EFFECTS OF FRUIT MATURITIES, COATINGS, AND STORAGE TEMPERATURES ON THE QUALITIES AND GREEN-LIFE OF CAVENDISH BANANA

Alamanda Katartika Fahri
Study Program of Magister of Agronomy, Faculty of Agriculture, University of Lampung
Prof. Dr. Soemantri Brodjonegoro Street, Bandar Lampung, 35145 Lampung, Indonesia
alamandafahri@gmail.com
https://orcid.org/0000-0003-2694-9532

Soesiladi Esti Widodo*
Department of Agronomy and Horticulture, Faculty of Agriculture, University of Lampung
Prof. Dr. Soemantri Brodjonegoro Str., Bandar Lampung, 35145 Lampung, Indonesia
*Corresponding author: sestiwidodo@gmail.com
https://orcid.org/0000-0003-4932-2759

Sri Waluyo
Department of Agricultural Engineering, Faculty of Agriculture, University of Lampung
Prof. Dr. Soemantri Brodjonegoro Str., Bandar Lampung, 35145 Lampung, Indonesia
sri.waluyo@fp.unila.ac.id
https://orcid.org/0000-0003-4334-3022

Zulferiyenni
Department of Agricultural Product Technology, Faculty of Agriculture, University of Lampung
Prof. Dr. Soemantri Brodjonegoro Str., Bandar Lampung, 35145 Lampung, Indonesia
zulferiyenni@gmail.com
https://orcid.org/0000-0002-9594-819X

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Highlight
fruit maturities; coatings and storage temperatures on Cavendish Banana.

Abstract
Cavendish banana is a climacteric fruit with a fast response to ethylene and a very high respiration rate during storage. Previous studies revealed that these characteristics shortened the green-life and fastened fruit damage, affecting the economic value. Therefore, this study aims to examine the effects of fruit maturity levels, coatings, and storage temperatures on the qualities and green-life of Cavendish banana. The result showed that the level of fruit maturity significantly increased the green-life duration, as well as maintained firmness, diameter loss, acidity, and starch content, but it had no effect on weight loss, °Brix, and glucose. Meanwhile, low temperature was able to delay senescence, promote starch degradation, as well as detain firmness and diameter loss. The results also showed that the combined application of maturity levels + temperatures affected all parameters, while maturities + coatings as well as coatings + storage had effects on firmness, acidity, and starch content. The 1% chitosan coating coverage was analyzed with a Scanning Electron Microscope (SEM), which showed fully covered surface of M1 finger rind tip and some crack points on finger rind base. Furthermore, there was full coverage on M2, and some crack points on M3.

Keywords
Cavendish banana; maturity; coating; storage; temperature.

Introduction

Cavendish banana is a fruit with high economic value and high nutritional contents, such as carbohydrates, minerals, as well as vitamins B6 and C. It is also a leading export commodity; hence, its production promotes international cooperation. Furthermore, the Indonesian government (2021) stated that in May 2021, Cavendish banana exports reached 5,500 tons [1]. It was exported globally in its green-life stage and received ethylene gassing to promote ripening with temperature treatment of 16°C in the market destination. Gonge (2013)

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reported that the storage of fruits at 16°C significantly affected the texture, flavor, color, and taste [2]. As a climacteric fruit, Cavendish banana has high respiration and ethylene production rates, which causes fast degradation of its qualities. Several studies reported the role of ethylene in the ripening process [3]. The high respiration and hormone production rates are believed to be the cause of the short shelf-life. Fruit coating is a post-harvest treatment, which can decrease the rate of respiration as well as lengthen the fruit shelf life [4]. Furthermore, chitosan is an edible coating, and it chemically plays a role in inhibiting the movement of O_2 and CO_2. The presence of materials, such as coating around fruits with low O_2 and high CO_2 is expected to reduce the respiration rate during storage [5] The application of chitosan causes the flesh of the fruit to be soft, but the skin remains green. This indicates that there is a need to add an anti-ethylene agent along with the treatment. The addition of other ingredients that can inhibit ethylene production is an effective way of controlling ripening in the fruit.

Gibberellic Acid (GA_3) is a growth regulator that can cause greening in citrus as well as delay the appearance of red color in tomatoes [6] It can also delay the ripening of bananas by counteracting ethylene and retaining chlorophyll, thereby maintaining the green color, minimum weight loss, percentage of moisture content, and low dry weight [7] The concentration of GA_3 greatly affects the success of its application. GA_3 can delay the ripening of Cavendish banana for 3-4 days at a concentration of 50-250 mg/L [8]. Several studies revealed that storage temperature also greatly affects the shelf life of fruit. Temperature has a direct effect on the rate of respiration, and at low levels, the rate is reduced. This is also supported by the delivery process of Cavendish banana, which are often given a low-temperature treatment ranging from 13-14°C [9]. The combinations of fruit maturities, coatings, and storage temperatures can extend the shelf life of Cavendish banana. These treatments can reduce economic loss caused by missed green-life period during exportation as well as increase farmers' income. The materials needed for the treatment are easy to obtain and apply, as well as environmentally friendly [10]. Therefore, this study aims to examine the effects of fruit maturities, coatings, and storage temperatures on the qualities and green shelf-life of Cavendish banana.

Methods

This study was carried out in the Laboratory Horticulture and Postharvest, Department of Agronomy and Horticulture, Faculty of Agriculture, University of Lampung, Bandar Lampung, Lampung, Indonesia, from July to September 2022. The samples used consisted of fruit clusters from Cavendish banana fruit bunches with 3 levels of maturity, namely immature, full mature, and over mature.[11] The banana sample was received from Great Giant Foods Co. Ltd., Plantation Group 4, which is previously known as Nusantara Tropical Fruits Co. Ltd., Labuhan Ratu, East Lampung in stage I (green phase). The fruit was relatively uniform in terms of harvest age and physical appearance. Furthermore, this study used a Completely Randomized Design with a factorial 3 x 4 x 2 with 3 replications. The first factor was the banana fruit at 3 levels of maturities, namely physiologically immature M1 (5^{th} cluster), full mature M2 (3^{rd} cluster), and over mature M3 (1^{st} cluster) [11]. The second factor was the fruit coating, namely non-coating or control (C1), 1% chitosan (C2), 150 ppm GA_3 (C3), and 1% chitosan + 150 ppm GA_3 (C4), which were applied on the rind tip and base. The third factor was the storage temperature, including room S1 (27 ± 1°C) and cold S2 (16 ± 1°C) temperatures. The observation was discontinued in this study either when the fruit rind changed to stage III (greenish yellow) at the end of the green shelf-life, or flesh was softened or past 35 days in the postharvest handling.The variables examined include days of storage (green shelf-life), fruit firmness, weight loss, diameter loss, °Brix, free acidity, glucose, starch, and SEM. The storage was measured by counting the days from the beginning to the end of observation. Furthermore, fruit firmness was analyzed with a penetrometer type FHM-5 Takemura Electric Work Ltd Japan, by peeling the skin of the sample. The process was carried out at three randomly selected locations around the middle or widest side of the Cavendish banana finger. Weight and diameter loss were analyzed using digital scales and vernier calipers. °Brix was assessed with a digital refractometer by grinding the flesh of bananas with mortar and pestle, followed by filtration using filter paper to collect and drip liquid on the refractometer lens. Free acidity was analyzed using titration with 0.1 N NaOH and phenolphthalein as an indicator. The glucose and starch contents were assessed by adding saturated Pb-acetate, Na-oxalate, and aquades during sample extraction, followed by heating at 90°C for 30 minutes. Furthermore, the rind surface pores were observed with Scanning Electron Microscope (SEM) by cutting the sample to the desired orientation, followed by fixation, dehydration, drying, and coating with a conductive layer. All data were analyzed with ANOVA, and further tested using Tukey's honestly significance difference (HSD) at 5% with the Minitab 19 version.

Results and Discussion

The observation of this study was terminated when the green-life of the banana ended with fruit flesh softening

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or 35 days of its shelf life. The green-life determines its shelf life and export quality, where the longer it is, the lower the risk of material loss during shipping time. This was because importers expect banana to arrive in their fresh green state before receiving ethylene gassing at the destination. Based on Table 1, the shelf life of Cavendish banana increased with the application of maturities, storage, maturities + storage, and coating + storage, but the use of only coatings had no effect. The best result was obtained from treatment M2S2, namely full maturity in cold storage with a shelf life of 34.75 days. This finding is consistent with Williams et. al. which reported similar results with the use of the treatment [12]. Meanwhile, fruit harvested at 75% maturity level and stored in a cold temperature of 12^{o}C had a green-life period of 35 days [2].

Full physiological maturity refers to the maximum growth and maturation, and it marks the start of normal ripening. Fruit at this stage was able to reach the optimum performance when combined with cold storage. Furthermore, storage at low temperatures is one of the manipulation of environmental conditions, which can decrease metabolic activity rate substantially, and this prevents senescence and quality degradation [13]. Maturities significantly affected the firmness and diameter loss. Treatment M1 showed higher firmness and diameter loss, followed by M2 and M3. This was closely related to the determination of the maturity levels of the banana cluster that were taken as samples in this study, where M1 was immature with harder firmness than M2 and M3. This finding is consistent with Widodo et al. (2021), where the younger cluster, which is farther away from the stem showed a higher value of firmness [11]. The 1% chitosan coating on C2 and C4 was only applied on the fruit rind tip and base, and there was still uncover in some areas. Consequently, the use of this coating treatment had no significant effect on all parameters of observation. The application of control (C1) and GA_3 150 ppm on C3 and C4 showed no significant difference. Cold storage temperature lengthened the shelf life and maintained firmness but did not detain weight and diameter loss. This finding is in line with Ahmed et al. (2001) that storage temperature had no significant effect on banana weight loss [14]. Based on Table 2, maturities significantly affected acidity and decreased starch content, but did not affect other chemical qualities, such as ^{o}Brix and glucose. The observation of parameters was carried out with the same criteria for each sample in the same stage to ensure the ^{o}Brix is not affected. Glucose is a simple sugar or monosaccharide, and other forms of sugar were not observed in this study. This was suggested to be the cause of the lack of effect on the glucose content. ^{o}Brix, acidity, glucose, and starch were not significantly affected by the control treatment due to coatings and storage, except for the effect of storage treatment on starch content. Low storage temperature affected lowered the starch content due to accelerated degradation. Based on enzyme activities, this treatment facilitated starch degradation through the pathway of alpha-amylase over that of beta-amylase and showed different granule structures [15]. The combined application of maturities and coatings as well as coatings and storage temperatures affected the acidity and starch content. Meanwhile, maturities + storage temperatures had an effect on all observed chemical qualities, such as ^{o}Brix, acidity, glucose, and starch content compared to the control. The use of coatings mostly did not affect the parameters of observation because the application of 1% chitosan was carried out on the tip and base of the rind only. This indicates that the treatment cannot inhibit the movement of O_2 and CO_2 of the fruit and reduce the respiration rate due to the uncoated stomata areas. The results showed that the application of chitosan coating fully on the surface of rind fruit reduced weight loss and chemical quality, and increasing the concentration gave better results [16]. A previous study revealed that the use of full coating caused the fruit flesh to become soft [14]. This indicates that the application of chitosan on Cavendish banana must be carried out in full on the fruit rind in combination with anti-ethylene to produce a longer shelf life with good physical quality. Slower rates of weight loss in coated fruits can be attributed to the barrier properties for gas diffusion of stomata, the organelles that regulate the transpiration process, and gas exchange between the fruit and the environment [16]. Coating showed better results when combined with cold storage temperature, but longer shelf life was still shown by the control treatment at low temperatures.

Based on figure 1, The SEM analysis of the 1% chitosan coating showed that it fully covered the tip finger rind, but there are some crack points on the base on M1. It also revealed full cover on M2, and some crack points on M3. The same concentration of 1% chitosan coating on the surface of banana rinds at different maturity levels showed different results. Coating on fruit rind at full physiological maturity level (M2) showed better results than at other maturity levels. This might be influenced by different skin textures at each maturity level, fruit respiration rate and stomata conductance during application. However, similarities in the appearance of layers on different coating materials can occur because in the coated condition, the stomata on the fruit surface are covered by the coating materials have been previously reported [17] Fruit coating with commercial wax and Shellac coating on the surface of strawberry fruit showed homogenous and uniform layer [18].

Table 1. The Effect of Maturities, Coatings, and Storage on the Fruit Shelf Life, Firmness and Diameter Loss[1]. *Source: Author.*

Treatments[2]	**Shelf-life (days)**	**Firmness (kg/m^2)**	**Weight Loss (%)**	**Diameter Loss (%)**
Maturities				
M1	28.31a	2.73a	0.21a	0.15a
M2	28.31a	1.66b	0.20a	0.12ab
M3	25.87b	1.47b	0.18a	0.10b
Coatings				
C1	28.00a	2.05a	0.20a	0.14a
C2	27.92a	2.03a	0.20a	0.13a
C3	27.25a	1.88a	0.20a	0.12a
C4	26.83a	1.86a	0.19a	0.12a
Storage				
S1	33.92a	2.39a	0.21a	0.13a
S2	21.08b	1.51b	0.18a	0.12a
Maturities* Coatings				
M2 C2	29.25a	1.63ab	0.19a	0.13a
M1 C1	29.00a	3.23a	0.20a	0.15a
M1 C2	28.75a	2.71ab	0.21a	0.13a
M2 C1	28.25a	1.05b	0.18a	0.11a
M2 C3	28.00a	1.26ab	0.20a	0.11a
M1 C3	27.75a	2.80ab	0.20a	0.18a
M1 C4	27.75a	2.19ab	0.22a	0.16a
M2 C4	27.75a	1.92ab	0.22a	0.15a
M3 C1	26.50a	1.36ab	0.19a	0.09a
M3 C4	26.25a	1.96ab	0.16a	0.10a
M3 C2	26.00a	1.81ab	0.20a	0.10a
M3 C3	24.75a	1.52ab	0.18a	0.10a
Maturities* Storage				
M2 S2	34.75a	0.75c	0.21ab	0.12ab
M1 S2	33.62a	2.24ab	0.22a	0.14ab
M3 S2	33.37a	1.55bc	0.20ab	0.12ab
M1 S1	23.00b	3.22a	0.20ab	0.16a
M2 S1	21.87b	2.19ab	0.19ab	0.13ab
M3 S1	18.37c	1.77bc	0.16b	0.078b
Coatings* Storage				
C1 S2	34.67a	1.34a	0.20a	0.11a
C2 S2	34.17a	1.64a	0.21a	0.11a
C4 S2	34.17a	1.73a	0.22a	0.15a
C3 S2	32.67a	1.35a	0.21a	0.14a
C2 S1	21.83b	2.46a	0.20a	0.13a
C1 S1	21.17b	2.42a	0.18a	0.12a
C3 S1	21.00b	2.37a	0.18a	0.12a
C4 S1	20.33b	2.32a	0.18a	0.12a

[1]Values in the same column of each treatment followed with the same letters were not significantly different at HSD 5%. Fruit firmness on the day of treatment (Day 0) was 4.21 kg/m^2.
[2]M1: physiologically immature (5th cluster), M2: full mature (3rd cluster), M3: over mature (1st cluster)[11]; C1: non-coating or control, C2: 1% chitosan, C3: 150 ppm GA_3, C4: 1% chitosan + 150 ppm GA_3; S1: room temperature (27 ± 1°C), S2: cold temperature (16 ± 1°C).

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Table 2. The Effect of Maturities, Coatings, and Storage on the Fruit °Brix, Acidity, Glucose and Starch[1]. *Source: Author.*

Treatments[2]	**°Brix (%)**	**Acidity (mg/100 g)**	**Glucose (mg/100 mg)**	**Starch (mg/100 g)**
Maturities				
M1	18.72a	0.75a	6.24a	22.87a
M2	18.27a	0.60b	5.78a	19.46b
M3	18.09a	0.57b	5.77a	19.44b
Coatings				
C1	18.78a	0.68a	6.32a	21.12a
C2	18.78a	0.65a	6.17a	20.63a
C3	18.06a	0.64a	5.80a	20.56a
C4	17.81a	0.59a	5.41a	20.06a
Storage				
S1	18.97a	0.76a	6.28a	22.51a
S2	17.75a	0.52a	5.58a	18.68b
Maturities* Coatings				
M2 C2	16.82a	0.59ab	5.41a	18.72b
M1 C1	19.82a	0.59ab	6.40a	18.83b
M1 C2	18.07a	0.54ab	5.37a	19.42b
M2 C1	18.67a	0.50b	6.31a	18.92b
M2 C3	19.67a	0.50b	5.07a	20.86ab
M1 C3	18.47a	0.69ab	5.74a	18.94b
M1 C4	16.70a	0.58ab	5.59a	20.66b
M2 C4	19.70a	0.69ab	6.30a	19.28b
M3 C1	17.85a	0.96a	5.81a	22.42ab
M3 C4	17.02a	0.67ab	7.07a	23.43a
M3 C2	19.27a	0.63ab	6.63a	23.55a
M3 C3	18.20a	0.73ab	5.44a	22.09ab
Maturities* Storage				
M2 S2	16.62b	0.52b	5.60ab	18.78b
M1 S2	17.57ab	0.56b	5.51ab	18.83b
M3 S2	19.05ab	0.49b	7.72a	18.42b
M1 S1	18.96ab	0.64b	6.04ab	20.09b
M2 S1	20.81a	0.62b	5.94ab	20.11b
M3 S1	17.12ab	1.01a	4.75b	27.33a
Coatings* Storage				
C1 S2	17.93a	0.43c	6.56a	18.37c
C2 S2	19.03a	0.52bc	5.93a	18.83bc
C4 S2	17.05a	0.55bc	7.15a	18.88bc
C3 S2	16.98a	0.59bc	5.47a	18.63c
C2 S1	17.08a	0.65abc	5.68a	22.30a
C1 S1	19.63a	0.94a	5.78a	21.74ab
C3 S1	20.58a	0.69abc	5.35a	22.63a
C4 S1	18.57a	0.75ab	5.49a	23.37a

[1 and 2]See Table 1. Fruit °Brix, acidity, glucose and starch in day 0 storage were 13.97%, 0.65 mg/100 g, 2.90 mg/100 g, and 28.47 mg/100 g.

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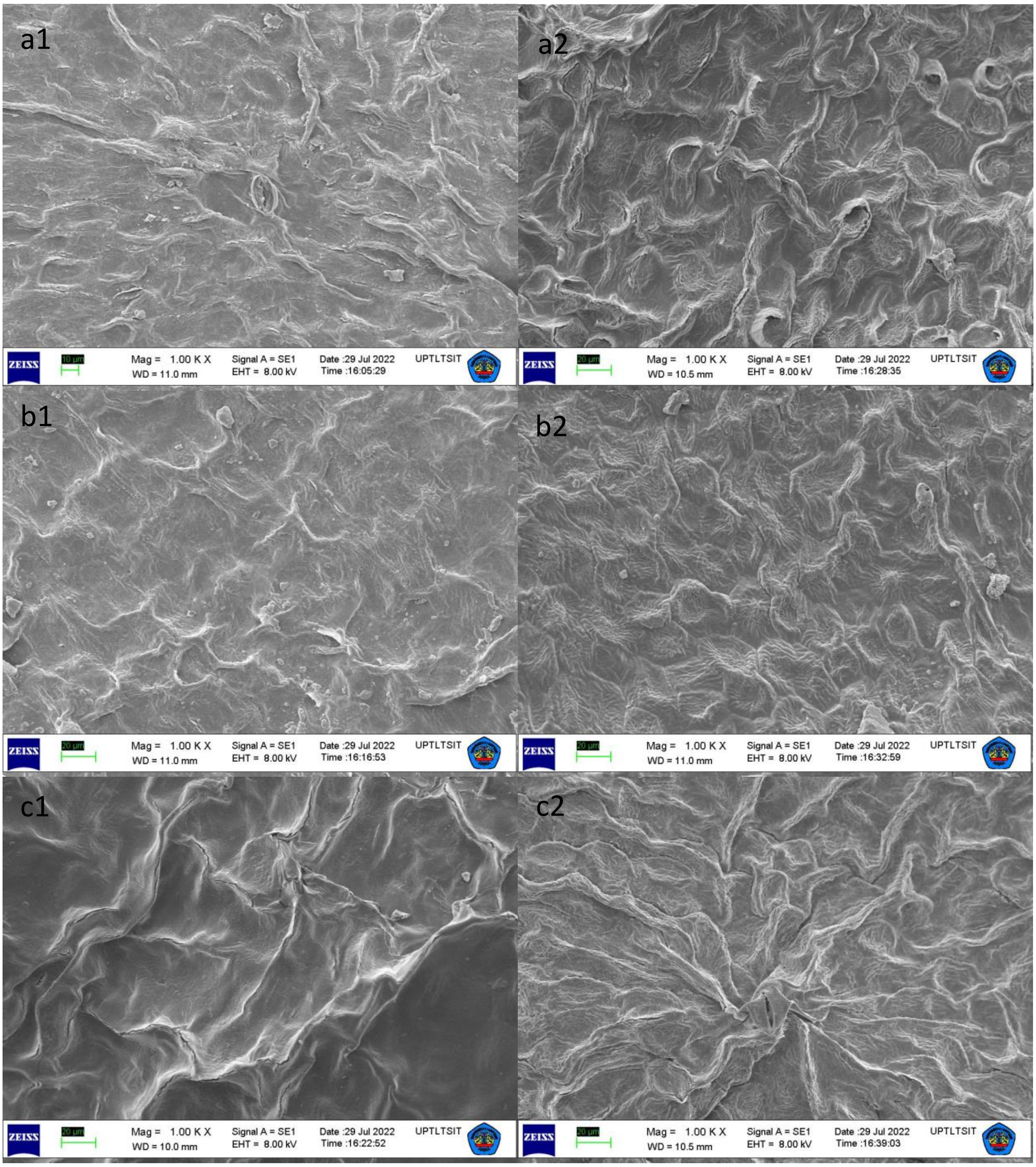

Figure 1. SEM Analyses on Cavendish banana finger rind tips and bases with SEM 1000x magnification. Banana finger rind tips and bases of 5th cluster from the top of the bunch (a1) and (a2), 3rd cluster from the top of the bunch (b1) and (b2), 1st cluster from the top of the bunch (c1) and (c2). *Source: Author.*

Impact

The harvest time of Cavendish banana for export determines its shelf life and quality. This information can support farmers in determining the target market for each cluster, thereby positively impacting their economic condition. Furthermore, when the cluster is not physiologically mature or over-mature, it can cause enormous losses and reduce the country's income due to rejection at the export destination. Post-harvest treatment with maturity level at the third cluster of the bunch (full physiological maturity) combined with cold temperature treatment (M2S2) can be recommended to all Cavendish banana farmers due to its long shelf life with an average of 34.75 days. The use of only chitosan coating is environmentally friendly so that it is safety to apply, but it had no effect on the shelf life compared to the control. This indicates that it must be combined with cold treatment to extend the green-life of Cavendish banana. Low-temperature treatment is very common for post-harvest

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products because it is very easy to apply and produces profitable results. SEM observations can be carried out at higher concentrations of chitosan and at full coverage to get a perfect coating appearance. The observation showed the effectiveness and help farmers to mitigate the risk of washed coating on the fruit surface.

Conclusions

The application of maturities significantly lengthened the shelf life as well as detained the firmness, diameter, acidity, and starch content. However, it did not reduce weight loss and had no effect on °Brix and glucose content. The results of the application of 1% chitosan, GA_3 150 ppm, or their combination on fruit rind tip and base were not different from the control and had no effect on all parameters. The results showed that a low storage temperature of 16 ± 1°C was able to delay senescence, promote starch degradation, as well as detain firmness and diameter. The combined application of maturities and storage affected all parameters of observations, while maturities and coatings, as well as coatings and storage only influenced the firmness, acidity, and starch content. The SEM analysis of the 1% chitosan coating showed that it fully covered the tip finger rind, but there are some crack points on the base on M1. It also revealed full cover on M2, and some crack points on M3.

Conflict of Interest

There are no conflicts to declare.

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