

Exploring Zeolite-Based Ethylene Absorption as a Preservation Technique for Prolonging Post-Harvest Shelf Life of Manalagi Mangoes

Kenneth Betanny¹; Dr. George Anwar²

Advisor²

^{1,2} Surabaya Intercultural School
Surabaya, Indonesia

Publication Date: 2025/10/09

Abstract: Mangoes are a key fruit in tropical regions, but they face post-harvest losses due to spoilage and shelf-life issues. This study investigated the effectiveness of zeolite as a low-cost alternative to preserve Manalagi mangoes. The Manalagi Mangoes were stored in a styrofoam box for 7 days, with different concentrations of treated zeolite (0, 25, and 50 percent). Firmness in kilogram per centimeter squared (kg/cm²) was used as a primary indicator of ripeness. The experiment showed that both treatments varied significantly from the mangoes with no treatment, with visible effects appearing from day 2. The 25% treatment performed comparably to the 50% treatment in retaining firmness starting on day 4. In conclusion, zeolite should be used as a non-toxic and widely available alternative to communities with a lack of access to refrigeration and Modern Atmospheric Packaging. Its adoption could help reduce postharvest losses in developing countries where refrigeration is limited.

Keywords: Zeolite, Firmness, Ethylene, Preservation, and Post-Harvest Losses.

How to Cite: Kenneth Betanny; Dr. George Anwar (2025) Exploring Zeolite-Based Ethylene Absorption as a Preservation Technique for Prolonging Post-Harvest Shelf Life of Manalagi Mangoes. *International Journal of Innovative Science and Research Technology*, 10(10), 272-279. <https://doi.org/10.38124/ijisrt/25oct232>

I. INTRODUCTION

➤ Problem Statement

Every year, in third-world countries such as Kenya, massive quantities of mangoes are wasted due to poor post-harvest infrastructure, limited access to preservation technologies, and a lack of efficient distribution systems. According to National Geographic, Kenya discards approximately 300,000 tons of mangoes annually [1]. The staggering loss of produce highlights the systemic issues in handling climacteric fruits, which are prone to rapid spoilage. The loss reflects not only the economic impact on thousands of farmers across the country but also highlights a deeper challenge to food security and storage. Rajshahi, a city in Bangladesh, has also faced challenges in storing these fruits. The Rajshahi Agricultural Extension Directorate reported that 17,943 tons of mangoes were cultivated in 2020, and 30 percent of them were wasted due to spoilage issues [2].

In a global effort to reduce food waste and hunger, preserving tropical fruits such as mangos presents unique challenges and opportunities. Mangoes, a vital source of nutrients and a primary agricultural product for many developing countries, are particularly vulnerable to rapid spoilage due to their climatic requirements and biological characteristics. Traditional preservation methods, notably refrigeration, can preserve ripe mangoes for 5-7 days [3], compared to 2-3 days [4] at room temperature; however, these methods often involve high energy costs and can be logistically complex in regions like Indonesia that lack infrastructure. Potential solutions, such as chemical fungicides and Modified Atmosphere Packaging (MAP), also have their drawbacks. Chemical fungicides, [5] as noted by Désiré Yao Adjouman, exemplify a preservation technique; however, the inclusion of the chemical hexane in the coating could potentially be toxic to humans. Modified Atmosphere Packaging [6] (MAP), which alters the composition of the air surrounding the fruit in its packaging to slow ripening and decay, can lead to CO₂ injury in the mangoes. In this condition, the fruit might suffer from

tissue damage. Subsequently, a solution to a nontoxic preservation technique that preserves the nutrients and shape of the mango is crucial for the fruit's market value and consumer appeal.

➤ *Background and Context*

Mangoes, a climacteric fruit, continue to ripen after being harvested, a process heavily influenced by ethylene production. Ethylene is a gaseous plant hormone vital in inducing the ripening process for many climacteric fruits such as mangoes, apples, and avocados [7]. As mangoes reach maturity, they increase ethylene production internally through the metabolic processes, specifically by converting S-Adenosylmethionine (SAM) into 1-aminocyclopropane-1-carboxylic acid (ACC). Once produced, ethylene gas diffuses from the mango's porous skin into the surrounding air. This release facilitates ripening by creating a microenvironment that can significantly impact the ripening of the ethylene-producing fruit and other fruits in proximity. You can conduct a simple experiment to see this: place a ripe mango next to green, unripe bananas and observe the changes. This will allow you to compare how the mango ethylene affects the bananas' ripening process.

In light of this, much research has been conducted on the effect of ethylene inhibitors on delaying ripening for many climacteric fruits. One such inhibitor, potassium permanganate (KMnO₄), works by oxidizing ethylene to ethylene glycol [8]. This inhibitor has proven effective in Brayan Ronaldo Gutierrez-Aguirre's research, stating that the mangoes treated with the optimum levels of KMnO₄ (30 grams) yielded maximum color, taste, aroma, and firmness [9]. However, Esin Korkut reported that the lethal dose of KMnO₄ for humans is approximately 10 grams, raising concerns about potential handling risks and the need for strict application controls in postharvest [10] use.

That being said, one effective method to delay the ripening of mangoes involves absorbing the ethylene gas they produce. A promising solution for this is the compound zeolite. Zeolite, primarily composed of silicon, aluminum, and oxygen, and has the general formula $M_n^{+} 1/n(AlO_2)_2$, excels in absorbing ethylene thanks to its highly porous structure [11]. This structure enables them to selectively allow smaller molecules, such as ethylene, to enter while excluding larger molecules [12].

➤ *Research Question*

How effective is zeolite treatment (0%, 25%, 50%) at delaying the ripening of Manalagi mangoes over a 7-day storage period, using firmness as a primary indicator of ripeness?

II. MATERIALS

- Freshly harvested mangoes (Manalagi) of similar dimensions, maturity, and weight were bought from a local supplier in Surabaya, Indonesia.
- Zeolite particles (particle size: 1–2 mm) were purchased online from a supplier in Bandung called Acquasolutions. Zeolite, stored in porous unfilled tea bags to prevent direct contact with the fruit while allowing ethylene absorption, was prepared in 20% and 40% concentrations based on the weight of the mangoes. 3 styrofoam boxes, measuring 16cm long, 35 cm wide, and 52 cm tall, were used to contain all the mangoes.
- A Taffware temperature and humidity monitor was used to track the temperature and humidity of the environment throughout the experiment.
- A Mini Fruit Hardness meter was used to measure the firmness of the mangoes as a quantitative indicator of ripeness.

III. METHOD

The experiment was designed to evaluate the effect of zeolite on the ripening process of mangoes, with firmness as the primary indicator of ripeness. To minimize variability, 36 uniform-sized Manalagi mangoes of the same maturity level and weight (+/-10 percent) were selected. The mangoes were washed with distilled water, dried thoroughly, and divided into three groups: a control group without zeolite, a 25% zeolite group, and a 50% zeolite group. The zeolite was weighed to match 25% and 50% of the total weight of the mangoes in the respective groups. We then heated the zeolites to 200 degrees Celsius for 2 hours, and let them cool for an entire day. This treatment will dry the zeolite, improving its ability to absorb ethylene [13]. The zeolite will later be poured into sachets, with one spoonful of zeolite in each. These, along with a paper towel on the bottom of the styrofoam box to mitigate humidity and the presence of mold, were placed inside the styrofoam containers with the mangoes to create a controlled storage environment, ensuring ethylene gas absorption while allowing the mangoes to respire.

The mangoes were stored at $28 \pm 1.5^\circ\text{C}$ and $62 \pm 12\%$ relative humidity (with daily temperature ranging from 26.9°C at 6 a.m. to 28.9°C at 12 p.m., and humidity ranging from 50% at 6 p.m. to 74% at 8 a.m.) to replicate typical storage conditions. A digital penetrometer was used to measure the firmness of the mangoes at 48-hour intervals. Measurements were taken at four equidistant points on each mango's surface, specifically 5.5-6.5 centimeters from the stalk of the fruit and 4-5.5 cm apart from each other. The skin of the mango at these spots will be peeled every 48 hours, 1 cm in diameter and 0.2 mm deep, using a knife. The paper towel at the bottom of the styrofoam box will be changed every 48 hours.

Firmness was selected as a primary quality indicator because it is a direct, quantifiable measure of mango ripening that correlates strongly with consumers' perception of ripeness. While other indicators, such as Brix, titratable acidity, and skin color, also reflect ripening, they require additional equipment, chemical reagents, and time to measure. Moreover, some mango varieties, such as the Manalagi mangoes, infrequently display skin colour change during ripening, making external appearance an unreliable indicator of maturity. Given the aim of developing a simple, low-cost, and replicable method suitable for tropical smallholder contexts, firmness offered the most practical and reliable metric for this study, as used by Ramesh Kumar in his research on the *Textural properties of Mango Cultivars During Ripening* [14].

The fruit tester will penetrate the flesh of the mango 1 centimeter deep using a constant amount of force. The peak

measurements measured by the device will then be recorded in kg/cm².

To analyze the results, the rate of firmness reduction was compared across the three groups, and statistical analysis, such as a t-test, was performed to determine the significance of differences.

IV. TABLES

Table 1 shows the firmness (kg/cm²) of each Manalagi mango and its loss of firmness over 7 days. Tables 2 and 3 show the zeolite at 25% and 50% of fruit weight on the rate of ripening, measured as firmness loss (kg/cm²) over 7 days. The values represent individual fruit measurements.

Table 1. Control Variable of the Study

Mango	CONTROL			
	Day 0 (kg/cm ²)	Day 2 (kg/cm ²)	Day 4 (kg/cm ²)	Day 6 (kg/cm ²)
C1: 307 gr	28.86	2.61	2.29	2.08
C2: 311 gr	14.58	4.98	2.83	1.2
C4: 315 gr	23.95	9.89	2.53	1.25
C5: 318 gr	18.6	8.52	2.97	2.05
C6: 319 gr	14.34	8.21	2.44	1.8
C7: 321 gr	22.71	5.88	3.12	2.04
C8: 322 gr	15.54	4.05	2.66	1.51
C9: 324 gr	15.63	5.92	1.66	1.17
C10: 324 gr	15.13	5.97	1.39	1.06
C11: 326 gr	15.02	5.59	2.27	1.22
C12: 333 gr	21.27	6.28	2.22	1.22

Some results were omitted due to mold and spoilage issues.

Table 2. Effect of storing Manalagi Mangoes with Zeolite at 25% of Fruit Weight on the Rate of Ripening

Mango	25%			
	Day 0 (kg/cm ²)	Day 2 (kg/cm ²)	Day 4 (kg/cm ²)	Day 6 (kg/cm ²)
25Z1 (333)	12.86	7.14	6.92	2.63
25Z2 (336)	11.23	7.03	5.11	2
25Z3 (334)	18.01	10.01	6.48	1.05
25Z4 (350)	16.64	6.49	4.77	2.86
25Z5 (355)	12.46	9.9	4.58	2.01
25Z6 (334)	10.44	8.01	5.53	2.76
25Z7 (351)	24.26	14.92	5.73	0.8
25Z9 (350)	14.8	9.86	4.91	2.97
25Z10 (356)	18.53	7.79	3.3	1.8

25Z11 (359)	13.28	7.37	3.96	3.8
25Z12 (360)	17.44	9.84	5.85	2.62

Some results were omitted due to mold and spoilage issues

Table 3. Effect of Storing Manalagi Mangoes with Zeolite at 50% of Fruit Weight on the Rate of Ripening.

Mango	50%			
	Day 0 (kg/cm ²)	Day 2 (kg/cm ²)	Day 4 (kg/cm ²)	Day 6 (kg/cm ²)
50Z1 (339)	25.39	10.01	3.89	3.57
50Z2 (338)	24.49	9.24	4.17	2.61
50Z3 (349)	32.76	12.97	4.33	2.66
50Z4 (341)	26.42	10.88	4.64	1.02
50Z6 (342)	31.14	12.58	5.96	2.9
50Z7 (340)	21.26	14.65	2.91	2.13
50Z8 (343)	16	7.92	6.21	0.16
50Z9 (342)	25.58	12.29	4.22	3.06
50Z10 (343)	12.72	11.27	6.01	2.97
50Z11 (345)	17.55	12.68	3.72	3.6
50Z12 (349)	23.83	9.67	7.7	3.58

Some results were omitted due to mold and spoilage issues

Table 4. Statistical Comparison of Firmness Loss in Manalagi Mangoes Stored Under Different Zeolite Treatments Over 6 Days. P-Values are from Independent Two-Sample t-Tests (Two-Tailed) Using Unequal Variances, with Significance Determined at $\alpha = 0.05$.

Comparison	Day	P-value (two-tail)	Significant? ($\alpha=0.05$)
25% vs Control	Day 0	0.2765448605	No
25% vs Control	Day 2	0.0141223858	Yes
25% vs Control	Day 4	0.000000516	Yes
25% vs Control	Day 6	0.0166075393	Yes
50% vs Control	Day 0	0.0301931436	Yes
50% vs Control	Day 2	0.0000199	Yes
50% vs Control	Day 4	0.00000997	Yes
50% vs Control	Day 6	0.0100302111	Yes
25% vs 50%	Day 0	0.0063081798	Yes
25% vs 50%	Day 2	0.0344236611	Yes
25% vs 50%	Day 4	0.9493007585	No
25% vs 50%	Day 6	0.6608492012	No

Values in bold indicate significant differences ($p < 0.05$) compared to the control or between treatments. Comparisons were conducted for 25% zeolite vs control, 50% zeolite vs control, and 25% vs 50% zeolite at each time point (Day 0, Day 2, Day 4, Day 6). A significant result suggests a measurable difference in the rate of firmness loss, implying an effect of zeolite concentration on mango preservation.

V. FIGURE

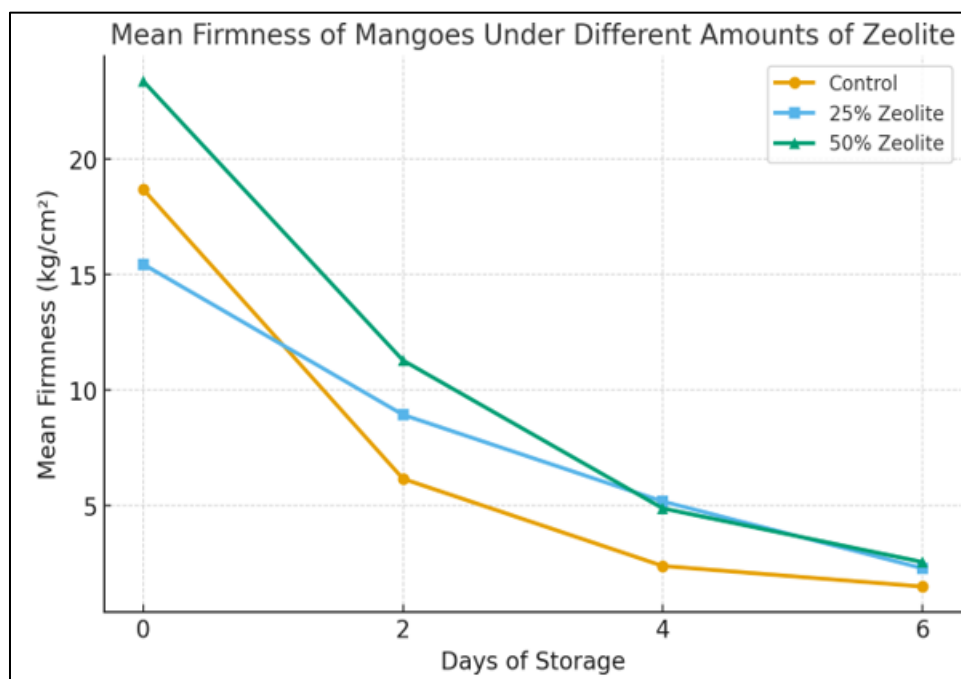


Fig 1. Mean Firmness (kg/cm²) of Manalagi Mangoes over 6 Days for the Control Group, 25% Zeolite Treatment, and 50% Zeolite Treatment. Firmness was Measured using a Handheld Digital Penetrometer, and Values Represent the Mean Firmness of All Mangoes in their Respective Treatment at the Corresponding Day.

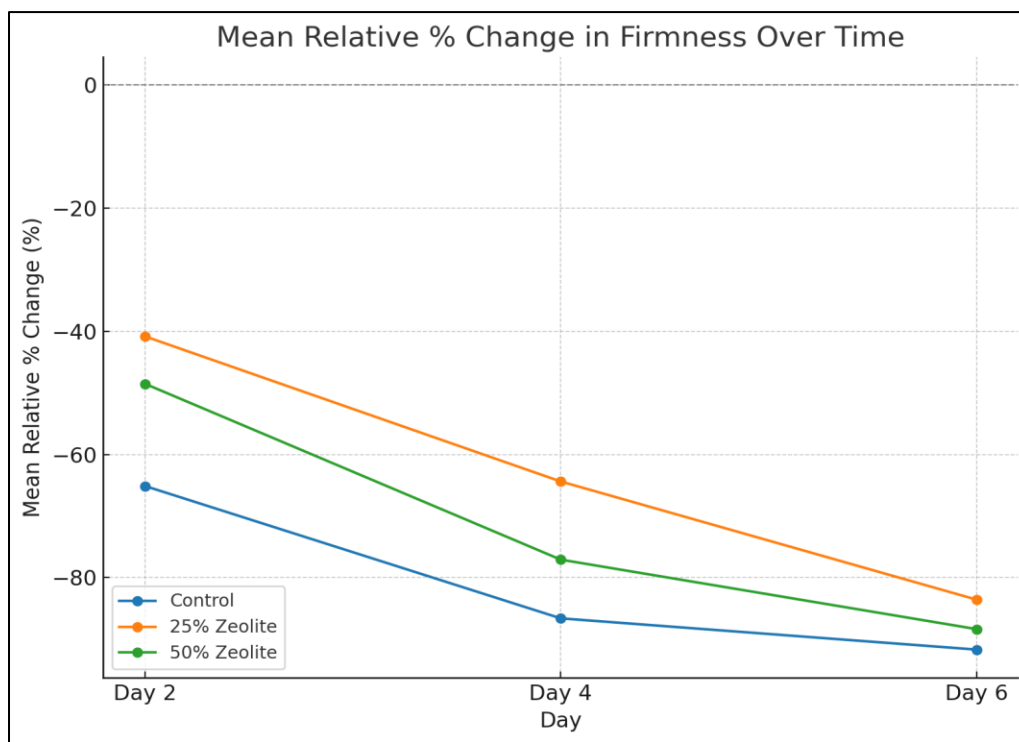


Fig 2. Mean Relative Percentage Change in Firmness of Manalagi Mangoes over 6 Days for the Control Group, 25% Zeolite Treatment, and 50% Zeolite Treatment. Firmness Loss was Calculated Relative to Day 0 Values for Each Mango, with Negative Values Indicating a Decrease in Firmness. Data Points Represent the Mean of all Replicates for Each Treatment at the Corresponding Day.

VI. DISCUSSION

A. The Effect of Zeolite Treatment on Firmness Retention

The results indicated that both the 25% and 50% zeolite treatments were effective in slowing the loss of firmness in Manalagi mangoes compared to the control group. Across all measured days, the control group exhibited a more rapid decline in firmness, as reflected in Figure 2. Additionally, this trend is also supported by the statistical analysis in Table 4, where two-tailed t-tests showed that, from Day 2 onwards, both zeolite treatments differed significantly from the control ($p < 0.05$).

On day 0, the 25% showed a statistically insignificant difference from the control ($p = 0.2765$), whereas the 50% did ($p = 0.0302$), suggesting a slight variation in initial firmness between groups. By day 2, however, both zeolite treatments had significantly lower firmness loss compared to the control (25%: $p = 0.0141$; 50%: $p = 1.99 \times 10^{-5}$), indicating that zeolite's ethylene-absorbing properties may slow respiration and delay ripening during early storage.

This effect persisted through Day 4 and Day 6, where both treatments retained significantly more firmness than the control (Table 4). Notably, the magnitude of difference between 25% and 50% zeolite diminished after Day 4, with p-values of 0.9493 (Day 4) and 0.6608 (Day 6) indicating no statistically significant difference in performance between the two concentrations during the latter part of the storage period.

B. Comparison Between the 25% and 50% Zeolite Treatment

While both treatments were significantly different from the control, their differences were less consistent. As shown in Table 4, days 0 and 2 ($p = 0.0063$ and $p = 0.0344$, respectively) demonstrated a significant difference between the two treatments, with the 50% zeolite group exhibiting a slightly more effective delay in fruit firmness. However, by day 4, this significance began to decline. By day 4 ($p = 0.9493$) and Day 6 ($p = 0.6608$), no statistically significant difference was found between the two treatments.

➤ Comparison with Other Research

Huimin Fu's work, along with many others' work on *Comparative Response of Mango Fruit towards Pre- and Post-Storage Quarantine Heat Treatments*, has shed light on the effect of ethylene on *Mangifera* mangoes [15]. Their treatments — hot water treatment (HWT), vapor heat treatment (VHT), and irradiation — are aimed at prolonging the ripening period for their mangoes. Fu, similarly, used a digital handheld penetrometer (firmness measured in newtons) as one of the key indicators of ripeness alongside several other quality parameters such as total soluble solids ($^{\circ}\text{Brix}$), titratable acidity, skin and pulp color, and weight loss.

However, their findings revealed that these heat-based treatments were not consistently effective in prolonging mango ripeness. Specifically, the HWT- and VHT-treated fruits had significantly lower firmness (114 N and 87 N, respectively)

compared to the control fruits (141 N), and similar declines were also observed in the post-storage heat-treated fruits. In fact, Fu's data suggests that both HWT and VHT treatments often accelerated ethylene production compared to the control, as measured using a three-gas analyzer. This increase in ethylene led to greater weight loss and reduced firmness, resulting in less marketable fruit. These results demonstrate a negative correlation between ethylene concentration and ripening duration—a relationship that this research on the effect of zeolite on mangoes also confirms.

Similarly, Tran et al.'s work on the *Effectiveness of KMnO_4 and Activated Carbon on Cat Hoa Loc Mangoes* investigated ethylene absorption capacity and firmness retention under room-temperature storage [16]. Using a GY-3 handheld firmness tester, they reported that untreated mangoes dropped to 0.49 kg/cm^2 by Day 8. In contrast, the 12 g/box KMnO_4 + activated carbon treatment maintained firmness at 0.91 kg/cm^2 , with better texture still evident by Day 10. Ethylene release, measured with an SKY2000-C2H4 gas analyzer, peaked in control fruits at 9.56 ppm on Day 8, while the optimal treatment delayed the peak to Day 10 at a lower 7.68 ppm. Accordingly, the Manalagi mangoes also slowed the decline in firmness, with the 25% zeolite treatment showing similar preservation to the higher 50% concentration over seven days.

These studies demonstrate the negative correlation between ethylene concentration and the number of ripening days. Their findings also reinforce the rationale behind zeolite treatment, which delays ripening by reducing ethylene levels in the storage environment.

➤ Limitation

One of the limiting factors in this study was the effect of humidity within the styrofoam storage boxes. The enclosed environment led to a buildup of moisture, which in turn promoted mould growth around the puncture holes in the mangoes. As a result, one mango from each treatment group had to be discarded and was excluded from the dataset. Additionally, the paper towels placed inside the boxes were found to be saturated every 48 hours, suggesting excessive moisture accumulation caused by the combined effects of fruit respiration within the box and high ambient humidity outside. This uncontrolled humidity may have influenced both the ripening process and the accuracy of the firmness measurements.

Secondly, while the zeolite used in this study was dried before application, other preparation methods may further improve its ethylene absorption performance. Mohamad Djaeni's research on *Preparation of Natural Zeolite for Air Dehumidification in Food Drying* suggests that treating zeolite with sodium hydroxide (NaOH) followed by heating can significantly enhance its ethylene absorption capacity [13]. Such treatment also improves the zeolite's ability to absorb

moisture, which could help address the humidity issue encountered in this study.

Finally, the experiment tested only two concentrations of zeolite. Exploring a broader range of concentrations may help determine the optimal amount for delaying ripening while maintaining fruit quality. This could provide valuable insight for scaling the method for commercial application.

VII. CONCLUSION

➤ Summary

Through this study, the data have confirmed that zeolite treatments do delay the ripening of Malangi mangoes based on a quantitative measure of firmness. The therapy started to display signs of delay from day 2 onwards. While the 50% treatment showed a slight early advantage, its benefit over 25% diminished after Day 4, indicating that lower zeolite concentrations can deliver comparable preservation results while reducing material costs.

➤ Implications

Zeolite's low cost, non-toxic nature, and widespread availability make it a promising post-harvest treatment, especially for developing countries in tropical regions where humidity accelerates ripening [17] and refrigeration is scarce. Alternative methods, such as refrigeration and KMnO_4 , cost IDR 7.12–14.99/kg/day (based on the fruit and weight) [18] and IDR 27,600 kg/day in the United States [19], respectively, which are more expensive. In comparison, zeolite costs IDR 5.64 kg/day, which is cheaper than both of the other alternatives [20]. Adoption of a 25% zeolite treatment could help producers extend shelf life and reduce postharvest losses without relying on synthetic and potentially hazardous preservatives.

Consequently, zeolite provide a promising alternative to Indonesia, and many other tropical countries and their growing problem of post-harvest losses in mangoes each year. By offering an effective preservation performance at a fraction of the cost of refrigeration or chemical treatment, zeolite presents a practical solution to the large population of farmers in Indonesia who lack refrigeration. Beyond economic benefits, its non-toxic and environmentally safe properties reduce reliance on hazardous preservatives such as KMnO_4 . Wider adoption of zeolite could therefore not only improve farmer income and reduce food waste but also enhance national food security by increasing the availability of fresh mangoes in local markets and for export.

➤ Future Research

Future research on this topic should continue to refine zeolite by maximizing their ethylene absorption capacity and address the limitations encountered in this study. For instance, treating zeolite with sodium hydroxide (NaOH) has been shown to enhance its absorption efficiency, which could help improve the rate at which ethylene is absorbed. Additionally, including many parameters to test ripeness of the mangoes such as °Brix,

titratable acidity, and skin or pulp color alongside firmness measurements would yield a more comprehensive assessment of the ripeness of the fruit. Finally, scaling up experiments to simulate commercial storage conditions and including larger sample sizes would help determine the feasibility of zeolite as a practical solution for farmers and distributors in tropical regions.

ACKNOWLEDGMENT

I would like to express my deepest gratitude to Dr. George Anwar of UC Berkeley for his invaluable guidance and mentorship throughout the course of this research. I am also thankful to the CCIR Research Mentorship Programme for providing the opportunity and resources to carry out this study, including access to research materials that were pivotal to my work. I extend my special thanks to Surabaya Intercultural School for allowing me to use their laboratory facilities. I am equally grateful to Dr. Kuncoro Kohar and Angie Tanaja for their guidance in analyzing raw data and for their thoughtful input, which greatly strengthened this research.

REFERENCES

- [1]. "National Geographic." *Facebook*, www.facebook.com/natgeo/posts/300000-tons-of-nutritious-mangoes-are-wasted-every-year-in-kenya-a-country-that-i/10153371949993951/. Accessed 15 Aug. 2025.
- [2]. Subscriber. "30 PC Mangoes Wasted Every Year Due to Lack of Storage." *30 Pc Mangoes Wasted Every Year Due to Lack of Storage*, 9 Oct. 2023, dailycountrytodaybd.com/story/30-pc-mangoes-wasted-every-year-due-to-lack-of-storage#:~:text=30%20pc%20mangoes%20wasted%20every,market%20with%20mangoes%20for%20sale.
- [3]. Dulaney, Markeisha. "How to Preserve Mangoes (plus How Long You Can Store Them)." *wikiHow*, wikiHow, 7 Feb. 2025, www.wikihow.com/Preserve-Mangoes.
- [4]. Leffler, Samantha. "How to Store Mangoes the Right Way." *Real Simple*, Real Simple, 23 May 2025, www.realsimple.com/food-recipes/shopping-storing/food/how-to-store-mangoes.
- [5]. Adjouman, Désiré Yao. (PDF) *Preservation of Mangoes (Mangifera Indica L. Variety "Kent") by Edible Coating Based Cassava Starch, Coconut Microfiber and Garcinia Kola Oil*, Oct. 2023, www.researchgate.net/publication/374726048_Preservation_of_Mangoes_Mangifera_Indica_L_Variety_Kent_by_Edible_Coating_Based_Cassava_Starch_Coconut_Microfiber_and_Garcinia_Kola_Oil.
- [6]. Potter, Lynneric. "Modified Atmosphere Packaging - 'the Carbon Dioxide Effect.'" *A Blog from Campden BRI*, 11 Feb. 2023, www.campdenbri.co.uk/blogs/modified-atmosphere-packing.php#:~:text=Due%20to%20solubility%2C%20h

- igh%20levels,tissues%2C%20discoloration%20and%20excessive%20drip.
- [7]. “Ethylene and the Regulation of Fruit Ripening.” *University of Maryland Extension*, 11 Mar. 2024, extension.umd.edu/resource/ethylene-and-regulation-fruit-ripening/.
 - [8]. “Influence of Packaging Material and Ethylene Scavenger on Biochemical Composition and Enzyme Activity of Apricot Cv. Habi at Ambient Storage.” *Research Gate*, Jan. 2015, www.researchgate.net/publication/271770283_Influence_of_Packaging_Material_and_Ethylene_Scavenger_on_Biochemical_Composition_and_Enzyme_Activity_of_Apricot_Cv_Habi_at_Ambient_Storage.
 - [9]. Fatima, Farzana, et al. “Trends in Potassium Permanganate (Ethylene Absorbent) Management Strategies: Towards Mitigating Postharvest Losses and Quality of Mango (*Mangifera Indica* L) Fruit - Food and Bioprocess Technology.” *SpringerLink*, Springer US, 15 Mar. 2023, link.springer.com/article/10.1007/s11947-023-03047-8.
 - [10]. Korkut, Esin, et al. “Suicidal Ingestion of Potassium Permanganate.” *World Journal of Emergency Medicine*, U.S. National Library of Medicine, Apr. 2013, [pmc.ncbi.nlm.nih.gov/articles/PMC4129898/](https://pubmed.ncbi.nlm.nih.gov/articles/PMC4129898/).
 - [11]. Pereyra, Andrea M. “Ethylene Adsorption Mechanisms in Exchanged Zeolite and Zeolite-PLA Composite for Versatile Use in Climacteric Produce Preservation.” *Microporous and Mesoporous Materials*, Elsevier, 19 May 2025, www.sciencedirect.com/science/article/abs/pii/S1387181125002161.
 - [12]. Chen, Xinyu, et al. “Research Progress on the Preparation of Transition Metal-Modified Zeolite Catalysts and Their Catalytic Performance for the Purification of Engine Exhausts.” *Journal of Materials Chemistry A*, The Royal Society of Chemistry, 6 June 2024, pubs.rsc.org/en/content/articlelanding/2024/ta/d4ta02492c/unauth.
<https://pubs.rsc.org/en/content/articlelanding/2024/ta/d4ta02492c/unauth>
 - [13]. Djaeni, Mohamad, et al. “Preparation of Natural Zeolite for Air Dehumidification in Food Drying.” *International Journal of Science and Engineering*, ejournal.undip.ac.id/index.php/ijse/article/view/8288/pdf. Accessed 13 Aug. 2025.
<https://ejournal.undip.ac.id/index.php/ijse/article/view/8288/pdf>
 - [14]. Jha, Shyam Narayan, et al. “Textural Properties of Mango Cultivars during Ripening.” *Journal of Food Science and Technology*, U.S. National Library of Medicine, Dec. 2013, [pmc.ncbi.nlm.nih.gov/articles/PMC3791236/](https://pubmed.ncbi.nlm.nih.gov/articles/PMC3791236/).
 - [15]. Javed, Saqib, et al. “Comparative Response of Mango Fruit towards Pre- and Post-Storage Quarantine Heat Treatments.” *MDPI*, Multidisciplinary Digital Publishing Institute, 20 June 2022, www.mdpi.com/2073-4395/12/6/1476.
 - [16]. Tran, Thanh Thang, et al. “Effectiveness of KMNO₄ and Activated Carbon on the Quality and Storage Properties of Mango Fruit.” *Advances in Horticultural Science*, Oct. 2024, oaj.fupress.net/index.php/ahs/article/view/15769.
 - [17]. Hussen, Arebu. (PDF) *a Review of Storage Temperature and Relative Humidity Effects on Shelf Life and Quality of Mango (Mangifera Indica L.) Fruit and Implications for Nutrition Insecurity in Ethiopia*, ResearchGate, Jan. 2021, www.researchgate.net/publication/381609990_A_review_of_storage_temperature_and_relative_humidity_effects_on_shelf_life_and_quality_of_mango_Mangifera_indica_L_fruit_and_implications_for_nutrition_insecurity_in_Ethiopia.
 - [18]. Hossain, Alamgir, et al. “Development and Performance Evaluation of a Refrigerated Storage Structure for Preserving Fresh Fruits and Vegetables - Discover Food.” *SpringerLink*, Springer International Publishing, 19 Aug. 2024, link.springer.com/article/10.1007/s44187-024-00156-x.
 - [19]. “Potassium Permanganate Prices Worldwide.” *Potassium Permanganate Price - Historical & Current*, Intratec Solutions, 6 Aug. 2025, www.intratec.us/solutions/primary-commodity-prices/commodity/potassium-permanganate-prices.
 - [20]. *Shopee.Co.Id*, shopee.co.id/product/159770619/21925952032?gads_t_sig=VTJGc2RHVmtYMTlxTFVSVVRdENkWWp3RFo3Mkw5czd4Z0hzdEF1WVFibDIwbkxoWHU1TGvkN2g4VnpjRkxIM3JZRTkxT2RwbmU5cWt3TE9aRXZVSIMzbmdjaU45NURMZ0VnL2NBMIldoS1BFdGhLdURodkpMNFkwNFB2eEt2a3RuZlVTSGVSVZmxazDFTMXVI MjhzbdJnPT0. Accessed 15 Aug. 2025.