

Postharvest coatings of ‘apple’ banana fruits

Revestimentos na pós-colheita de frutos de banana-maçã

Recubrimientos poscosecha de frutos de plátano ‘manzana’

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Abstract

Banana is a fruit of great importance for Brazilian agribusiness, in terms of consumption by the Brazilian population, second only to orange. Correct handling after harvesting is decisive to favor the longevity of the fruits during marketing, reducing losses caused by mechanical damage and poor packaging. The objective of this work was to evaluate the influence of seven post-harvest coatings on apple banana fruits. The experiment was carried out in a phytotechnic laboratory, using a completely randomized design with five replications. Each parcel consisted of a bouquet with three units of fruit. The treatments evaluated were: T1 = 28% sucupira extract solution; T2 = 57% sucupira extract solution; T3: 14% moringa extract solution; T4 = 9% grape oil solution, T5 = 14% coconut oil solution, T6 = 14% soy oil solution, T7 = 14% wax solution and T8 = Control (no coating applied). Beeswax provided the smallest losses in length, fruit diameter, and loss of fresh fruit mass during the storage period. The sucupira and moringa extracts provided the highest levels of soluble solids at the end of storage, and all coatings used in the post-harvest treatment of bananas reduced the ripening of the fruit.

Keywords: *Musa* spp.; Oils; Waxes; *Moringa oleifera*; *Bowdichia virgilioides*.

Resumo

A banana é uma fruta de grande importância para o agronegócio brasileiro, em termos de consumo pela população brasileira, só perde para a laranja. O correto manejo após a colheita é decisivo para favorecer longevidade dos frutos durante a comercialização reduzindo as perdas geradas por danos mecânicos e mal acondicionamento. Objetivou-se com este trabalho avaliar a influência de sete revestimentos pós colheita em frutos de banana maçã. O experimento foi conduzido em laboratório de fitotecnia, utilizando-se delineamento inteiramente casualizado com cinco repetições. Cada parcela foi composta por um buquê com 3 unidades de frutas. Os tratamentos avaliados foram: T1 = solução de extrato de sucupira 28%; T2 = solução de extrato de sucupira 57%; T3: solução de extrato de moringa 14%; T4 = solução de óleo de uva 9%, T5 = solução de óleo de coco 14%, T6 = solução de óleo de soja 14%, T7 = solução de cera 14% e T8 = Testemunha (sem aplicação de revestimento). A cera de abelha propiciou as menores perdas de comprimento, diâmetro dos frutos e perda de massa fresca dos frutos durante o período de armazenamento. os extratos de sucupira e

moringa propiciaram os maiores teores de sólidos solúveis no final do armazenamento e todos os revestimentos utilizados no tratamento pós colheita da banana diminuíram o amadurecimento do fruto.

Palavras-chave: *Musa* spp.; Óleos; Ceras; *Moringa oleifera*; *Bowdichia virgilioides*.

Resumen

El banano es una fruta de gran importancia para la agroindustria brasileña, en términos de consumo por parte de la población brasileña, solo superada por la naranja. Un correcto manejo después de la cosecha es decisivo para favorecer la longevidad de los frutos durante la comercialización, reduciendo las pérdidas ocasionadas por daños mecánicos y mal empaquetado. El objetivo de este trabajo fue evaluar la influencia de siete recubrimientos poscosecha en frutos de banano manzana. El experimento se llevó a cabo en un laboratorio fitotécnico, utilizando un diseño completamente al azar con cinco repeticiones. Cada paquete constaba de un ramo con 3 unidades de fruta. Los tratamientos evaluados fueron: T1 = 28% de solución de extracto de sucupira; T2 = solución de extracto de sucupira al 57%; T3: solución de extracto de moringa al 14%; T4 = solución de aceite de uva al 9%, T5 = solución de aceite de coco al 14%, T6 = solución de aceite de soja al 14%, T7 = solución de cera al 14% y T8 = control (sin recubrimiento aplicado). La cera de abejas proporcionó las pérdidas más pequeñas en longitud, diámetro de la fruta y pérdida de masa de fruta fresca durante el período de almacenamiento. los extractos de sucupira y moringa proporcionaron los niveles más altos de sólidos solubles al final del almacenamiento y todos los recubrimientos utilizados en el tratamiento poscosecha de los bananos redujeron la maduración de la fruta.

Palabras clave: *Musa* spp.; Aceites; Ceras; *Moringa oleifera*; *Bowdichia virgilioides*.

1. Introduction

The banana crop is of great importance in the world scenario; it is one of the most consumed fruits in the world. In Brazil, the banana is the second most-produced fruit, and in 2018, it yielded around 6 million tons. A large part of the production (97%) was consumed in the domestic market, and the export was almost 80 thousand tons of fresh and dried fruit in 2019 (Horti&Fruti, 2020). Its cultivation occurs predominantly on small properties, making it an important economic activity for family farmers, contributing to their settlement in the countryside (Oliveira, 2010).

It is a food with high energy potential, as 100 g of pulp is equivalent to 100 calories, carbohydrates are on average 22% and are quickly metabolized by the body, has vitamins C, A, B1, B2, and in lower amounts of vitamins D and E. Regarding minerals, this fruit is rich in potassium, phosphorus, calcium, and iron, compared to other fruits such as apples and oranges (Oliveira & Santos, 2015).

Fruits, due to their high nutrient content, excessive moisture, easily damaged texture, and high respiratory rates, are very perishable (Passos, 2014). The leading causes of fresh fruit losses are, in general, physiological, represented by excessive loss of moisture associated with storage temperature, gases such as CO₂, absence of pre-cooling of the product and accumulation of ethylene; phytopathological damage involving the aggression of microorganisms and mechanical damage, resulting from cutting, compression, impact, and vibration (Bleinroth et al., 1992). Proper processing after harvest increases the shelf life of the fruits, favoring commercialization (Oliveira & Santos, 2015).

Banana is a climacteric fruit and, therefore, it has very active breathing, carrying out a sequence of biochemical and physiological changes during ripening. Storage and ripening are decisive steps to guarantee the nutritional and qualitative aspects of the banana fruit (Bleinroth et al., 1992). The harvest point is defined, in most cases, visually by observing the disappearance of the edges of the fruits of some cultivars, in the second bunch, the diameter of the fruit and the age of the bunch (Borges et al., 2015).

This harvest point may not be well evaluated in many cases, accelerating post-harvest losses of climacteric fruits such as bananas. Kanchana et al. (2021) evaluated different harvest times of banana fruits (AAB cv. "Embul") after the plant flowering in Anuradhapura, in the north-central province of Sri Lanka. In the study, fruits were collected from 7 to 110 days after flowering. The authors observed that, for this cultivar, harvesting from 77 to 84 days after flowering is essential for foreign commerce, and, for local commerce, it is better to harvest the ripest fruits between 84 and 104 days after flowering. However, environmental and agronomic factors, such as temperature and fertilization, have a fundamental influence on the banana tree's flowering behavior.

In addition to harvesting at the right point, another key factor for increasing the banana tree's fruit quality is the well-done post-harvest management, which begins in the orchard and continues until the fruit is sold. Fruits, both climacteric and non-climacteric, are easily damaged, requiring proper post-harvest handling. Physical methods such as manual cleaning, heat treatment, modified packaging (MAP), ultraviolet light, and radiofrequency heating are simple methods that can be used for fruits after harvest (Indiarto et al., 2020).

We also have plant extracts that help post-harvest management, inhibiting the development of several pathogens (Oliveira et al., 2013). Neem and garlic extracts were considered promising in the parameters of color, weight, flesh firmness, and disease incidence, for example, when post-harvest treatment was performed for banana cultivation in the laboratory (Kamal et al., 2019). Edible coatings, such as carnauba wax and other vegetables, beeswax, vegetable oils, and cassava starch, can be used in post-harvest treatments (Silva et al., 2012).

In a study with 'Palmer' mango fruits, Junqueira et al. (2004) evaluated mango fruits, coated with soybean oil, sucupira extracts, and chemical treatment with fungicides in post-harvest treatments. In the study, they found that soybean oil, isolated or added with benomyl or thiabendazole, extended the shelf life of Palmer mango, being efficient in controlling anthracnose. Alternative post-harvest treatment increases the shelf life of fruits and vegetables and prevents losses during storage. Therefore, this study aimed to evaluate the effect of coatings on the post-harvest treatment of apple banana fruits stored under room temperature conditions in Goianésia, Goiás.

2. Material and Methods

The experiment was carried out with 'apple' banana fruits, harvested in October 2016, from the orchard under the rainfed system of the Itajá farm, municipality of Goianésia, Goiás (latitude S 15° 19' 33" and longitude W 49° 7' 2", altitude of 638 m). A completely randomized design was used, with eight treatments and five replications.

After being harvested, the bunches were transported to the Phytotechnics laboratory of Evangelical Faculty of Goianésia, Goiás state, Brazil, and cleaning and standardization of the fruits were carried out. In the laboratory, the fruits were dropped and underwent pre-cleaning, eliminating the last bunch, rachis, and cultural remains; then, there was a standard post-harvest treatment for all fruits, which consisted of immersing the fruits in a tank with water, 2% aluminum sulfate and neutral detergent for five minutes. Then, peeling, rinsing, and drying of the fruits for 20 minutes was carried out.

The fruits of the bunches were separated into bouquets (3 fingers) with an average of 226.8 g of fresh mass and measuring 103.7 mm in length and 34.6 mm in diameter and stage 1 of maturation (skin coloration) green according to the diagrammatic scale of Von Loesecke (Pbmh & Pif, 2006). Bouquets were selected and standardized by size and absence of visual damage or defects; each bouquet constituted a sampling unit (experimental portion).

The previously standardized and clean fruits were prepared for post-harvest treatments according to (Table 1).

Table 1. Post-harvest treatments were applied to ‘apple’ banana fruits in 2016 in Goianésia, Goiás states, Brazil.

Code	Treatments
T1	Sucupira extract 28%
T2	Sucupira extract 57%
T3	Moringa extract 14%
T4	Grape oil 9%
T5	Coconut oil 14%
T6	Soybean oil 14%
T7	Wax 14%
T8	Witness

Source: Authors.

The preparation of the coatings consisted of grinding, with the aid of a blender, separately the seeds of sucupira (*Pterodon emarginatus*) and leaves of moringa (*Moringa olerifera* Lambert), both with the addition of 500 ml of distilled water. The sucupira seeds were acquired in the local market (fairs) in the city of Goianésia, Goiás state. The moringa leaves were obtained from plants grown on the campus of the Goiano Federal Institute campus Ceres. The grinding time varied according to each treatment and consisted of 90 and 120 seconds for treatments 1 and 2, respectively, and 30 seconds for the moringa leaves (treatment 3). Then, the solutions were placed in separate containers, to which 100 ml of hydrated ethyl alcohol were added in each treatment and left for 24 hours.

For beeswax (treatment 7), the bar was cut into small pieces and heated in a bain-marie until the wax dissolved. The oils (treatments 4, 5, and 6) were added in distilled water at the time of application to the fruits, stirring with a glass rod throughout the handling of each treatment.

Except for treatment 7 (beeswax), the immersion was quick; the other treatments were applied by immersion in solution for 2 minutes. After applying the treatments, the fruits were kept on a masonry bench at room temperature (average of 30°C, with a minimum of 25.5°C and a maximum of 35.5°C) for 12 days phytotechnics laboratory of Evangelical Faculty of Goianésia, Goiás state.

The physical and ripening evaluations of the fruits were carried out every two days until the 12th day of storage. The ripening of banana fruits over the period was performed according to the diagrammatic scale of Von Loesecke (Pbmh & Pif, 2006). Total soluble solids and pH data were obtained at the end of the experimental period. The loss of fresh mass was performed with the equation below:

PMF: $\frac{\text{Final Weight} - \text{Initial Weight}}{\text{Initial Weight}} \times 100$

Initial Weight

The pH and Brix analyze were performed at the Chemistry Laboratory of Evangelical Faculty of Goianésia. For these analyses, a solution was prepared using a blender and, subsequently, a mixer to grind and homogenize each repetition, obeying the following proportions: 10% banana pulp and 90% distilled water, making a total of 100 ml of solution. The pH was assessed using a benchtop pH meter with a magnetic stirrer, and the Brix was assessed using a refractometer.

The collected data were subjected to analysis of variance and subsequently to the *Tukey's* test at 5% significance.

3. Results and Discussion

Significant differences were observed concerning the different types of post-harvest treatments performed on banana fruits. Regarding the chemical characteristics of the analyzed banana fruits, the treatments differed ($P \leq 0.05$) for the soluble solids content and pH (Table 2).

Table 2. Chemical characteristics and ripening of apple banana fruits in 2016 in Goianésia, Goiás, Brazil.

Code	Treatments	Soluble Solids (°Brix)		Maturation*		pH	
T1	Sucupira extract 28%	23.8	a	5.8	b	5.7	bc
T2	Sucupira extract 57%	22.8	a	6	b	5.44	c
T3	Moringa extract 14%	22	a	4	cd	5.68	bc
T4	Grape oil 9%	11	bc	3	de	5.68	bc
T5	Coconut oil 14%	6.4	d	2.6	e	6.57	a
T6	Soybean oil 14%	7.8	cd	3	de	6.41	a
T7	Wax 14%	14.6	b	4.4	c	5.83	b
T8	Witness	23.6	a	7.4	a	5.83	b
C.V		13.38		13.76		2.52	

Means followed by the same letter in the column do not differ statistically from each other. The *Tukey's* test was applied at the 5% probability level. * Von Loesecke diagrammatic scale (Pbmh & Pif, 2006) to assess maturation. Source: Authors.

It was observed that the treatments performed with sucupira and moringa extract were the ones that obtained the highest levels of total soluble solids (TSS) and were statistically equal to the control. In comparison, the treatments with the addition of oil and waxes showed the lowest levels of TSS at the end of the 12th day of storage. Junqueira et al. (2004) did not observe the effect of plant extracts on TSS. These authors evaluated the effect of sucupira extract with soybean oil on post-harvest conservation of mango cv. Palmer and observed that the treatments did not interfere with the TSS at 15 days of storage. Still, the authors claim that sucupira extracts had the same effect as pure water, that is, no effect on the TSS.

Regarding the fruit pH indices, an increase in fruit pH values is expected as a consequence of the decrease in total titratable acidity, and this reduction occurs typically in all fruits during ripening. Botrel et al. (2002) report that the soluble solids content increases, reaching values of up to 27%. The acidity increases until reaching a maximum when the bark is entirely yellow, but then it can decrease malic acid predominating. The pH of the unripe fruit varies from 5.0 to 5.6 and the ripe fruit from 4.2 to 4.7.

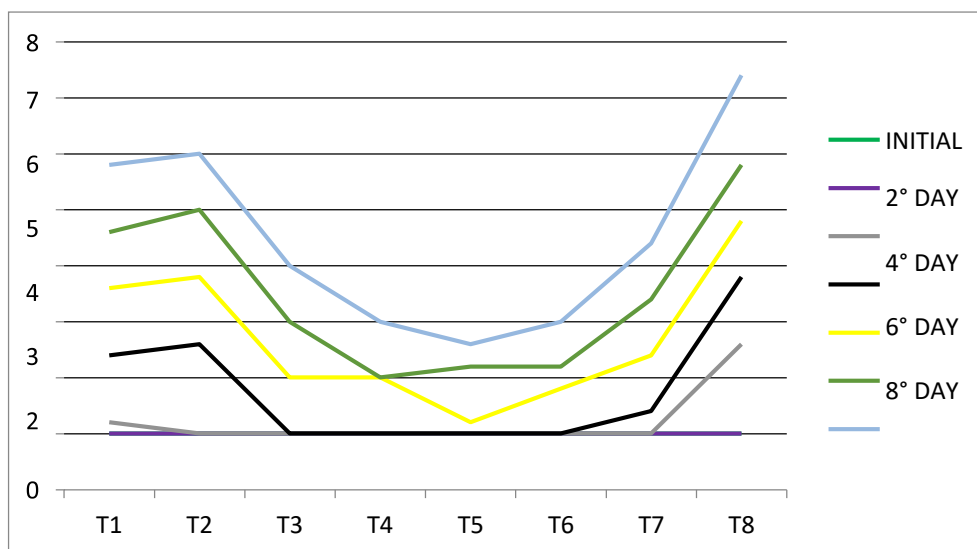
In the present work, the pH reading was carried out at the end of the experimental period. It is not possible to verify how the pH behavior was throughout the storage period of the fruits. The treatments carried out with coconut and soybean oils presented fruits with the highest pH with the other treatments. The treatment using sucupira had the lowest pH at 12 days of storage and one of the highest rates of ripening and soluble solids content, which can be compared to the treatment of moringa.

In their trial, Tacca et al. (2018) showed a reduction in pH (highest observed mean of 4.83), and the foods did not maintain the quality for consumption. For ripening, all treatments with the use of coatings (plant extracts, oils, or wax) had a significant effect ($P \leq 0.05$) with the control (Table 1), which had the highest ripening score on the 12th day of storage (7.4).

Analyzing the ripening of banana fruits over the period, and according to the diagrammatic scale of Von Loesecke (Pbmh & Pif, 2006), the treatments with coatings with oils obtained the lowest grades of ripening throughout the experiment compared

to other treatments (Figure 1).

Figure 1. Fruit maturation throughout the experimental period.



Source: Authors.

For the physical characteristics of the analyzed fruits (Table 3), the treatment with beeswax presented fruit weight, length, and diameter greater than the other treatments ($P \leq 0.05$). Pego (2015) demonstrates that the use of edible skins contributes to slower fruit ripening due to reduced metabolic rate, prolonging food shelf life.

Table 3. Physical characteristics of apple banana fruits for the attributes mean length (CM), mean diameter (DM), peel thickness (EC), mean weight (PM), and mean mass weight (MWP) in Goianésia, Goiás state, Brazil.

Treatments	CM	DM	EC	PM	PMF
Sucupira extract 28%	98.26 b	30.46 b	0.94 bc	156.42 b	131.47 bc
Sucupira extract 57%	95.06 b	30.26 b	0.9 bc	155.59 b	134.33 b
Moringa extract 14%	100.93 a b	28.93 b	0.9 bc	162.42 b	141.66 b
Grape oil 9%	98.73 b	29.4 b	1.1 bc	158.78 b	129.14 bc
Coconut oil 14%	98.26 b	28.46 b	1.12 bc	145.55 b	117.32 bc
Soybean oil 14%	94.93 b	30.73 b	1.24 b	151.14 b	106.43 c
Wax 14%	108.13 a	36.26 a	1.88 a	227.72 a	179.75 a
Witness	97.59 b	28.33 b	0.64 c	149.23 b	129.14 bc
C.V (%)	3.65	6.17	26.41	7.68	10.19

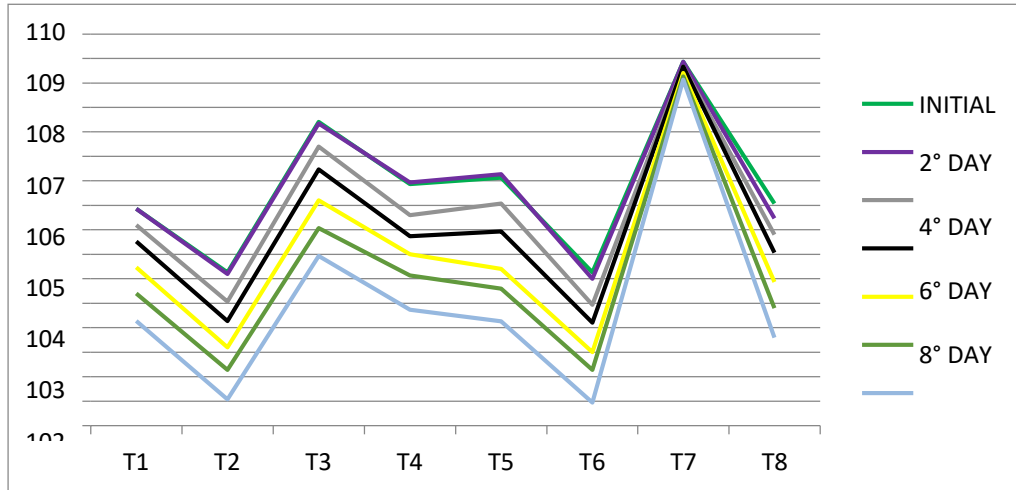
Means followed by the same letter in the column do not differ statistically from each other. The Tukey's test was applied at the level of 5% significance. Source: Authors.

Wax treatment also had the lowest PMM (5.7%) among the treatments used. The PMM reached 60.3% with the coconut oil treatment. Zahoorellah et al. (2017) observed their work coating bananas with chitosan, lactic acid, and Tween 80. The smallest loss of weight and firmness was observed in the coated banana in control was the highest value observed.

For the fruit length (Fig. 2) over the experimental period, it was observed that the measurements decreased for all treatments. However, the minor loss of fruit length was obtained in the fruits treated with beeswax. The mean of this treatment

was 10.79% higher than the control and 13.9% higher than the treatment using soybean oil (14%), which presented the minor measures.

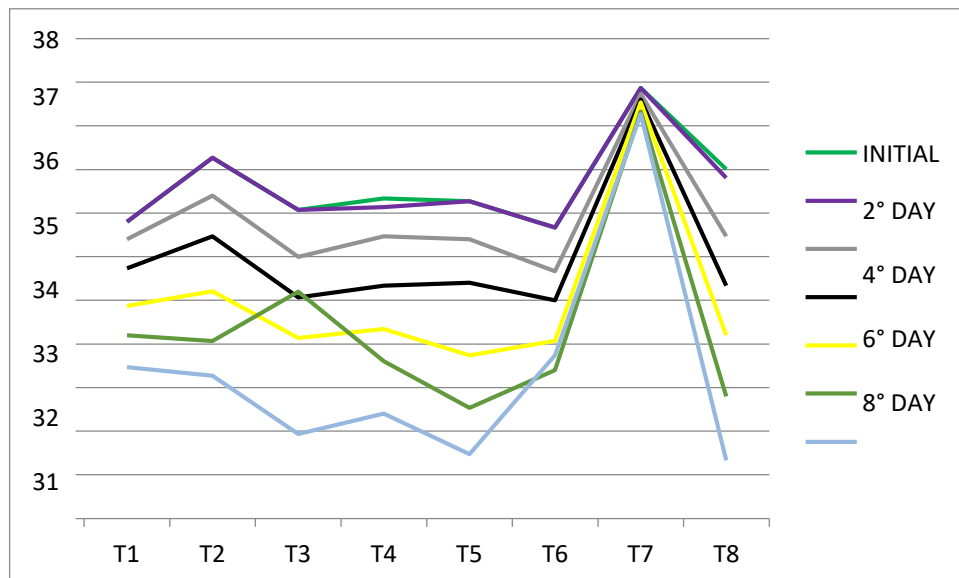
Figure 2. Length of fruits as a function of time.



Source: Authors.

Regarding the fruit diameter data (Figure 2) during the period evaluated, it was observed that the treatment with beeswax showed the lowest losses over 12 days. The average of this treatment was 28% higher than the average found for the control. All treatments affected and showed a reduction in diameter smaller than that found for the control.

Figure 3. Diameter of fruits as a function of time.



Source: Authors.

The benefit of oils in the coating of fruits was observed by Junqueira et al. (2004) because soybean oil, isolated or mixed with benomyl and or thiabendazole, increased the shelf life of Palmer mangoes and was influential in controlling anthracnose.

Oliveira and Santos (2015) report that post-harvest fruit coatings have the function of inhibiting or reducing the migration of moisture, oxygen, lipids, and aromas as they form semi-permeable barriers. The use of coatings is used to reduce

the loss of water and gases and improve the structural properties and appearance of the product. This occurs by controlling permeabilities to oxygen and carbon dioxide, which slows down the lipid oxidation of foods and improves their flavor and texture (Fratari et al., 2021).

4. Conclusion

Beeswax provided the smallest losses in length, fruit diameter, and loss of fresh fruit mass during the storage period.

The sucupira and moringa extracts provided the highest levels of soluble solids at the end of storage.

All coatings used in the post-harvest treatment of bananas decreased fruit ripening.

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