AGROTECH–FOOD SCIENCE, TECHNOLOGY AND ENVIRONMENT VOL. 2 NO. 2 (2023) P.67-74

AGROTECH

ISSN: 2773-4870 **eISSN:** 2821-3106
DOI: https://doi.org/10.53797/agrotech.v2i2.9.2023

Responses of Postharvest Quality of Banana (*Musa paradisiaca* L. var. Ambon) to Different Concentrations of 1-Methylcyclopropene

Mamat, Mohammad Rizwan[1], Yusoff, Siti Fairuz[1] & Hashim, Rohasmizah[2*]

[1]Agricultural Science Department, Faculty of Technical and Vocational, Universiti Pendidikan Sultan Idris, 35900, Tanjong Malim, Perak, MALAYSIA

[2]Food Technology Department, Faculty of Applied Science, Universiti Teknologi MARA (UiTM), Kuala Pilah Campus, Pekan Parit Tinggi, 72000, Kuala Pilah, Negeri Sembilan, MALAYSIA

*Corresponding author: rohasmizah@uitm.edu.my

Received 13 September 2023; Accepted 15 November 2023; Available online 16 December 2023

Abstract: Banana (*Musa paradisiaca* L. var. Ambon) is a climacteric fruit known for its high perishability due to rapid ripening mediated by ethylene. Postharvest losses significantly impact marketability, particularly during long-distance transport. 1-Methylcyclopropene (1-MCP) is an ethylene action inhibitor that has shown promise in delaying ripening and extending shelf life in various horticultural crops. This study investigated the effects of different concentrations of 1-MCP (0, 0.2, 0.4, and 0.6 g) on the postharvest quality of banana fruits during a 9-day storage period. Key quality parameters evaluated included weight loss, soluble solids concentration (SSC), titratable acidity (TA), pH, and maturity index. Results showed that higher 1-MCP concentrations significantly delayed ripening, reduced weight loss, suppressed SSC and TA accumulation, and maintained lower maturity indices compared to untreated controls. Bananas treated with 0.6 g 1-MCP exhibited the most prolonged retention of quality attributes and slowest ripening progression. These findings support the application of 1-MCP as an effective postharvest treatment to extend the marketable life of bananas during storage and distribution.

Keywords: 1-Methylcyclopropene (1-MCP), banana ripening, postharvest quality, ethylene inhibition, Musa paradisiaca

1. Introduction

Banana (*Musa paradisiaca* L. var. Ambon) is a widely consumed climacteric fruit, botanically classified as a simple fleshy berry. It is cultivated in many tropical and subtropical regions and holds substantial economic and nutritional importance (Ahmad et al., 2006; FAO, 2023). The fruit is predominantly parthenocarpic and seedless, resulting from crosses between *Musa acuminata* and *Musa balbisiana*. Due to its sweet flavor, high energy content, and health-promoting bioactive compounds, bananas play a critical role in food security and trade in many developing countries (Robinson & Galán Sauco, 2010; Marriott et al., 2006).

Being a climacteric fruit, banana undergoes rapid physiological and biochemical changes after harvest, characterized by increased respiration and ethylene production. Ethylene acts as a natural plant hormone that triggers ripening, softening, and senescence processes, thus significantly reducing shelf life (Wills et al., 2007; Tacken et al., 2010). Rapid postharvest deterioration poses a challenge for banana producers, especially when targeting distant markets, as quality losses during storage and transportation can lead to substantial economic setbacks (Kader, 2002; Morita et al., 1992).

Postharvest handling techniques, including temperature control, packaging, and chemical treatments, are employed to maintain fruit quality. However, many of these methods are costly and resource-intensive (Kitinoja & Kader, 2002). Therefore, low-cost and efficient alternatives are continuously being explored. One such alternative is the use of 1-methylcyclopropene (1-MCP), a synthetic ethylene action inhibitor that binds irreversibly to ethylene receptors, thereby delaying ethylene-mediated responses (Blankenship & Dole, 2003; Sisler & Serek, 2006).

Previous studies have demonstrated that 1-MCP can effectively delay ripening and senescence in apples, tomatoes, mangoes, and bananas by preserving firmness, reducing respiration rate, and maintaining visual and nutritional quality (Jiang & Joyce, 2002; Fan et al., 1999; Hofman et al., 2001). However, its effectiveness depends on concentration,

**Corresponding author: rohasmizah@uitm.edu.my*

exposure time, and the commodity's physiological characteristics (Mahajan et al., 2008). While 1-MCP has been commercially applied in several fruit industries, further investigation is required to optimize its use in specific varieties like *Musa paradisiaca* var. Ambon.

This study was conducted to (i) evaluate the effects of different concentrations of 1-MCP on the ripening process of *Musa paradisiaca* L. var. Ambon during storage and (ii) identify the optimum concentration that can best maintain postharvest quality. Findings from this research are expected to provide a practical solution for extending the shelf life of bananas and reducing postharvest losses in supply chains.

2. Materials and Methods

2.1 Experimental Site and Sample Preparation

This study was conducted at the Postharvest Laboratory, Faculty of Technical and Vocational, Universiti Pendidikan Sultan Idris (UPSI). Mature green banana hands (*Musa paradisiaca* L. var. Ambon) were obtained from a local market in Tanjong Malim, Perak. Only fruits of uniform size, color, and free from visible defects were selected. The maturity stage was standardized at index 2 based on the Federal Agricultural Marketing Authority (FAMA) classification, indicating the fruit was mature and green with slight yellow coloration, suitable for extended storage and transport.

2.2 Treatment Application

After sorting, the fruits were dipped in a benomyl fungicide solution to remove latex and suppress postharvest fungal infections. The fruits were then exposed to four different concentrations of 1-Methylcyclopropene (1-MCP): 0 g (control), 0.2 g, 0.4 g, and 0.6 g. The 1-MCP treatments were applied in sealed storage boxes for 24 hours at ambient temperature. Following the treatment, the fruits were stored under room temperature conditions (25 ± 2°C), and observations were conducted over a storage duration of 0, 3, 6, and 9 days. Each treatment was arranged in a Completely Randomized Design (CRD) with three replications.

2.3 Quality Assessments

To evaluate postharvest changes, several quality parameters were measured, including weight loss, soluble solids concentration (SSC), titratable acidity (TA), pH, and maturity index.

Weight Loss (%) was determined by weighing individual fruits before and after storage using an electronic balance (OHAUS PA 512). The percentage of weight loss was calculated using the formula:

$$\text{Weight loss (\%)} = (\text{Initial weight} - \text{Final weight})/\text{Initial weight}) \times 100$$

Soluble Solids Concentration (SSC) was measured using a refractometer. Juice was extracted by homogenizing 20 g of banana pulp in 80 mL of distilled water and filtered through cotton wool. The SSC was measured in °Brix, and values were adjusted to 20°C with a correction factor.

Titratable Acidity (TA) was analyzed using 5 mL of extracted juice, titrated against 0.1 M NaOH using phenolphthalein as an indicator until the endpoint of pH 8.2 was reached. The results were expressed as percentage of citric acid.

pH of the juice was recorded using a digital pH meter. The meter was calibrated with buffer solutions of pH 4.0 and 7.0 prior to measurements.

Maturity Index was determined visually based on skin color development, using the seven-stage index developed by FAMA. Index 1 indicates fully green (immature) fruits, while index 7 corresponds to fully yellow (overripe) bananas.

2.4 Statistical Analysis

The experiment followed a factorial arrangement (4 concentrations × 4 storage durations) in a CRD with three replicates. Data were analyzed using analysis of variance (ANOVA), and significant differences among treatment means were separated using the Least Significant Difference (LSD) test at $P \leq 0.05$. Where interaction effects were significant, regression analysis was conducted to determine the relationship between storage duration and each postharvest parameter under different 1-MCP concentrations. Statistical analyses were performed using SAS software version 9.3.

3. Results

3.1 Weight Loss

The analysis revealed significant interaction effects between 1-MCP concentration and storage duration on banana fruit weight loss ($P \leq 0.05$) as depicted in Figure 1. Weight loss increased linearly with storage time across all treatments, but the rate of increase varied by 1-MCP concentration. After 9 days of storage, bananas without 1-MCP treatment (0 g) recorded the highest weight loss (9.05%), while those treated with 0.6 g 1-MCP exhibited the lowest (6.01%).

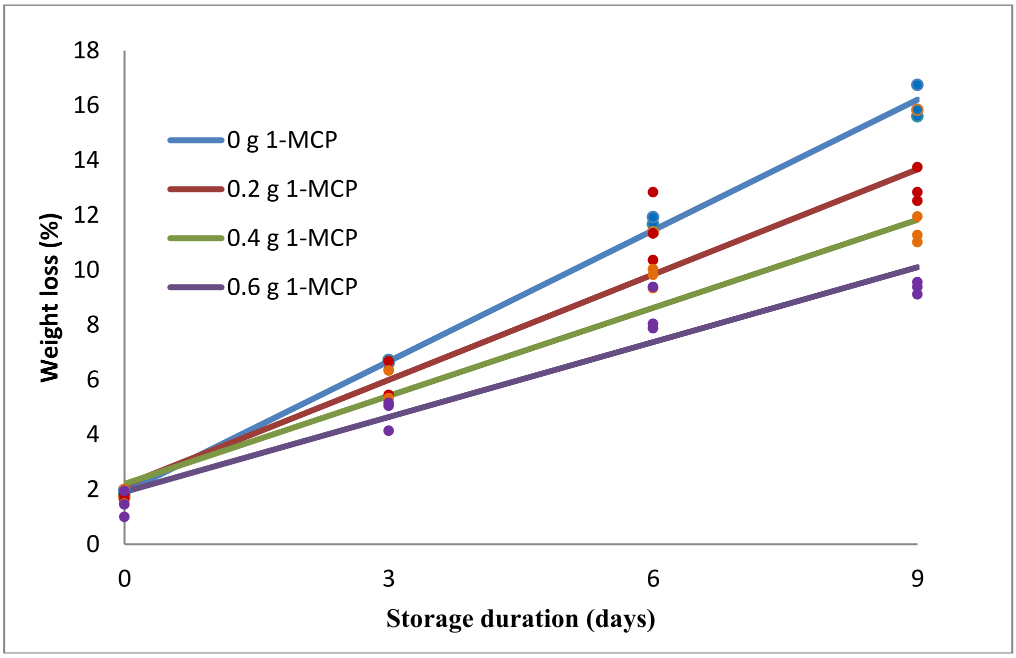

Fig. 1: Relationship between percentages of weight loss and storage duration of *Musa Paradisiaca L var* Ambon in different concentration of 1-MCP. Solid lines indicate significant responses at $P \leq 0.05$.

Regression analysis showed strong linear relationships between weight loss and storage duration ($R^2 = 0.93$ to 0.99), with higher concentrations of 1-MCP resulting in lower rates of weight loss. This trend supports the hypothesis that 1-MCP mitigates ethylene-induced metabolic activity, thereby reducing transpiration and respiration losses (Harris et al., 2000; Tacken et al., 2010).

3.2 Soluble Solids Concentration (SSC)

Figure 2 shows soluble solids concentration, an indicator of sugar accumulation during ripening, was significantly influenced by both 1-MCP concentration and storage duration ($P \leq 0.05$). SSC values increased progressively in all treatments but were significantly lower in 1-MCP-treated fruits.

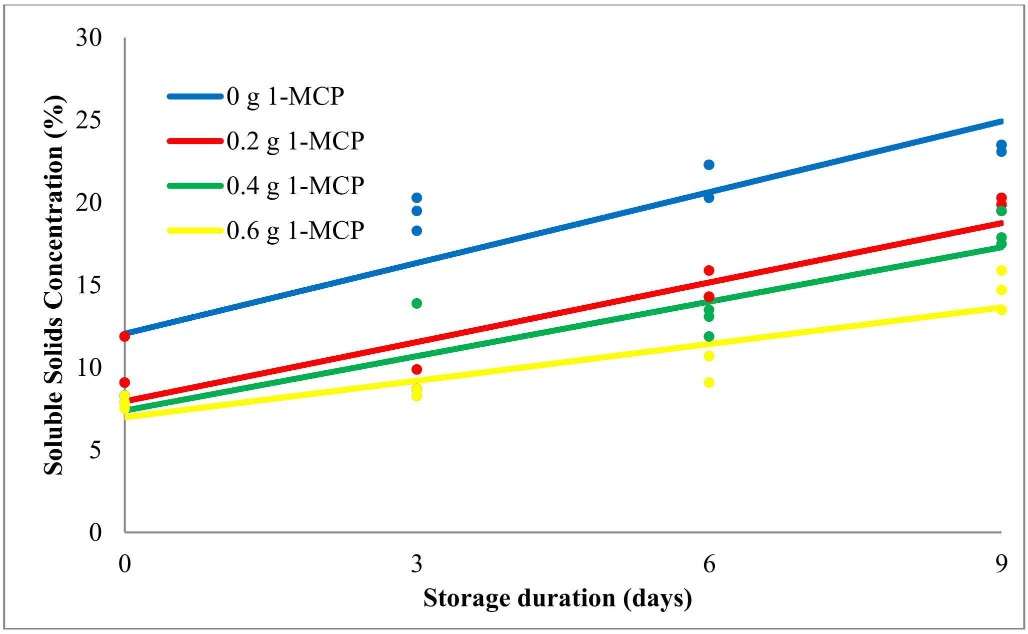

Fig. 2: Relationship between percentages of SSC and storage duration of *Musa Paradisiaca L var* Ambon in different concentration of 1-MCP. Solid lines indicate significant responses at P ≤ 0.05.

Bananas treated with 0 g 1-MCP had the highest SSC (18.51%) after 9 days, while 0.6 g 1-MCP-treated fruits had the lowest (10.28%). Linear regression showed R^2 values ranging from 0.81 to 0.83 across treatments. The lower SSC in 1-MCP-treated bananas can be attributed to delayed starch-to-sugar conversion due to ethylene inhibition (Marriott et al., 2006; Mota et al., 2000).

3.3 Titratable Acidity (TA)

A significant interaction between 1-MCP concentration and storage duration was observed for titratable acidity ($P \leq 0.05$) in Figure 3. TA increased with storage duration in untreated and low-concentration treatments, with the highest TA recorded in 0 g 1-MCP (0.53%). In contrast, bananas treated with 0.6 g 1-MCP had the lowest TA (0.31%).

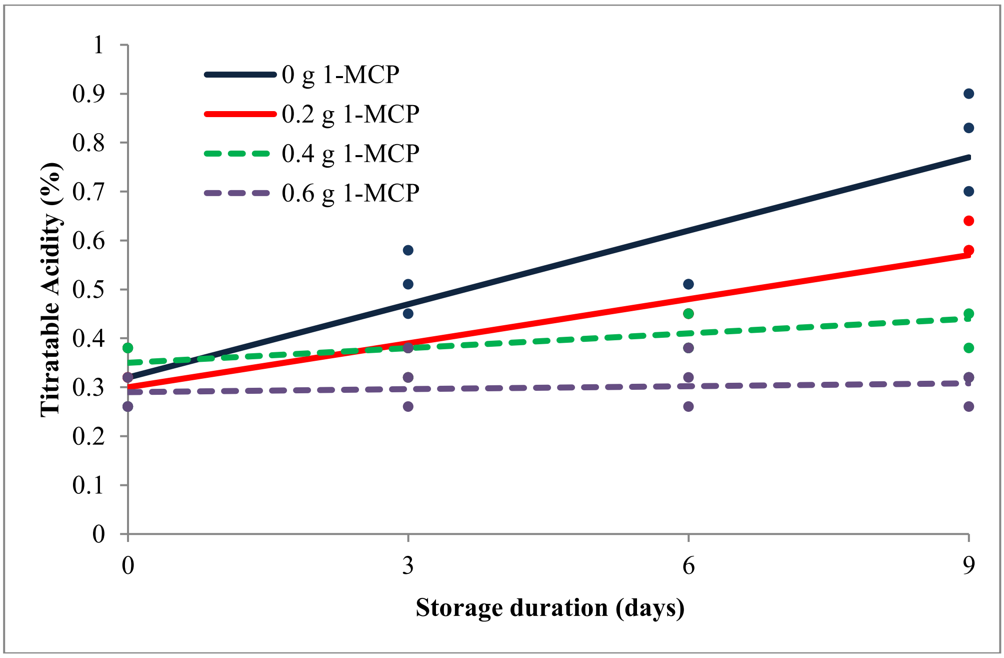

Fig. 3: Relationship between percentages of TA and storage duration of *Musa Paradisiaca L var* Ambon in different concentration of 1-MCP. Solid lines indicate significant responses at P ≤ 0.05.

TA increase in untreated fruits reflects accelerated organic acid metabolism during ripening, whereas 1-MCP mitigated acid catabolism. These results are consistent with previous findings where 1-MCP treatments suppressed acid degradation and respiration in climacteric fruits (Jimenez et al., 2002; Huang et al., 2013).

3.4 pH

The pH of banana juice increased over the storage period, reflecting reduced acidity (Table 1). While there was no significant interaction between 1-MCP concentration and storage duration on pH, both factors independently influenced the outcome. Bananas treated with 0 g 1-MCP had the highest pH (5.79), whereas the lowest values were observed in 0.4 g and 0.6 g 1-MCP treatments (5.62 and 5.71, respectively).

Table 1: Main and interaction effects between concentration of 1-MCP (0 g, 0.2 g, 0.4 g, 0.6 g) and storage duration (0, 3, 6 and 9 days) on pH of *Musa Paradisiaca L. var Ambon.*

Factor	pH
Concentration of 1-MCP (g)(C)	
0	5.79 a
0.2	5.65 ab
0.4	5.62 b
0.6	5.71 b
Storage Duration (day) (SD)	
0	5.26 c
3	5.69 b
6	5.62 a
9	5.95 a
Interaction	
C x SD	ns

[z] Means with the same letters within a column and each factor are not significantly different at P≤0.05 using DMRT test.
*, significant at P≤0.05.

These findings suggest that 1-MCP delays the biochemical changes responsible for organic acid breakdown, thus maintaining acidity and limiting pH rise. This inverse relationship between TA and pH is well-documented in ripening studies (Moing et al., 2001; Thammawong & Arakawa, 2010).

3.5 Maturity Index

The maturity index based on peel color transitioned from green to yellow over the 9-day storage period. Bananas treated with 0 g 1-MCP reached index 7 (fully ripe), while 0.6 g 1-MCP-treated fruits remained between indices 4 and 5, indicating partial ripening.

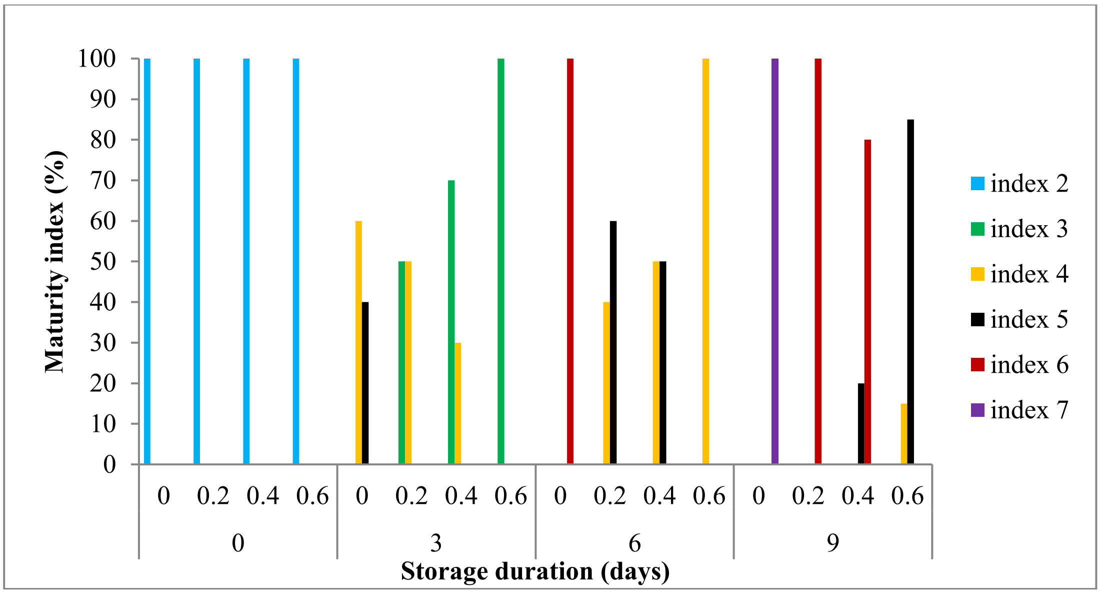

Fig. 4: Relationships between percentage of maturity index and storage duration of *Musa Paradisiaca L. var Ambon* with different concentrations of 1-Methylcyclopropene.

Visual assessment confirmed that 1-MCP delayed external color development, likely through inhibition of chlorophyll degradation and anthocyanin synthesis. The treatment effectively maintained fruit firmness and reduced visual senescence, aligning with earlier studies on banana and mango (Soltani et al., 2010; Jiang & Joyce, 2002).

4. Discussion

The application of 1-Methylcyclopropene (1-MCP) demonstrated a significant impact on the postharvest physiology of *Musa paradisiaca* L. var. Ambon, particularly in reducing weight loss, delaying ripening, and preserving biochemical quality. The findings support the ethylene-inhibitory role of 1-MCP, consistent with its mechanism of binding irreversibly to ethylene receptors, thereby hindering the ethylene perception pathway (Blankenship & Dole, 2003; Sisler & Serek, 2006).

The observed reduction in weight loss with increasing 1-MCP concentrations aligns with previous studies on climacteric fruits such as bananas, mangoes, and apples, where 1-MCP delayed respiratory activity and water loss (Nelson et al., 2006; Mahajan et al., 2008). Weight loss is a common physiological consequence of increased respiration and transpiration rates, both of which are ethylene-mediated processes (Kader, 2002). In the present study, fruits treated with 0.6 g 1-MCP exhibited the lowest weight loss, indicating that the treatment effectively slowed down these physiological mechanisms, preserving fruit mass and marketability during storage.

Soluble solids concentration (SSC) is an important indicator of sweetness and consumer acceptability. The study revealed that SSC increased in all treatments over time, but the increment was significantly suppressed in 1-MCP-treated fruits, particularly at higher concentrations. This suppression is likely due to delayed starch hydrolysis and reduced enzymatic activity involved in sugar biosynthesis, a process accelerated by ethylene during ripening (Marriott et al., 2006; Thammawong & Arakawa, 2010). Lower SSC values in 1-MCP-treated bananas suggest a delayed conversion of starch to sugars, thus extending the ripening timeline.

Titratable acidity (TA) also increased in untreated fruits, reflecting higher rates of organic acid metabolism. In contrast, 1-MCP treatments especially 0.6 g significantly limited TA accumulation, possibly due to a reduction in enzymatic activity associated with organic acid biosynthesis and respiration (Jimenez et al., 2002; Huang et al., 2013). The inverse relationship observed between pH and TA further confirms the ripening delay in 1-MCP-treated bananas. As acids are consumed during ripening, pH tends to rise, yet this progression was slowed under 1-MCP treatment, maintaining lower pH values for a longer duration (Moing et al., 2001).

The maturity index, based on peel color change, is a practical and visible indicator of ripening stage. The results confirmed that bananas treated with higher concentrations of 1-MCP exhibited delayed chlorophyll degradation and color transition. This is attributed to ethylene suppression, which in turn delays the activation of chlorophyllase enzymes and synthesis of carotenoids (Guillon et al., 2008; Hofman et al., 2001). Untreated bananas reached full ripeness by day 9, while those treated with 0.6 g 1-MCP remained in earlier ripening stages, providing evidence of the treatment's efficacy in extending shelf life.

These findings support previous work showing that 1-MCP effectively reduces ethylene-related physiological changes in climacteric fruits (Jiang & Joyce, 2002; Soltani et al., 2010). The significant interactions between 1-MCP concentration and storage duration for key quality parameters such as weight loss, SSC, and TA suggest that the treatment provides a dose-dependent benefit. Notably, 0.6 g 1-MCP consistently outperformed lower concentrations, indicating its potential as an optimal dosage for preserving postharvest quality in bananas.

In conclusion, the results confirm that 1-MCP serves as an effective tool to maintain fruit quality during storage, potentially benefiting banana supply chains by reducing spoilage, enhancing market flexibility, and increasing consumer satisfaction. However, the exact mechanisms of interaction between 1-MCP, fruit metabolism, and storage microenvironment require further investigation to optimize treatment protocols across different cultivars and storage conditions.

5. Conclusion

This study demonstrated that the application of 1-Methylcyclopropene (1-MCP) significantly influenced the postharvest quality of *Musa paradisiaca* L. var. Ambon. Among the concentrations tested, 0.6 g 1-MCP was most effective in delaying ripening, reducing weight loss, minimizing sugar accumulation (SSC), and maintaining titratable acidity and pH balance during a 9-day storage period. The maturity index progression was also markedly slower in fruits treated with higher concentrations of 1-MCP, indicating extended shelf life and delayed senescence. These findings support the use of 1-MCP as a practical ethylene-inhibiting treatment to improve storage and distribution outcomes for climacteric fruits like banana.

It is recommended that future studies investigate the interaction between 1-MCP treatment and different storage conditions (temperature, humidity, and packaging types) to further optimize its use. Additionally, examining the effects of 1-MCP on other banana varieties and extending the storage duration beyond 9 days may offer deeper insights into its long-term efficacy. Economic analysis of 1-MCP application in commercial banana production systems is also warranted to assess its cost-effectiveness and scalability in export-oriented supply chains.

Acknowledgement

The authors would like to express their gratitude to the Universiti Pendidikan Sultan Idris and Universiti Teknologi MARA (UiTM), Kuala Pilah Campus for their support in providing both facilities and financial assistance for this research.

Conflict of Interest

The authors declare no conflicts of interest.

References

Ahmad, S. A. E. E., Chatha, Z. A., Nasir, M. A., Aziz, A., & Mohson, M. (2006). Effect of relative humidity on the ripening behaviour and quality of ethylene treated banana fruit. *Journal of Agriculture & Social Sciences, 1*(2), 54–57.

Blankenship, S. M., & Dole, J. M. (2003). 1-Methylcyclopropene: A review. *Postharvest Biology and Technology, 28*(1), 1–25. https://doi.org/10.1016/S0925-5214(02)00246-6

Fan, X., Blankenship, S. M., & Mattheis, J. P. (1999). 1-Methylcyclopropene inhibits apple ripening. *Journal of the American Society for Horticultural Science, 124*(6), 690–695. https://doi.org/10.21273/JASHS.124.6.690

Guillon, F., Philippe, S., Bouchet, B., Devaux, M.-F., Frasse, P., Jones, B., Bouzayen, M., & Lahaye, M. (2008). Down-regulation of an auxin response factor in the tomato induces modification of fine pectin structure and tissue architecture. *Journal of Experimental Botany, 59*(10), 273–288. https://doi.org/10.1093/jxb/erm312

Harris, D. R., Seberry, J. A., Wills, R. B. H., & Spohr, L. J. (2000). Effect of fruit maturity on efficiency of 1-methylcyclopropene to delay the ripening of bananas. *Postharvest Biology and Technology, 20*(3), 303–308. https://doi.org/10.1016/S0925-5214(00)00135-1

Hofman, P. J., Jobin-Decor, M., Meiburg, G. F., Macnish, A. J., & Joyce, D. C. (2001). Ripening and quality responses of avocado, custard apple, mango and papaya fruit to 1-methylcyclopropene. *Australian Journal of Experimental Agriculture, 41*(4), 567–572. https://doi.org/10.1071/EA00166

Huang, H., Jing, G., Guo, L., Zhang, D., Yang, B., Duan, X., & Jiang, Y. (2013). Effect of oxalic acid on ripening attributes of banana fruit during storage. *Postharvest Biology and Technology, 84*, 22–27. https://doi.org/10.1016/j.postharvbio.2013.03.011

Jiang, Y., & Joyce, D. C. (2002). 1-Methylcyclopropene treatment effects on intact and fresh-cut apple. *Journal of Horticultural Science and Biotechnology, 77*(1), 19–21. https://doi.org/10.1080/14620316.2002.11511402

Jimenez, A., Creissen, G., Kular, B., Firmin, J., Robinson, S., Verhoeyen, M., & Mullineaux, P. (2002). Changes in oxidative processes and components of the antioxidant system during tomato fruit ripening. *Planta, 214*(5), 751–758. https://doi.org/10.1007/s00425-002-0764-5

Kader, A. A. (2002). *Postharvest technology of horticultural crops* (3rd ed.). UCANR Publications.

Mahajan, B. V. C., Singh, G., & Dhatt, A. S. (2008). Studies on ripening behaviour and quality of winter guava with ethylene gas and ethephon treatments. *Journal of Food Science and Technology, 45*(1), 81–84.

Marriott, J., Robinson, M., & Karikari, S. K. (2006). Starch and sugar transformation during the ripening of plantains and bananas. *Journal of the Science of Food and Agriculture, 32*(10), 1021–1026. https://doi.org/10.1002/jsfa.2740321015

Moing, A., Renaud, C., Gaudillère, M., Raymond, P., Roudeillac, P., & Denoyes-Rothan, B. (2001). Biochemical changes during fruit development of four strawberry cultivars. *Journal of the American Society for Horticultural Science, 126*(4), 394–403.

Nelson, S. C., Ploetz, R. C., & Kepler, A. K. (2006). Musa species (bananas and plantains). In C. R. Elevitch (Ed.), *Species profiles for Pacific island agroforestry*. Permanent Agriculture Resources. https://www.agroforestry.org/images/pdfs/Musa_banana_plantain.pdf

Sisler, E. C., & Serek, M. (2006). Inhibitors of ethylene responses in plants at the receptor level: Recent developments. *Postharvest Biology and Technology, 41*(1), 1–8. https://doi.org/10.1016/j.postharvbio.2005.10.004

Soltani, M., Alimardani, R., Omid, M., & Rajabipour, A. (2010). Changes in aroma volatile compounds of banana fruit during ripening. *Australian Journal of Crop Science, 4*(6), 453–458.

Tacken, E. J., Ireland, H. S., Gunaseelan, K., Karunairetnam, S., Wang, D., Schultz, K., ... & Johnston, J. W. (2010). The role of ethylene and other hormones in the regulation of fruit softening. *Plant Physiology, 153*(3), 1559–1570. https://doi.org/10.1104/pp.109.149286

Thammawong, M., & Arakawa, O. (2010). Starch degradation and enzyme activities during banana ripening. *Postharvest Biology and Technology, 57*(1), 38–45. https://doi.org/10.1016/j.postharvbio.2009.09.010

Wills, R. B. H., McGlasson, W. B., Graham, D., Joyce, D. C., & Horticultural Research and Development Corporation. (2007). *Postharvest: An introduction to the physiology and handling of fruit, vegetables and ornamentals* (5th ed.). UNSW Press.