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Abstract

Since it is a climacteric fruit, banana can be harvested still green, but in a state of complete physiological development, and due to the high release of ethylene, it needs appropriate post-harvest conservation to increase its conservation, and for that, coating with starch-based biofilm becomes an alternative. Thus, the aim of this study was to verify the effects of corn starch biofilm and refrigeration on 'Prata' banana fruits in order to develop an accessible and more sustainable technology in the conservation and protection of fruits. Bananas from the 'Prata' subgroup were used, submitted to refrigeration and / or coating with corn starch biofilm and evaluated in three post-harvest periods. The design was completely randomized in a 4x3 factorial scheme, with nine replicates. It could be concluded that low temperature provided by refrigeration is able to delay the ripening process of 'Prata' banana, preserving its measurable characteristics. Biofilm is capable of providing protection, less water loss, consequently preserving measurable characteristics, such as refrigeration; however, with the advantage of allowing fruits to ripen, resulting in better consumption properties.

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ABSTRACT

Since it is a climacteric fruit, banana can be harvested still green, but in a state of complete physiological development, and due to the high release of ethylene, it needs appropriate post-harvest conservation to increase its conservation, and for that, coating with starch-based biofilm becomes an alternative. Thus, the aim of this study was to verify the effects of corn starch biofilm and refrigeration on 'Prata' banana fruits in order to develop an accessible and more sustainable technology in the conservation and protection of fruits. Bananas from the 'Prata' subgroup were used, submitted to refrigeration and / or coating with corn starch biofilm and evaluated in three post-harvest periods. The design was completely randomized in a 4x3 factorial scheme, with nine replicates. It could be concluded that low temperature provided by refrigeration is able to delay the ripening process of 'Prata' banana, preserving its measurable characteristics. Biofilm is capable of providing protection, less water loss, consequently preserving measurable characteristics, such as refrigeration; however, with the advantage of allowing fruits to ripen, resulting in better consumption properties.

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1. INTRODUCTION

Banana, *Musa* sp. L, is a fruit species belonging to the Musaceae family, widely cultivated in all regions of the world with tropical climate, being one of the most popular fruits in the world [1].

Brazilian production reached values of 449,284 ha of total harvested area, with production of 6,752,171 t and average yield of 15.03 t ha^{-1}, being produced mainly in the States of São Paulo, Bahia and Minas Gerais, remaining in second place in terms of volume of fruit marketed in the national market and placing the country in fourth place in terms of world production [2].

The evolution of the culture led to the emergence of a wide range of varieties. In the beginning, the Brazilian banana activity had only two varieties, 'Branca' and 'Pacovan' [3]. From these varieties, new varieties originated by natural mutation. 'Branca' variety originated all varieties of the 'Prata' subgroup, directly, as in the case of 'Prata', 'Prata-Anã' and 'SCS451 Catarina', or indirectly, as in the case of 'Pacovan' and 'Prata-Gorutuba' [4], with 'Prata' subgroup representing 24% of world banana production [5].

However, banana is a climacteric fruit and its ripening process is greatly influenced by the presence of ethylene, and this physiological characteristic leads to rapid ripening and short post-harvest life [6].

Thus, in view of the high perishability of climacteric fruits and post-harvest losses, it is necessary to develop appropriate techniques that maintain quality and extend the shelf life of fruits [7]. The refrigeration technique (10ºC) is among them, which is directly related to the physiological and metabolic processes of fruits, where low temperature allows the delay of the ripening and senescence process, preserving the product with characteristics desirable by consumers [8].

Another method to increase the post-harvest life of vegetables is the use of edible coatings, defined as a thin layer of edible material deposited on foods as a coating [9], among them biological films, which can be used for the same purpose as wax, since they protect fruits and can still be consumed or washed off [10].

In this sense, storage technologies have profound effects, with marked consequences on composition and general flavor of foods and, therefore, on commercial life and consumer acceptance [11].

Thus, the present study aimed to verify the effects of corn starch biofilm and refrigeration on 'Prata' banana fruits in order to develop an accessible and more sustainable technology in the conservation and protection of fruits.

2. MATERIAL AND METHODS

The experiment was conducted at the Faculty of Agricultural and Technological Sciences, FCAT / UNESP, Campus of Dracena, using ‘Prata’ banana fruits acquired from a commercial production area located in the municipality of Dracena - SP, whose geographical coordinates are 21 ° 28 '57 ”S and 51 ° 31'58” W and average 421 m a.s.l., with regional climate of Subtropical Cwa type (mild and dry winters, followed by very hot summers), and average annual temperature of 23.6 ° C [12].

Fruits were harvested considering the point of harvest when they were still green, but in the stage of physiological development, characterized by the disappearance of corners [13], being submitted to superficial disinfestation with 70% alcohol and 2% sodium hypochlorite solution.

Biofilm was produced from the solubilization of corn starch in deionized water at proportion of 3% (weight / volume) by heating to 70°C under constant agitation until gelatinous consistency was obtained.

After natural cooling, fruits were submerged in the biofilm until complete coverage for uniform coating, followed by vertical conditioning of fruits for draining and drying.

The experiment design was completely randomized, totaling four treatments: control (fruits without coating or refrigeration), biofilm (fruits coated and kept at room temperature 25°C), refrigeration (fruits without coating kept in BOD chamber at 10ºC) and, finally, biofilm with refrigeration (fruits coated and kept in BOD chamber at 10ºC). Each treatment consisted of nine fruits, each fruit being considered a replicate, which were divided into three subplots for periodic evaluations in three periods (0, 7 and 14 days after harvest), totaling 36 fruits.

The evaluated characteristics of fruits were: mass, in grams (using scale with accuracy of 1 g), length, in centimeters (measured with the aid of graduated ruler), diameter, in millimeters (measured with the aid of digital caliper), soluble solids (using portable refractometer, with values obtained in ºBrix) and sensory evaluation carried out in the last two evaluation periods (evaluation given by scores from 1 to 5, where 1 was considered very poor and 5 was excellent according to taste). Results obtained were submitted to analysis of variance using the SISVAR software [14], in order to verify the statistical significance among the different values. Post-hoc analyses were performed with the Tukey test at 5% probability.

3. RESULTS AND DISCUSSION

The superficial appearance of fruits treated with biofilm was visually similar to untreated fruits, that is, they did not appear to present covering of the vegetable tissue, thus not interfering in the product presentation.

From analyses performed, it could be observed that there was no variation in the content of soluble solids among fruits on day 0, indicating that fruits were in maturation stage similar to the beginning of the experimental period, which was expected due to the selection of fruits with similar physical characteristics in order not to influence the results over time.

The content of soluble solids is a great indicator of fruit ripeness, which indicates the greatest sweetness for consumption. Table 1 shows the results for control (without biofilm and without refrigeration) and for fruits with biofilm stored at 25°C at 7 and 14 days after the beginning of the experiment, and the superiority of values, not differing from each other, comparing each study period. The same was observed for fruits without biofilm stored at 10 ° C and with biofilm plus refrigeration, that is, they also did not differ from each other in the different study periods.

Regarding the content of soluble solids, it is worth mentioning that fruits kept in refrigerator at 10 ° C and with biofilm plus refrigerator, °Brix did not differ statistically over time, starting from 6.3 to 7.6 ° Brix and 6.3 to 8.3 °Brix, respectively, differing from control, which started with 6.3; 19.6 and 19 ° Brix, respectively at periods of 0, 7 and 14 days after the beginning of the experiment.

In climacteric fruits such as banana, the increase in °Brix over time is normal, especially if there are no ripening inhibitors or delayers in this process. When still green, it has high starch content, which undergoes hydrolysis in the post-harvest period, being the precursors of sugars [15], promoting fruit ripening. These authors found 24.38 °Brix for 'Prata' banana on the 10th day after harvest, which remained constant until the 14th day after harvest. Although this value is higher than that found in the present study, these authors reported that minimum values from 19.72 to 22.36 °Brix have already been reported by other authors.

TABLE 1: Content of soluble solids (° Brix) of 'Prata' banana according to treatments and evaluation periods after treatments. Dracena, 2019.

TREATMENTS	EVALUATION PERIODS (DAYS)		
	0	7	14
Control	6.3 Ba[1]	19.6 Aa	19 Aa
Biofilm	6.3 Ca	21.6 Aa	16 Ba
Refrigerator (10°C)	6.3 Aa	5.6Ab	7.6Ab
Biofilm + Refrigerator (10°C)	6.3 Aa	5Ab	8.3 Ab
CV (%)[2]	18.1		

[1] Values followed by the same uppercase letter in the row and lowercase in the column do not differ statistically from each other by the Tukey Test at 5% probability. [2]CV (%): coefficient of variation.

Temperate fruit crops are commonly stored at temperatures close to freezing (0–1 ° C), while those of tropical or subtropical origin should be kept at higher storage temperatures (7–15°C) to avoid losses due to the development of cold injuries [11].

Changes induced by low temperatures in a biological system are positive in terms of shelf life, as it slows down the general metabolism and reduces changes in composition and, consequently, the respiration rate [16], which is directly related to ethylene synthesis.

Ethylene is a gaseous hormone involved in plant growth and development, including abscission, leaf senescence, seed germination, organogenesis and ripening [17] [18].

As a general effect, low-temperature storage positively regulates stress-responsive genes, affects primary and secondary metabolism and blocks signal transduction of ethylene-related processes [19] [20]. Thus, differences presented in the content of soluble solids of fruits stored at room temperature and under refrigeration can be explained by the lower ethylene production rate and consequent lower rate of conversion of starch into soluble sugars.

Treatment with biofilm presented the highest values at 7 days of evaluation (21.6), followed by a significant decrease, reaching mean value of 16 °Brix on the 14th day of storage (Table 1), which can be attributed to fruit senescence [21].

In addition, reductions in total soluble solids may be due to the increase in the water content during storage, changing the proportion of solids in the total mass, or be related to the consumption of part of the substrate by microorganisms [22].

Significant reduction in the content of reducing sugars for all treatments was found when the storage of powdered prickly pear packaged in laminated packages under different temperatures and relative humidity [23]. And significant increase in the content of reducing sugars was also found when storing osmotically dried jackfruit slices in sucrose syrup with different contents of soluble solids (35, 40, 45 and 50 ° Brix) packed in high-density polyethylene plastic packages in ambient conditions for 240 days [24].

Regarding length, diameter and mass data, influence of evaluation periods was observed, thus, it could be observed that all parameters decreased their values with advancing fruit storage period (Table 2).

For variable length, regardless of treatment, value observed at 7 days (17.45 cm) did not differ from that of day 0 (17.85 cm), but there was a reduction at 14 days (16.51 cm), showing a subtle and gradual reduction (Table 2).

Regarding diameter, no significant difference was observed between fruits evaluated at 7 (39.87 mm) and 14 days (38.21 mm), both being statistically different from the value observed at the beginning of the experiment (42.32 mm) (Table 2).

For mass, all values observed were significantly different from each other, with the highest value obtained at the beginning of the experiment (167.00g) and the lowest at 14 days (134.25g), probably indicating water loss due to transpiration and dry mass consumption.

TABLE 2: Influence of the evaluation period on length, diameter and mass of "Prata" banana fruits submitted to different treatments. Dracena, 2019.

PERIOD	LENGTH (cm)	DIAMETER (mm)	MASS (G)
0	17.85 a[1]	42.32 a	167.00 a
7	17.45 ab	39.87 b	147.83 b
14	16.51 b	38.21 b	134.25 c
CV (%)[2]	5.82	4.65	8.37

[1] Values followed by the same lower case letter in the column do not differ statistically by the Tukey Test at 5% probability.

[2]CV (%): coefficient of variation.

Among treatments, the only variable that showed statistical difference was mass, and control differed from the other treatments, showing the lowest value (132.6g), indicating greater mass loss, as shown in Table 3.

Fruits coated with biofilm and kept at room temperature did not differ statistically from fruits kept under refrigeration, showing higher mass value (159.4 g), indicating that despite temperature, biofilm was able to create a protection in relation to water loss due to transpiration.

TABLE 3: Influence of treatments on the mass of "Prata" banana. Dracena, 2019.

TREATAMENT	MASS (G)
Control	132.6 b[1]
Biofilm	159.4 a
Refrigerator (10°C)	151.5 a
Biofilm + Refrigerator (10°C)	155.1 a
CV (%)[2]	8.37

[1] Values followed by the same lower case letter in the column do not differ statistically by the Tukey Test at 5% probability.

[2]CV (%): coefficient of variation.

In experiment with tomato fruits using 2 and 3% cassava starch coating, was observed that treatments did not significantly influence mass loss [25]. However, in experiment with guava fruits treated with 2% cassava starch films stored at room temperature (19.5-27ºC), and it was obtained mass loss of 18.93% compared to 27.60% of control on the 11th day of storage [26].

Water from plant tissue is the source of oxygen and hydrogen in organic biomatter [27]. As in other plant organs, fruit epidermis plays an important role in the gas exchange between product and environment, allowing fruits to maintain high water content, despite the low relative air humidity around the product. This protection against dehydration is particularly important after harvest, when fruits will no longer receive water from the plant [28].

Thus, the higher moisture content of treatment with coating may indicate that the film would be preventing marked moisture loss, acting as an "extra" epidermis in fruits. Another hypothesis would be the fact that films can retain part of the existing moisture in the environment, since they are hydrophilic [9].

Table 4 presents the results regarding taste sensory analysis. It is observed that the fruits treated with biofilm and evaluated at 7 days were considered the best, obtaining the highest score (5) and differing from all treatments and evaluation periods, indicating that biofilm at 7 days of storage at room temperature, in addition to replacing refrigeration in the mass preservation, also presented the best flavor, mainly due to the higher °Brix observed (Table 1), enabling the physiological changes caused by ethylene, without fruit degradation.

TABLE 4: Scores of the taste sensory analysis of “Prata” banana according to treatments and evaluation periods.

TREATAMENT	**EVALUATION PERIODS (DAYS)**	
	7	14
Control	2.5 Bb[1]	3.2 Aa
Biofilm	5.0 Aa	2Bb
Refrigerator (10°C)	1.2 Bc	2Ab
Biofilm + Refrigerator (10°C)	1.0Bc	3 Aa
CV (%)[2]	12.25	

[1] Values followed by the same uppercase letter in the row and lowercase in the column do not differ statistically by the Tukey Test at 5% probability. [2]CV (%): coefficient of variation.

Thus, it could be concluded that the low temperature provided by refrigeration is able to delay the ripening process of ‘Prata’ banana, preserving its measurable characteristics. Biofilm is capable of providing protection, reducing water loss and, consequently, conserving its measurable characteristics, such as refrigeration; however, with the advantage of allowing fruits to ripen, resulting in better consumption properties.

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