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Effectiveness of Synthetic and Natural Antifungals Against Postharvest Diseases and Quality of Barangan Bananas (*Musa acuminata*)

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Abstract

This study was conducted to evaluate the effects of antifungal treatments and storage duration on the physical, biochemical, and post-harvest disease quality of Barangan bananas (*Musa acuminata*). Barangan bananas are a premium agricultural commodity from North Sumatra, popular as table bananas due to their sweet taste and distinctive aroma. Four treatments were applied: kawalan (untreated control), 0.3% cinnamon oil, 200 ppm sodium dichloroisocyanurate (NaDCC), and 200 ppm propiconazole. The parameters evaluated included skin color (brightness, chroma, hue angle), weight loss, texture, pH, citric acid content, total soluble solids (TSS), vitamin C, TSS:TTA ratio, and the severity of crown rot and anthracnose during seven days of storage at room temperature. The results showed that storage duration significantly affected color, weight loss, pH, acidity, and the TSS:TTA ratio, while the treatments did not show significant differences ($p > 0.05$) for most parameters. However, the 200 ppm propiconazole treatment demonstrated the best performance in maintaining a uniform yellow color, minimizing weight loss, and reducing root rot infection compared to other treatments. Therefore, the use of propiconazole at a moderate concentration is recommended as an effective postharvest treatment for Barangan bananas, suitable for both the local fresh market and medium-term export, especially under non-refrigerated storage conditions.

Keywords: Colletotrichum Musae, Crown Rot, Post-Harvest Quality, Propiconazole, Sodium Dichlorocyanurate

1. Introduction

Bananas (Musa spp.) are among the world's leading tropical fruit commodities and play a vital role in Malaysia's agricultural economy. According to the Food and Agriculture Organization (FAO, 2023), bananas are the most traded fruit globally, with annual production exceeding 125 million tonnes, primarily in tropical countries such as India, the Philippines, Indonesia, and Ecuador. In Malaysia, bananas rank among the highest-producing fruits, with total production reaching approximately 342,000 metric tonnes in 2022 (Sinaga et al., 2025). The Barangan banana, in particular, is highly valued for its sweet taste, soft texture, and appealing aroma, making it a superior variety for both domestic consumption and export markets.

However, post-harvest losses of bananas are reported to be high, ranging from 20–40% at the distribution and marketing chain level (FAO, 2023) . These losses are caused by fungal decay that develops rapidly after harvest, primarily crown rot and anthracnose. Crown rot is usually caused by pathogens such as Colletotrichum musae, Lasiodiplodia theobromae, and Fusarium spp., which infect the crown tissue after cutting the bunch (Hu et al., 2022) . Meanwhile, anthracnose attacks the skin surface and often appears as a latent infection in the field (Ranasinghe et al., 2002) . Both diseases not only cause physical damage and quality loss, but also affect the market value and consumer acceptance of bananas.

Good postharvest practices are crucial to ensure optimal fruit quality during storage and shipping. Various methods have been used to control postharvest diseases, including the use of synthetic fungicides such as

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propiconazole, thiabendazole, and imazalil (Alvindia et al. , 2004). Cinnamon essential oil has previously been reported as a source of antifungal agents (Wilis et al., 2017) . A previous study by Sinantia et al., 2024, to control crown rot disease in bananas also confirmed the effectiveness of cinnamon oil. This oil contains compounds such as cinnamaldehyde, which have been tested on fresh fruits such as mandarin, kiwi, and rambutan to control postharvest diseases (Tamamiya, Nilta Ukkida, 2024).

Therefore, this study was conducted to evaluate the effect of several antifungal treatments (propiconazole, cinnamon oil, and NaDCC) on the physical, biochemical, and postharvest disease quality of Berangan bananas during storage at room temperature. This study also aimed to determine the most appropriate treatment to maintain fruit quality, reduce postharvest losses, and increase the potential market value of local bananas as a competitive export commodity.

2. Material and Methods

2.1. Place and Time

The research was conducted in the laboratory at the Post-Harvest Complex of the Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor, Malaysia, located at coordinates 3°00′16″ N and 101°42′48″ E with an altitude of ± 59 meters above sea level (masl). The research was conducted from September 22 to October 10, 2025. On September 22 to October 10, 2025.

2.2. Fruit source

Barangan bananas have been used as experimental samples, obtained from local farmers at the Selangor Wholesale Market. The fruit used in this study was at the stage of commercial maturity for export markets (Index 2).

2.3. Postharvest Treatment and Storage

Barangan bananas, which are late-ripening from local farmers, are then combed, grated, and sorted. They are then washed in water to remove dirt and sap. This observation has 4 treatments, namely:

1. Control (without treatment)
2. 0.3% cinnamon oil (cinnamaldehyde 15 ml + span 80 5 ml + 4,980 liters of water)
3. 200 ppm sodium dichloroisocyanurate (NaDCC)
4. 200 ppm propiconazole

After mixing each treatment, the bananas are placed on a drying rack with the help of an industrial fan. Dry bananas are stored in boxes with a total of 3 combs/box. Bananas are ripened using ethylene gas (75 ppm) for 52 minutes and stored at ambient (room) temperature for 7 days.

2.4. Measurement of Fruit Weight Loss

For data on fruit weight loss percentage, three bunches of bananas for each treatment were separated to collect weight loss data. Fruit weight was measured weekly until the treatment samples were damaged. The rate of water loss in the fruit was calculated using the method (Luengwilai & Beckles et al., 2010). The results were converted into fruit weight loss percentage using the following equation:

$$\textbf{\% weight loss} = (W0 - Wf/\ W0) \times 100$$

Where:
W0 = weight of bananas on the first day of experimental treatment
Wf = weight of bananas per week during storage

2.5. Measurement of fruit firmness

Fruit firmness was measured using a Texture Analyzer, TA-XT Plus (Micro Stable Systems, UK) connected to a computer. Each fruit for each treatment, with 3 replicates, with 3 fruits for each replicate, was peeled first, then measurements were taken on the fruit mesocap. The total force generated by the needle to penetrate the mesocap was read by the machine. This machine was set at a maximum pressure of 20 mm/min using a 0.5 mm diameter crosshead. The compressive strength was measured at the maximum peak level recorded on the force graph and converted as Newton (N). Three readings of firmness (N) for each treatment were recorded.

2.6. Measurement of fruit skin color

Changes in the color of the skin and flesh of the fruit were determined based on the brightness (L*), hue (H˚), and chroma (C*) parameters which were evaluated individually on each fruit for each treatment with 3 replications, with each replication consisting of 3 fruits. Parameter measurements were based on a CIE Lab System using a Chromameter model Minolta CR300 (Minolta Camera Co., Japan).

2.7. Total Dissolved Solids Measurement

The fruit from each treatment was peeled and blended using a blender without water for 3 minutes at medium speed. Analysis was carried out immediately to obtain the total soluble solids results. The fruit juice obtained from the grinding results was measured using a Digital Refractometer (Model: DBX-55) from Atago Co. Ltd., Tokyo, Japan. Before the measurement was carried out, the refractometer was calibrated first using distilled water to obtain a result of 0%. The readings were taken at room temperature and the results were interpreted in % (˚Brix).

2.8. Determination of Ascorbic Acid (Vitamin C) Content

Ascorbic acid was determined using the dye method (Ranggana et al. , 1977). A 10 g of ground sample was mixed with 90 mL of metaphosphoric acid (HPO3) at a concentration of 3%. The sample volume was adjusted to 100 mL. A 5 mL sample was titrated using a dye solution (2,6-dichlorophenol indophenol) until the solution turned bright pink, lasting for 15 seconds before turning clear. The ascorbic acid content was calculated based on:

Vitamin C (mg/100g) = [Titration value (ml) x Dye Factor x Volume added (ml) x 100] / [Sample volume (ml) x Sample weight (g)]

For the dye factor, the calculation is based on: 5 mL of standard ascorbic acid is taken and 5 mL of HPO3 with a concentration of 3% is added. The mixture is titrated with the dye solution until it turns bright pink. The dye factor is calculated based on:

Dye Factor = μg ascorbic acid / Dye titration value (ml)

2.9. Procedure Implementation Study

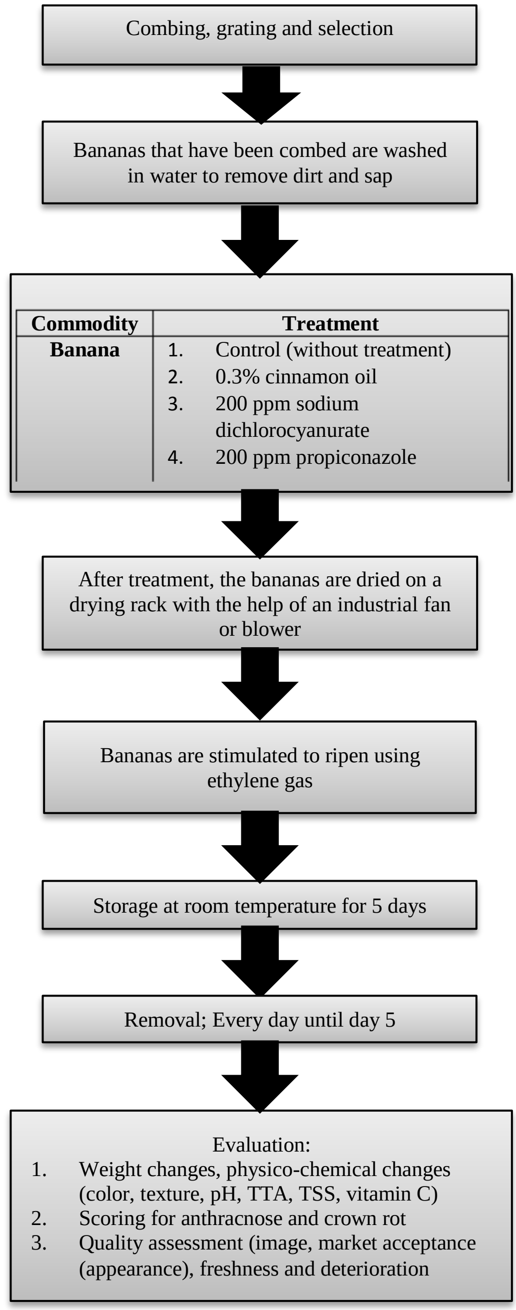

Figure 1. Flowchart Procedure Study

2.10. Measurement of pH Value and Total Titrated Acidity (TTA) Content

The pH value was determined using an automatic pH meter (WTW Microprocessor pH 539 meter, Germany). The pH meter was calibrated using pH buffers at pH 4.0 and 7.0 before use. After the electrode needle was inserted into the fruit juice solution, a stable pH reading was recorded. The titrated acidity was analyzed using the titration method of Ranggana et al. (1977). A 5 g of mashed fruit sample was mixed with 20 mL of distilled water. The solution was titrated with 0.1 N sodium hydroxide (NaOH) to an endpoint of pH 8.1. The titration value was recorded and the result was interpreted as the percentage of citric acid based on the following calculation:

Amount of Acidity (%) = [Titrate value (ml) x Normality of NaOH (0.1N) x Amount make (ml) x citric acid weight equation (64g) x 100]/ [Sample weight x 100]

2.11. Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) in SAS software (Version 94, SAS Institute Inc., Cary, NC, USA). Comparison of means was performed using Duncan's Multiple Range Test (DMRT) at $p < 0.05$ to determine significant differences between treatments and storage duration. The results are presented in tables and figures. Experimental data are presented as mean ± standard deviation for each sample.

3. Results and Discussion

3.1. The Effect of Treatment and Storage Time on the Physical Quality of Bananas

3.1.1. Changes in banana peel color

The color parameters (Brightness, Chroma, and Hue Angle) showed significant changes ($p<0.05$) during the storage period, but there was no significant difference between treatments (Table 1.1). The Brightness value increased from 47.86 (day 0) to 62.22 (day 4), indicating an increase in skin brightness along with the change from green to yellow during the ripening process. However, this value decreased again to 48.57 on day 7, indicating that the skin began to lose its brightness due to the aging process and the appearance of brown spots (senescence).

The chroma value increased from 35.81 (day 0) to 54.00 (day 4) and decreased to 38.43 (day 7). This indicates that the yellow color becomes more saturated at the full ripening phase and then fades as the skin begins to turn brown. The hue angle decreased from 114.95° (day 0) to 72.29° (day 7), indicating a color change from green to yellow and then to brown, which is a typical pattern of banana ripening. There were no significant differences between treatments for all color parameters ($p>0.05$), but the average showed that propiconazole (200 ppm) maintained slightly higher Lightness and Hue values than the other treatments, indicating brighter skin and stable yellow. This may be due to good fungal control, thereby reducing the activity of oxidative enzymes that accelerate skin browning.

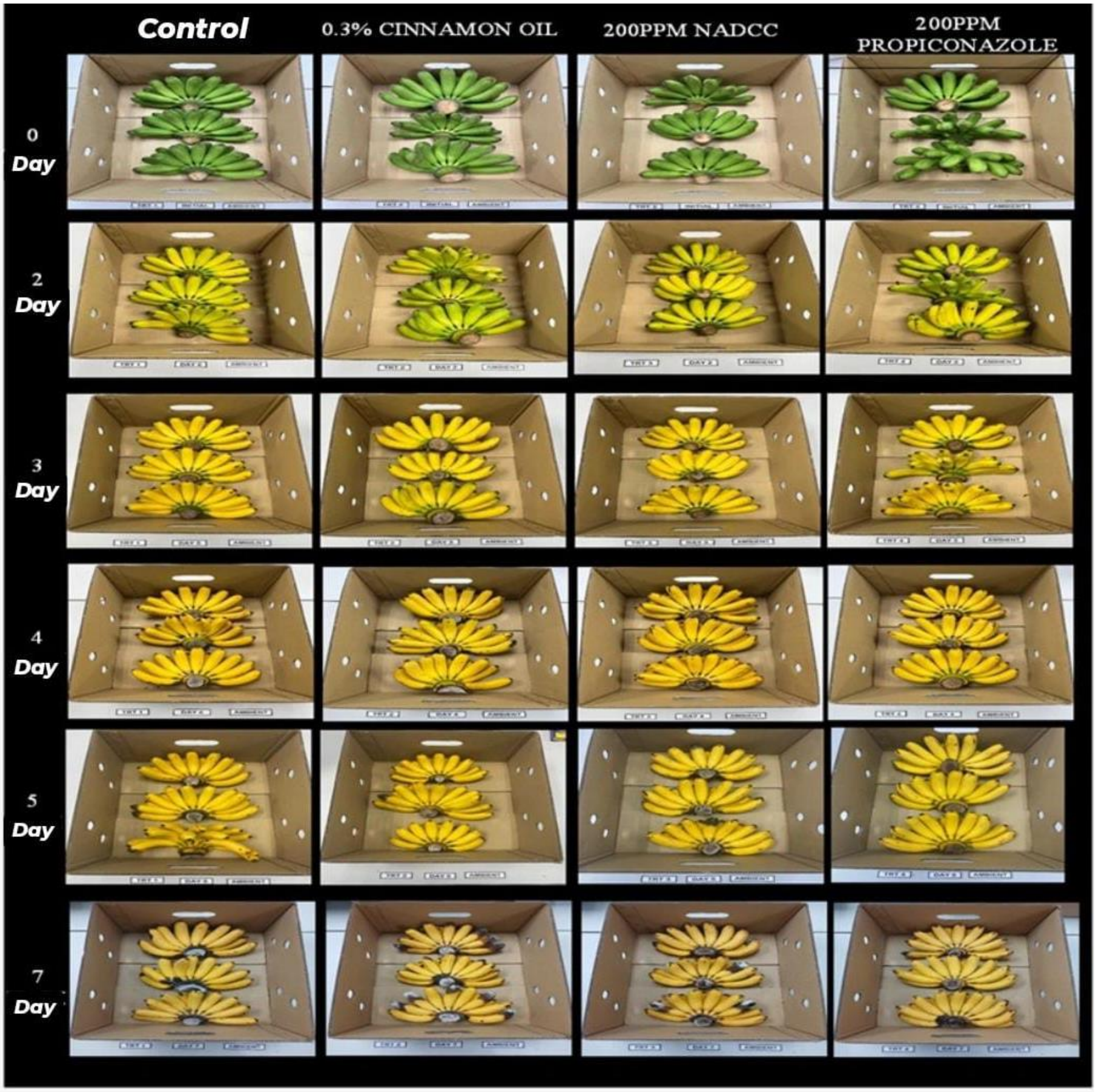

Figure 2. Physical changes in bananas during 7 days of storage at room temperature with different treatments.

Table 1. Physical Changes in Barangan Bananas with Various Treatments After 7 Days at Room Temperature.

Treatment	Lightness	Chroma	Hue	Weight loss (%)	Texture (N)
Control	56.09^{ab} ± 1.719	47.08^{a} ± 1.83	90.30^{a} ± 3.19	5.93^{ab} ± 0.896	2.27^{a} ± 0.083
0.3% cinnamon oil	55.35^{ab} ± 1.746	46.21^{a} ± 1.948	91.24^{a} ± 3.479	5.65^{b} ± 0.861	2.31^{a} ± 0.078
250 ppm sodium dicholocyanurate	53.23^{b} ± 1.858	45.62^{a} ± 2.209	89.08^{a} ± 3.615	6.15^{a} ± 0.939	2.32^{a} ± 0.088
200 ppm propiconazole	56.77^{a} ± 1.108	47.50^{a} ± 1.513	90.92^{a} ± 2.875	5.66^{b} ± 0.847	2.18^{a} ± 0.08
F Test Significant	ns	ns	ns	ns	ns

Table 1. *cont.*

Storage Days (TP)	Lightness	Chroma	Hue	Weight loss (%)	Texture (N)

0	47.86c ± 0.721	35.81d ± 0.501	114.95a ± 0.287	0f	
2	58.31b ± 0.81	47.70c ± 0.743	97.84b ± 1.178	3.44e ± 0.073	
3	58.46b ± 0.813	52.77ab ± 0.504	87.56c ± 0.473	4.86d ± 0.108	2.37a ± 0.053
4	62.22a ± 0.747	54.00a ± 0.406	85.09d ± 0.21	6.79c ± 0.121	2.19a ± 0.064
5	56.73c ± 0.767	50.93b ± 0.467	84.56d ± 0.263	8.79b ± 0.143	2.18a ± 0.08
7	48.57c ± 2.709	38.43d ± 2.262	72.29e ± 1.91	11.22a ± 0.209	
F Test Significant	*	*	*	*	ns
Interaction (R x TP)	ns	ns	ns	ns	ns

This change is consistent with the report of Alvindia & Natsuaki (2008) which stated that post-harvest banana ripening is accompanied by chlorophyll degradation and an increase in carotenoids which causes a decrease in the Hue angle. This study also showed that the use of propiconazole can maintain fruit brightness by reducing oxidative stress due to fungal infection.

3.1.2. Loss of fruit weight

The decrease in fruit weight showed a significant difference ($p<0.05$) during the storage period, but not There were significant differences between treatments. The fruit weight loss increased gradually from 0% (day 0) to 11.22% (day 7). This increase was caused by water evaporation and loss of respiratory substances (CO_2 , sugars, organic acids) during the ripening process. Bananas stored for longer periods showed higher levels of fruit weight loss due to increased metabolic and respiratory activity, which was in line with increased internal temperature and ethylene accumulation.

Among all treatments, the highest average weight loss was observed with NaDCC (6.15%), while propiconazole (5.66%) showed the lowest weight loss. Although the difference was not significant, this trend suggests that propiconazole has the potential to help maintain skin moisture by stabilizing the integrity of the fruit epidermis. These results are in line with findings (Bautista-Baños et al. 2013) which reported that systemic antifungal treatment can reduce fruit respiration and transpiration rates, thereby slowing weight loss during storage.

3.1.3. Texture

Pulp hardness values (expressed in Newton, N) did not show significant differences between treatments or storage periods ($p>0.05$). The average value ranged from 2.18 to 2.37 N, indicating that there was a change in texture but it was not significant during seven days of storage. This indicates that all treatments did not negatively affect the hardness of banana pulp. According to (Iswara *et* al. , 2023), which states that texture is one of the important quality attributes in fresh fruit commodities. Fruit that loses its firmness of texture indicates a ripening process or even leading to decay.

Similar values between treatments also indicate that the use of propiconazole, NaDCC, or cinnamon oil did not affect the mechanical properties of the fruit. This is important for consumer acceptance, as a texture that is too soft can reduce market value. These results are consistent with findings (Arrebola et al., 2010) that the use of fungicides and sanitation does not significantly affect the physical properties of tropical fruit as long as the active ingredients are not phytotoxic to pulp tissue.

3.2. Crown Rot Disease Severity Index During Storage

The severity of banana stem rot infection was assessed using a seven-point scale based on the method (Marsuni, 2012) . A score of 0 indicates no symptoms of infection, while a score of 7 indicates severe rot that covers the entire crown and internal tissues. Figure 2 shows the change in disease severity over seven days of storage for four different treatments, namely control (no treatment), 0.3% cinnamon oil, 250 ppm sodium dichloroisocyanurate (NaDCC), and 200 ppm propiconazole.

On day 0, all samples showed a severity score of 0, indicating no visible signs of infection after treatment and packaging. On day 3, the control and cinnamon oil treatments began to show early signs of browning on the crown (indexes around 2), while the NaDCC and propiconazole treatments each recorded lower scores (around 1–1.5). This indicates that both agents were able to slow the initial growth of the fungus on the crown.

After four days of storage, disease progression became more pronounced in the control and cinnamon oil treatments (indexes around 2–2.5), while NaDCC showed moderate levels (≈2.3) and propiconazole remained the lowest (≈1.8). By day 5, the severity score for the control increased significantly to an index of 4, indicating a blackish-brown discoloration spreading to the base of the radius. The cinnamon oil and NaDCC treatments also showed moderate increases (≈3.5–3.8), while propiconazole maintained the lowest score (≈1.5), indicating the efficacy of this fungicide in controlling the development of the root rot pathogen.

On day 7, the control and cinnamon oil treatments achieved the highest scores (≈6–6.2), indicating severe infection with extensive decay and dark internal tissue, consistent with the severity index of 6–7 reported by Alvindia (2004). The NaDCC treatment showed a slightly lower score (≈5.5), indicating moderate efficacy but insufficient for long-term protection. In contrast, propiconazole (200 ppm) maintained the lowest score (≈4), where the crown tissue still appeared intact with limited infection.

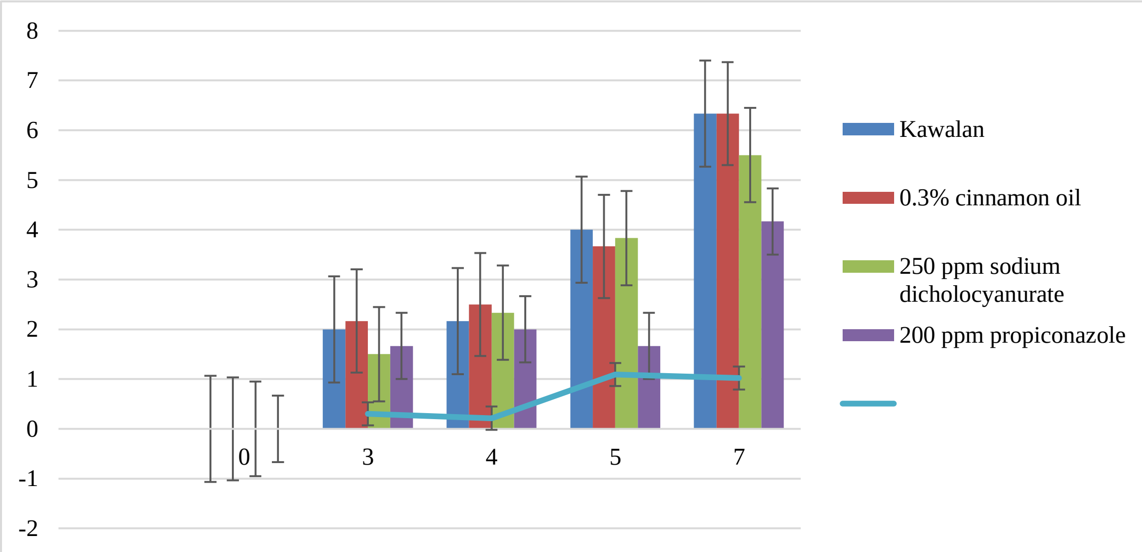

Figure 2. Severity level of stem rot disease on Bananas During Storage

Overall, 200 ppm propiconazole treatment was most effective in controlling the development of root rot disease during the seven-day storage period, followed by NaDCC and cinnamon oil. The control sample showed the fastest disease development rate. The effectiveness of propiconazole is contributed by its mechanism of action as a systemic fungicide from the triazole group that inhibits ergosterol biosynthesis in the fungal cell membrane, thereby disrupting mycelial growth and sporulation. Meanwhile, the moderate protective effect of NaDCC and cinnamon oil is due to their surface antimicrobial action (contact action), which is only effective in the early stages but decreases with increasing humidity and ethylene concentration during storage.

This finding aligns with a report (Ahmad et al., 2024) stating that technically, pesticide use should be avoided due to its negative impacts on humans and the surrounding environment. Therefore, alternatives to controlling plant disease-causing pathogens are being explored, including the use of biological agents, including Trichoderma spp., Gliocladium, and/or Aspergillus fungi.

3.3. Anthracnose Disease Score

The severity of anthracnose disease on banana peels was assessed using a scale of 0 to 4, with a score of 0 indicating no symptoms, while a score of 4 indicates complete decay of the entire fruit surface. Based on Figure 3, the results show that no anthracnose symptoms were detected in all samples from day 0 to day 5 of storage (score = 0). Initial symptoms only began to appear on day 7, with all treatments showing an average score of approximately 1.0, indicating the presence of small lesions covering less than 25% of the fruit peel surface. There was no significant difference ($p>0.05$) between the control, 0.3% cinnamon oil, 250 ppm sodium dichloroisocyanurate (NaDCC), and 200 ppm propiconazole treatments.

These results indicate that anthracnose disease develops very slowly during the seven-day storage period. The main factors contributing to the absence of significant symptoms include the short storage period and proper storage conditions (controlled humidity and temperature), which are able to suppress the activity of the fungus Colletotrichum musae, the main pathogen of this disease. According to (Rumahlewang, W. & Amanupunyo, 2012) who stated that the development of anthracnose disease in bananas, which is assessed by increasing the intensity of damage per unit per day, does not always affect the rate of infection of the fungus that causes the disease.

This observation is in line with the findings of (Sinthuja & Prasannath, 2020) who reported that anthracnose symptoms in bananas usually begin to appear after seven to ten days of storage, depending on temperature, relative humidity, and fruit ripeness. A study by (Santos et al., 2025) also explained that the fungus C. musae can remain dormant until the skin tissue becomes softer and more easily penetrated during the ripening process. In the context of this study, all treatments showed almost the same protective effect in controlling early infection, indicating that post-harvest sanitation methods and good storage conditions play a more dominant role than the type of treatment material during short storage periods.

Overall, the results showed that anthracnose infection levels during seven days of storage were very low for all treatments. This demonstrates that clean postharvest procedures and the use of mild antifungals are sufficient to control the initial growth of C. musae during long-term storage. However, to assess the true effectiveness of treatments such as propiconazole in controlling anthracnose, storage periods longer than ten days are recommended because the disease usually appears in the late ripening phase when the bark tissue begins to undergo physiological degradation.

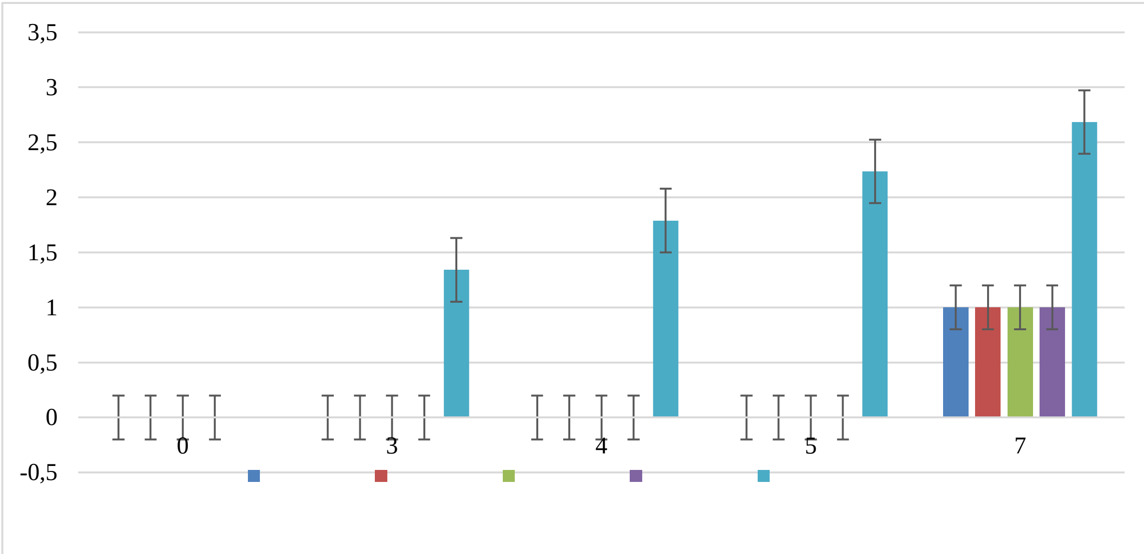

Figure 3. Anthracnose disease severity in bananas during storage at room temperature. Blue indicates control treatment (no treatment), orange indicates 0.3% cinnamon oil treatment, gray indicates 250 ppm sodium dichloroisocyanurate (NaDCC) treatment, and yellow indicates 200 ppm propiconazole treatment. Values are displayed as the average disease severity score based on a scale of 0–4.

3.4. Crown rot and anthracnose disease assessment

Assessment of crown rot and anthracnose diseases. According to (Zhang et al., 2022) stated that rot at the base of banana combs is a symptom of *crown end root disease* caused by infection with the microorganism *Colletotrichum musae* . According to (Zakaria, 2021) *Crown end root* or crown rot is caused by mycelial fungi such as *Colleotrichum musae* which can affect fruit quality due to the development of necrosis in the fruit and can trigger premature ripening of bananas during shipping. Attacks of *crown end root disease* and anthracnose are suspected to be the cause of rapid changes in the banana peel color scale index during storage. In addition, high ethylene production in bananas affects rapid fruit ripening which is characterized by the loss of green color in the fruit skin. According to (Aljawasim et al., 2023), the change in banana peel color from dark green to yellow is due to the gradual degradation of chlorophyll during ripening which is not covered by carotenoid pigments.

Table 2. Physical Changes in Barangan Bananas in Bunch after 7 Days at Room Temperature

Treatment	**pH**	**Citric acid (%)**	**TSS (°Brix)**	**Vitamin C**	**TSS:TTA**
Control	4.71 ± 0.114 b	0.46 ± 0.03 a	21.41 ± 0.912 a	2.04 ± 0.087 a	48.17 ± 4.158 a
0.3% cinnamon oil	4.78 ± 0.104 b	0.45 ± 0.032 a	22.51 ± 0.295 ab	2.20 ± 0.093 a	51.91 ± 3.678 a
200 ppm NaDCC	4.79 ± 0.1 b	0.46 ± 0.04 a	23.07 ± 0.329 b	2.34 ± 0.153 a	52.43 ± 4.214 a
200 ppm propiconazole	4.77 ± 0.102 b	0.44 ± 0.025 a	24.98 ± 0.256 b	2.05 ± 0.065 a	53.71 ± 3.404 a
F test	ns	Ns	ns	Ns	ns
Storage Days (TP)					
3	4.38 ± 0.018 c	0.54 ± 0.0 12 a	22.03 ± 0647 a	2.13 ± 0.0 67 a	41.17 ± 1.884 c
4	4.80 ± 0.021 b	0.46 ± 0.026 b	22.61 ± 0.188 a	2.06 ± 0.109 a	50.44 ± 2.362 b
5	5.09 ± 0.011 a	0.36 ± 0.006 c	22.84 ± 0.478 a	2.28 ± 0.096 a	63.05 ± 1.709 a
F Test Significant	*	*	ns	ns	*
Interaction (R x TP)	ns	ns	ns	ns	ns

3.5. pH and Acidity (Citric Acid%)

Banana pH values showed a significant increase (p<0.05) during storage, but did not differ significantly between treatments (Table 4.5). The pH value increased from 4.38 (day 3) to 5.09 (day 5), indicating a decrease in acidity as the ripening process progressed. This pattern is consistent with the decrease in citric acid value from 0.54% on day 3 to 0.36% on day 5.

This phenomenon reflects the use of organic acids as respiratory substrates in the ripening process. As fruit ripens, respiratory enzyme activity increases, converting organic acids (citric and malic acids) into sugars and energy compounds. According to Mao et al. (2023), the pH value is influenced by the activity of inorganic acids present in the sample. The degree of acidity (pH) is calculated on a scale of 1-14. If the pH value obtained is <7, the acidity value will increase, and vice versa. The level of ripeness is also known to affect the pH value, causing a decrease in organic acids, which results in a continuous increase in the fruit's pH.

Among all treatments, there were no significant differences in pH Among all treatments, there were no significant differences in pH or citric acid levels, indicating that the use of propiconazole, NaDCC, or cinnamon oil did not affect the internal metabolic activity of the fruit. However, the propiconazole treatment (pH 4.77, acid content 0.44%) showed slightly higher pH values and lower acidity, indicating a slight delay in the respiration process compared to the control. This may be due to fungal control reducing oxidative stress and fruit respiration (Neagoe et al., 2025).

3.6. Total Dissolved Solids (TSS, °Brix)

The TSS value showed an increase during the storage period, from 22.03 °Brix (day 3) to 22.84 °Brix (day 5), and this difference was significant ($p<0.05$). According to (Hassan, 2005) total soluble solids were measured using a refractometer. The banana pieces taken were the top, bottom and middle of the fruit. Each part of the banana flesh was squeezed to obtain the filtrate. The filtrate was placed on the refractometer lens for reading the results. Total soluble solids were expressed in °brix units. Quality analysis was carried out on the total soluble solids and starch content of the banana.

Although there was no significant difference between treatments, the highest average TSS value was obtained from the propiconazole treatment (24.98 °Brix) followed by NaDCC (23.07 °Brix). This indicates that these treatments do not inhibit physiological ripening, but rather help maintain sugar balance by slowing degradation after the fruit reaches optimal ripeness.

3.7. Vitamin C Content

Vitamin C content did not show significant differences between treatments or storage periods ($p>0.05$), with an average value between 2.04–2.34 mg/100 g. This indicates that respiratory activity and ascorbate oxidation remained under control during storage.

According to (ElGamal et al., 2023) , vitamin C is easily oxidized at high temperatures and exposure to oxygen. Therefore, the stability of the vitamin C values obtained indicates that the storage conditions used (moderate temperature and controlled humidity) are able to maintain the stability of this antioxidant. Furthermore, treatment ingredients such as propiconazole and cinnamon oil can play a role in reducing oxidative activity on the fruit surface through their antifungal and mild antioxidant effects (Parker et al., 2022).

3.8. Ratio of total dissolved solids to acidity

The TSS:TTA (total soluble solids to titratable acidity) ratio increased significantly from 41.17 (day 3) to 63.05 (day 5). This increase in the ratio indicates major physiological changes in banana fruit, namely increased sweetness and decreased acidity during ripening.

A high TSS:TTA value indicates an optimal balance of sweetness and sourness and an optimal level of maturity. This is consistent with Miah et al.'s (2020) finding that total soluble solids can be used to interpret residual sugars such as lactose, which are broken down during the kefir fermentation process. This finding is also consistent with Sjölin et al.'s (2024) finding that sucrose is broken down into monosaccharides, namely glucose and fructose, through the help of the invertase enzyme, resulting in glucose as a metabolite produced by yeast. The resulting glucose is then broken down into organic acids.

Overall, storage time significantly affected pH, acidity, TSS, and the TSS:TTA ratio, while treatment type did not significantly affect any chemical parameters. An increase in pH and TSS and a decrease in acidity indicated normal physiological maturity. Although there was no significant effect between treatments, propiconazole (200 ppm) showed a positive trend in maintaining internal fruit quality with the highest TSS and TSS:TTA values and the lowest acid loss. This indicates that this treatment was able to maintain fruit flavor and quality while effectively controlling fungal infections.

4. Conclusion

The results showed that 200 ppm propiconazole was the most effective treatment for suppressing fungi and maintaining the physical-biochemical quality of bananas without changing flavor, color, and texture. NaDCC and cinnamon oil had positive effects, but were less stable after five days of storage. Therefore, medium-concentration propiconazole is recommended as a superior postharvest treatment for Berangan bananas, especially for non-refrigerated storage.

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