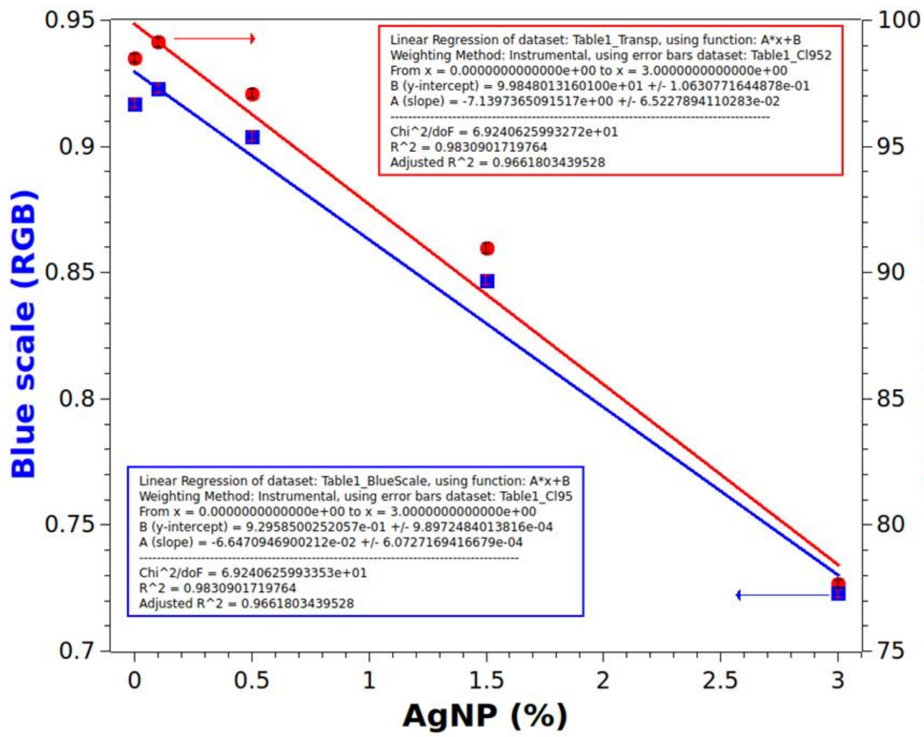


**Figure 2.** Average blue channel and transparency values as a function of AgNP amount

The means values of the thickness and grammage of the biofilms are shown in Table 3. For the T1 treatment, the thickness was 0.05 mm and the grammage 50.25 g / cm$^2$. Statistically significant differences were observed between treatments. Similar thickness results for cassava biofilm and gelatin use have already been reported (17, 18). For the T4 and T5 treatment, the thickness was 0.07 mm and the grammage 56.61 and 60.15 g / cm$^2$. The grammage is directly related to the mechanical resistance of the films. Larger weights offer greater mechanical resistance (19).

**Table 3.** Medium values of the thickness and grammage results.

| Treatments | Thickness (mm) | Grammage (g/cm$^2$) |
|---|---|---|
| T1 | 0.04$^a$ | 50.25$^a$ |
| T2 | 0.05$^b$ | 54,54$^b$ |
| T3 | 0.06$^c$ | 55,26$^c$ |
| T4 | 0.07$^d$ | 56,61$^d$ |
| T5 | 0.07$^d$ | 60,15$^e$ |
| CV (%) | 5.02 | 0.86 |

Means followed by the same lowercase letter in the column do not statistically differ from each other by Tukey's test at 5% probability. CV- Coefficient of variation.

The means values of fresh mass loss as a function of time are shown in figure 3. At the end of the analysis period, the control group had a 39.70% loss, followed by T5 (29.01%), T4 (29.00%), T3 (29.05%), T2 (26.00%), and T1 (25.50%). The best results were found in the T1 and T2 groups. Significant statistical differences were found between treatments. The mass loss occurs through the outlet in the form of water vapor to the environment (20), so the results obtained demonstrated that the biofilms protected fruits by minimizing water loss through perspiration, avoiding fruit shrinkage and shriveling as a natural indication of ripeness. observed similar results with cassava biofilm without the addition of nanoparticles (21).

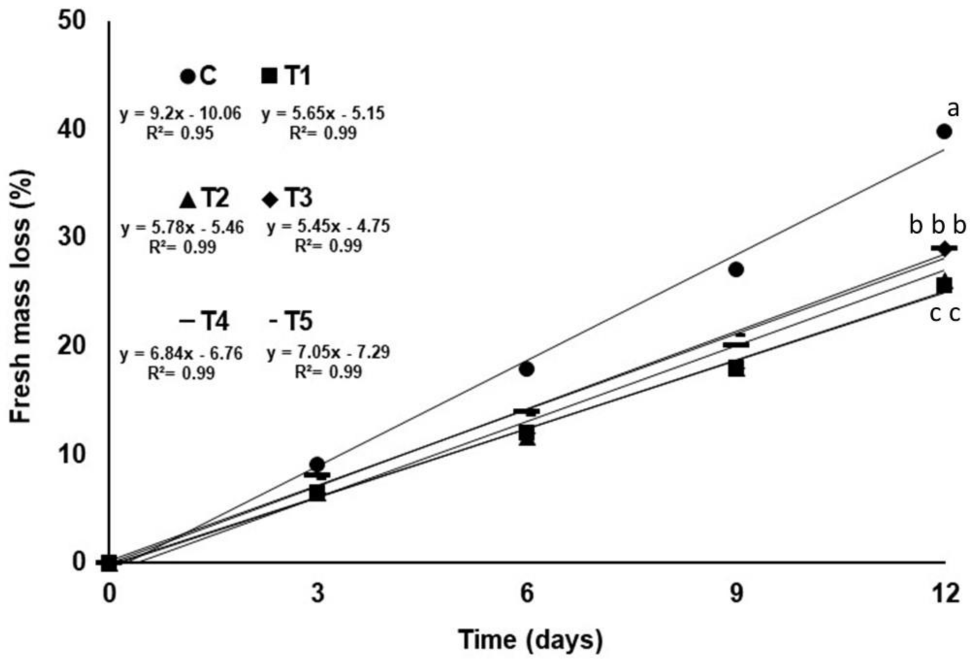


**Figure 3.** Fresh mass loss as a function of the two biofilms during twelve days of the storage. (●) Control group; (■)T1 (2,6% starch (m/v) + 0.0% of np (v/v) + 2.5 g of gelatin + 300 mL of distilled water); (▲)T2 (2,6% starch (m/v) + 0.1% of np (v/v) + 2.5 g of gelatin + 300 mL of distilled water); (♦)T3 (2,6% starch (m/v) + 0.5% of np (v/v) + 2.5 g of gelatin + 300 mL of distilled water); (—)T4 (2,6% starch (m/v) + 1.5% of np (v/v) + 2.5 g of gelatin + 300 mL of distilled water); (-)T5 (2,6% starch (m/v) + 3.0% of np (v/v) + 2.5 g of gelatin + 300 mL of distilled water). Means values followed by the same lower-case letter do not differ statistically by Tukey's test at 5% probability test.

The samples treated with biofilm T1 and T2 showed a better color, appearance and were the ones that had the most negligible loss of water during the analysis period (Figure 4). On the other hand, treatments T3, T4, and T5 showed the darkest coloration and the most significant moisture loss at the end. The application of biofilm was efficient in reducing the fruit's contact with oxygen in the air, delaying the enzymatic browning, forming a barrier to water loss, reducing exudation, and guaranteeing better quality of fruits for a longer time (17).


**Figure 4.** Application of biofilm in banana (*Musa* Subgroup Prata) during 12 days of the experiment. (A) Control group; (B) T1 (2,6% starch (m/v) + 0.0% de np (v/v) + 2.5 g de gelatin + 300 mL of distilled water); (C) T2 (2,6%

starch (m/v) + 0.1% de np (v/v) + 2.5 g de gelatin + 300 mL of distilled water); (D) T3 (2,6% starch (m/v) + 0.5% de np (v/v) + 2.5 g de gelatin + 300 mL of distilled water); (E) T4 (2,6% starch (m/v) + 1.5% de np (v/v) + 2.5 g de gelatin + 300 mL of distilled water); (F) T5 (2,6% starch (m/v) + 3.0% de np (v/v) + 2.5 g de gelatin + 300 mL of distilled water).

According to table 4, the mean values of the soluble solids content ranged from 21.5 to 25 °Brix during the 12 days of storage. Statistically significant differences were observed between treatments. T1 and T2 groups did not show significant differences. The soluble solids in bananas range from 19.72 to 22.36 °Brix for the ripe fruit (22, 23). Additionally, only groups T1 and T2 are within the reference values. Several factors are related to the content of soluble solids, among them, the state of ripeness, edaphoclimatic conditions in which the fruit was produced, conditions of artificial ripening and storage (24).

**Table 4.** Result of totals soluble solids.

| Treatments | Totals soluble solids (°Brix) |
|---|---|
| Control | 25.0$^{a}$ |
| T1 | 21.8$^{b}$ |
| T2 | 22.1$^{b}$ |
| T3 | 22.7$^{c}$ |
| T4 | 23.3$^{d}$ |
| T5 | 24.6$^{a}$ |
| CV (%) | 2.57 |

Means followed by the same lowercase letter in the column do not statistically differ from each other by Tukey's test at 5% probability. CV- Coefficient of variation.

## 5. CONCLUSION

This study revealed the efficiency of cassava starch biofilm with gelatin addition to reduce the enzymatic browning rate and increase the shelf life of bananas (*Musa* Subgroup Prata). However, no significant results were observed with the addition of commercial silver nanoparticles.

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## Sample CRediT author statement

**Sérgio Thode Filho**: Conceptualization, Methodology, Data analysis, and Writing-Original draft preparation. **Fernando Gomes de Souza Junior**: Methodology, Supervision, Data analyses, and Reviewing. **Emanuele Nunes de Lima Figueiredo Jorge**: Conceptualization, Supervision, Reviewing and Editing. **Franklin Parrini Sampaio**: Reviewing. **Ricardo Schmitz Ongaratto**: Reviewing and Editing.

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