

# Extending the Storage Life of Tomato (*Lycopersicon esculentum* L.) Using Different Rice Hull-Based By-Products

Rey G. Loplop<sup>1\*</sup> and Lodifel C. Deypalan<sup>1</sup>

<sup>1</sup>Sultan Kudarat State University, ACCESS Campus

\*[rgloplop@scsc.edu.ph](mailto:rgloplop@scsc.edu.ph)

Date Submitted:

**March 18, 2026**

Date Accepted:

**April 29, 2026**

Date Published:

**May 10, 2026**

DOI:

**10.5281/zenodo.20110854**

## ABSTRACT

This study determined the effectiveness of rice hull-based by-products in extending tomato storage life, maintaining fruit quality, and improving economic return under ambient storage conditions. A 2 x 5 factorial experiment in a Completely Randomized Design with three replications was used. Factor A consisted of two tomato varieties, Diamante Max F1 and Avatar TY F1, while Factor B included five storage treatments: control, carbonized rice hull, rice hull ash, milled rice hull, and rice bran. The evaluated parameters included days to ripening, firmness, weight loss, marketable and non-marketable fruits, color index, storage life, sugar content, total soluble solids, pH, visual quality rating, decay incidence, and return

on investment. Results showed that carbonized rice hull significantly delayed ripening, reduced weight loss, increased marketable fruits, extended storage life, and minimized decay incidence. Diamante Max F1 generally exhibited better storage performance than Avatar TY F1 because of slower ripening, lower weight loss, slower color development, and lower decay incidence. The interaction between variety and rice hull-based treatment significantly affected weight loss, marketable fruits, visual quality rating, and decay incidence, with Diamante Max F1 treated with carbonized rice hull producing the best postharvest performance, including the lowest non-marketable fruits at 21.67%. Firmness, total soluble solids, pH, and visual quality rating were not significantly affected by the main treatments. Economically, Avatar TY F1 under the control treatment obtained the highest return on investment at 39.92%, while Diamante Max F1 treated with carbonized rice hull recorded the highest net income for the variety and a 39.20% return on investment. The findings indicate that carbonized rice hull is a practical, low-cost, locally available, and eco-friendly storage medium for reducing tomato postharvest losses, especially for Diamante Max F1.

**Keywords:** *tomato, storage life, postharvest quality, rice hull-based by-products, carbonized rice hull, return on investment*

## INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is one of the most widely cultivated and economically important vegetable crops because of its role in food security, nutrition, and agricultural income. It is valued in both fresh and processed markets and is a source of vitamin C, provitamin A, beta-carotene, potassium, lycopene, polyphenols, and other bioactive compounds associated with improved human health (Collins et al., 2022; FAO, 2016; Zhang et al., 2023). However, tomato is a climacteric fruit whose respiration and ethylene production increase rapidly during ripening. This physiological behavior accelerates softening,

color development, moisture loss, and quality deterioration, especially under the warm and humid conditions common in tropical areas (Saltveit, 2019; Yu et al., 2023).

Postharvest losses of tomatoes remain a persistent problem in developing countries. Losses in fruits and vegetables can reach 30-40% because of poor handling, inadequate storage systems, moisture loss, mechanical injury, and microbial decay (Tiamiyu et al., 2023). These losses reduce food availability and lower the income of farmers and traders. In the Philippines, tomatoes remain a common and culturally important vegetable, but fluctuating supply and price conditions make postharvest quality management especially important for producers and market actors.

The use of low-cost and locally available agricultural by-products has gained attention as a sustainable postharvest strategy. Rice hulls are abundant by-products of rice milling and are often underutilized despite their potential value in agricultural applications (IRRI, 2017). Rice hull-based materials such as carbonized rice hull, rice hull ash, milled rice hull, and rice bran possess physical and chemical properties that may support tomato preservation. Their porosity, moisture adsorption capacity, silica content, and potential antimicrobial or ethylene-regulating properties may help reduce transpiration, respiration, ripening speed, and decay during storage (Haider et al., 2020; Zhang et al., 2021).

Given the short shelf life of tomatoes and the need for affordable postharvest interventions, this study evaluated the effectiveness of different rice hull-based by-products in extending the storage life and maintaining the quality of two tomato varieties. The study also assessed the economic feasibility of these treatments to guide farmers, traders, and agripreneurs in reducing postharvest losses using locally available resources.

## **Literature Review**

### ***Tomato quality and postharvest deterioration***

Tomato quality is influenced by cultivar, maturity stage, storage environment, and postharvest handling. Because tomato is a climacteric fruit, ethylene strongly regulates ripening and triggers physiological and biochemical changes, including chlorophyll degradation, carotenoid accumulation, tissue softening, and conversion of carbohydrates into sugars (Li et al., 2019; Quinet et al., 2019). Water loss through transpiration and substrate use through respiration contribute to weight reduction, shriveling, and reduced marketability (Fich et al., 2020). As ripening advances, fruit tissues soften and become more susceptible to fungal and bacterial infection, which results in decay and market rejection (Oladipo et al., 2025; Peralta-Ruiz et al., 2020).

### ***Varietal differences in tomato storage performance***

Tomato varieties differ in firmness, cuticle permeability, ethylene response, color development, and resistance to microbial invasion. Varieties with firmer tissues, thicker cuticles, and slower ripening behavior tend to maintain marketability longer because they lose less moisture and resist pathogen entry more effectively. In this study, Diamante Max F1 and Avatar TY F1 were compared because varietal characteristics may determine how fruits respond to rice hull-based storage materials. Differences in ripening speed and decay incidence are important because they directly affect storage life, marketable yield, and economic return.

### ***Rice hull-based by-products as postharvest storage materials***

Carbonized rice hull is a porous carbon-rich material produced by burning rice hulls under limited oxygen. Its porosity can help regulate moisture around stored fruits, while its silica content may contribute to reduced tissue deterioration and microbial activity. Recent work on carbonized rice husk and calcium applications reported improved tomato shelf life and reduced fungal disease incidence (Mapiemfu-Lamare

et al., 2025). Rice hull-based ethylene scavengers have also been shown to delay ripening and maintain the postharvest quality of tomato fruits (Haider et al., 2020).

Rice hull ash is a silica-rich residue obtained from burned rice hulls and may help regulate moisture and reduce microbial growth. Ash-based storage media have been reported to maintain firmness and extend shelf life in tomatoes (Bakpa et al., 2018). Milled rice hull retains the fibrous structure and silica-rich composition of rice hulls, offering a potential cushioning and moisture-regulating medium (Nguyen et al., 2022). Rice bran contains phenolics, tocopherols, gamma-oryzanol, waxes, and other bioactive compounds that may contribute to antioxidant and antimicrobial effects. Rice bran-based coatings and polysaccharide treatments have been associated with quality maintenance in tomato during storage (Friedman, 2013; Liu et al., 2023).

### **Synthesis**

The literature shows that tomato postharvest quality is strongly affected by moisture loss, ethylene-mediated ripening, tissue softening, and microbial decay. Rice hull-based by-products may address these problems through moisture regulation, cushioning, ethylene adsorption, and antimicrobial action. However, their effectiveness may vary by tomato variety and by type of rice hull-derived material. This study therefore provides localized experimental evidence on the storage and economic performance of rice hull-based by-products for tomatoes under practical ambient conditions.

## **METHODS**

### **Research Design**

The study used a 2 x 5 factorial experiment arranged in a Completely Randomized Design with three replications. Factor A consisted of two tomato varieties: A1, Diamante Max F1; and A2, Avatar TY F1. Factor B consisted of five storage treatments: B1, control or no application; B2, 3 kg carbonized rice hull per 20 tomato fruits; B3, 3 kg rice hull ash per 20 tomato fruits; B4, 3 kg milled rice hull per 20 tomato fruits; and B5, 3 kg rice bran per 20 tomato fruits.

Table 1. *Treatment Structure Used in the Study*

Factor	Level	Description
Factor A	A1	Diamante Max F1 tomato variety
Factor A	A2	Avatar TY F1 tomato variety
Factor B	B1	Control or no application
Factor B	B2	3 kg carbonized rice hull per 20 fruits
Factor B	B3	3 kg rice hull ash per 20 fruits
Factor B	B4	3 kg milled rice hull per 20 fruits
Factor B	B5	3 kg rice bran per 20 fruits



Figure 1. *Experimental setup of tomato fruits stored with different rice hull-based by-products.*

### Materials and Treatment Preparation

The materials used in the study included green-mature tomato fruits, rice hull ash, carbonized rice hull, milled rice hull, rice bran, plastic crates, dried banana leaves, banana bracts, weighing scale, color chart, pH meter, thermometer, and refractometer. Rice bran, milled rice hull, and rice hull ash were obtained from a local agricultural feed supplier in Surallah, South Cotabato, while carbonized rice hull was obtained from a local rice mill in Barangay Dajay, Surallah. The materials were selected based on availability, cleanliness, uniform texture, absence of mold, and suitability for postharvest storage.

### Research Locale and Sample Selection

Tomato fruit samples were sourced from Barangay Luhib, Lake Sebu, South Cotabato. Fruits were collected at the green-mature stage during the second harvesting period to ensure uniform physiological maturity. The fruits were selected based on similarity in size, weight, maturity, and freedom from visible defects, insect damage, and disease symptoms. Before treatment application, fruits were cleaned by wiping with a dry cloth to remove dirt and foreign materials.

### Treatment Application and Monitoring

The storage area was cleaned and disinfected before the experiment. Each treatment material was sterilized and weighed at 3 kg for every 20 tomato fruits. Plastic crates were lined with banana bracts and dried banana leaves. Half of the treatment material was placed at the bottom of the crate, followed by the tomato fruits, and then covered with the remaining treatment material. Fruits were monitored every seven days until the end of the storage period. Crates were opened during monitoring to record fruit condition, ripening, quality, and spoilage indicators.



Figure 2. *Application of rice hull-based storage treatments to tomato fruits.*

### Data Gathered

The study measured days to ripening, firmness, weight loss, percentage of marketable fruits, percentage of non-marketable fruits, color index, storage life, sugar content, total soluble solids, pH, visual quality rating, decay incidence, and cost and return. Days to ripening were counted from treatment application until fruit samples became predominantly red. Firmness was evaluated using a rating scale from very firm to soft. Weight loss was computed by comparing initial and final fruit weights. Marketability was

determined by counting fruits that remained suitable for sale, while decay incidence was computed from the number of spoiled fruits.

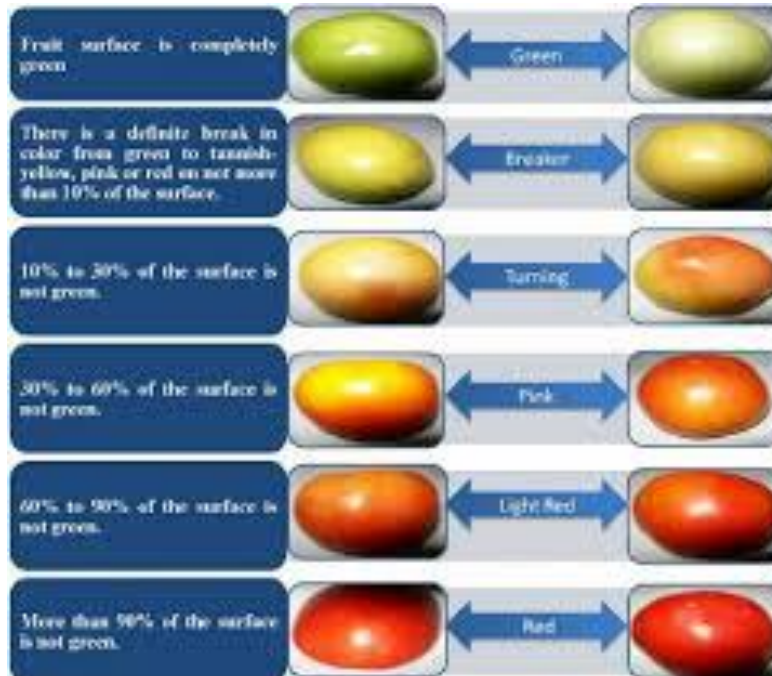


Figure 3. Tomato color chart used in assessing ripening and color index.

### Data Analysis

All data were subjected to Analysis of Variance for a factorial Completely Randomized Design. Treatment means were compared using Tukey's Honest Significant Difference test. Economic performance was evaluated through cost and return analysis using the simulated application of treatments to 1,000 kg of tomato fruits.

### Ethical Consideration

The study followed accepted ethical standards in agricultural and postharvest research. Tomatoes and rice hull-based materials were obtained through legal and responsible means. Experimental procedures were conducted with honesty, accuracy, and transparency. Proper handling, storage, and disposal of materials were observed to prevent contamination and protect the environment. Sources and related studies were acknowledged appropriately.

## RESULTS AND DISCUSSION

### Ripening Period

Tomato variety significantly influenced ripening period. Diamante Max F1 ripened more slowly, with a mean of 15.47 days, compared with Avatar TY F1, which ripened in 8.13 days. Rice hull-based by-products also significantly affected ripening. Carbonized rice hull produced the longest mean ripening period at 13.00 days, comparable with milled rice hull at 12.67 days and rice hull ash at 12.33 days, while the control recorded the shortest period at 9.67 days. The longest ripening period was observed in Diamante Max F1 treated with carbonized rice hull at 17.00 days. These results suggest that carbonized rice hull delayed ripening, likely through moisture regulation and possible ethylene adsorption. The findings align

with studies indicating that ethylene regulation and storage materials can slow ripening in climacteric fruits (Charoensuk et al., 2024; Haider et al., 2020).

*Table 2. Ripening Period of Tomato Fruits as Affected by Variety and Rice Hull-Based By-Products*

Rice hull-based by-product	Diamante Max F1	Avatar TY F1	Treatment mean
Control	13.00	6.33	9.67 c
Carbonized rice hull	17.00	9.00	13.00 a
Rice hull ash	16.00	8.67	12.33 a
Milled rice hull	16.67	8.67	12.67 a
Rice bran	14.67	8.00	11.33 b
Variety mean	15.47 a	8.13 b	

### Firmness

Firmness was not significantly affected by tomato variety, rice hull-based by-products, or their interaction. Diamante Max F1 recorded a mean firmness of 3.32, while Avatar TY F1 recorded 3.35. These values fall within the firm category, indicating that the fruits remained slightly soft but structurally acceptable. Although not statistically significant, milled rice hull recorded the lowest mean value, suggesting slightly firmer fruits, while rice bran recorded the highest value, indicating relatively softer fruits. The lack of significant difference suggests that the treatments delayed some aspects of deterioration but did not strongly alter tactile firmness under the storage conditions of the study.

*Table 3. Firmness of Tomato Fruits as Affected by Variety and Rice Hull-Based By-Products*

Rice hull-based by-product	Diamante Max F1	Avatar TY F1	Treatment mean
Control	3.50	3.33	3.42
Carbonized rice hull	3.54	3.21	3.38
Rice hull ash	3.38	2.88	3.13
Milled rice hull	2.75	3.33	3.04
Rice bran	3.42	4.00	3.71
Variety mean	3.32	3.35	

### Weight Loss

Weight loss was highly affected by variety and by the interaction between variety and treatment. Diamante Max F1 had lower mean weight loss at 380 g than Avatar TY F1 at 650 g. Carbonized rice hull produced the lowest treatment mean weight loss at 277 g, while rice bran produced the highest at 767 g. The best combination was Diamante Max F1 treated with carbonized rice hull, which recorded only 250 g of weight loss. The results demonstrate that carbonized rice hull effectively reduced moisture loss, probably because of its porous structure and moisture-regulating capacity. Since tomato weight loss is mainly caused by transpiration and respiration, storage materials that reduce water loss help maintain quality and marketability (Fich et al., 2020; Haider et al., 2020).

*Table 4. Weight Loss of Tomato Fruits as Affected by Variety and Rice Hull-Based By-Products*

Rice hull-based by-product	Diamante Max F1 (g)	Avatar TY F1 (g)	Treatment mean (g)
Control	500	530	517
Carbonized rice hull	250	300	277
Rice hull ash	430	630	533
Milled rice hull	400	580	492
Rice bran	320	1,220	767
Variety mean	380	650	

### Marketable and Non-Marketable Fruits

Rice hull-based by-products significantly affected the percentage of marketable and non-marketable fruits. Carbonized rice hull recorded the highest marketable fruit percentage at 71.67% and the lowest non-marketable fruit percentage at 28.33%. The best treatment combination was Diamante Max F1 with carbonized rice hull, which produced 78.33% marketable fruits and only 21.67% non-marketable fruits. These results confirm that carbonized rice hull maintained fruit quality more effectively than the other treatments. Its high porosity and silica-rich composition may have reduced moisture loss, minimized microbial infection, and delayed fruit deterioration. Similar findings have shown that carbonized rice hull and rice-derived materials can improve fruit resistance to deterioration and maintain postharvest quality (Liu et al., 2023; Mapiemfu-Lamare et al., 2025).

Table 5. *Marketable and Non-Marketable Fruits as Affected by Variety and Rice Hull-Based By-Products*

Treatment combination	Marketable fruits (%)	Non-marketable fruits (%)
A1B1: Diamante x Control	56.67	43.33
A1B2: Diamante x Carbonized rice hull	78.33	21.67
A1B3: Diamante x Rice hull ash	51.67	48.33
A1B4: Diamante x Milled rice hull	28.33	71.67
A1B5: Diamante x Rice bran	65.00	35.00
A2B1: Avatar x Control	58.33	41.67
A2B2: Avatar x Carbonized rice hull	65.00	35.00
A2B3: Avatar x Rice hull ash	35.00	65.00
A2B4: Avatar x Milled rice hull	61.67	38.33
A2B5: Avatar x Rice bran	23.33	76.67

### Color Index and Storage Life

Tomato variety significantly affected color development. Diamante Max F1 had a mean color index of 3.86, corresponding to the yellow-red stage, while Avatar TY F1 had a mean of 5.40, corresponding to the red stage. This indicates that Avatar TY F1 ripened faster and reached a more advanced color stage after storage. Rice hull-based by-products did not significantly affect color index, although Diamante Max F1 generally retained less advanced color development. Color change in tomato is linked to chlorophyll degradation and lycopene accumulation during ripening (Quinet et al., 2019).

Storage life was significantly affected by rice hull-based by-products. Carbonized rice hull produced the longest mean storage life at 32.50 days, followed by rice hull ash and milled rice hull at 31.67 days. The control recorded the shortest storage life at 27.33 days. Diamante Max F1 treated with carbonized rice hull, rice hull ash, and milled rice hull each reached 33.33 days of storage life. These results confirm that rice hull-based materials, especially carbonized rice hull, can extend tomato storage life by improving the postharvest environment, limiting moisture loss, and reducing decay risk (Haider et al., 2020; Mapiemfu-Lamare et al., 2025).



Plate 1. Representative Diamante Max F1 tomato fruits after storage under rice hull-based treatment.



Plate 2. Representative Avatar TY F1 tomato fruits after storage under rice hull-based treatment.

Table 6. Storage Life of Tomato Fruits as Affected by Variety and Rice Hull-Based By-Products

Rice hull-based by-product	Diamante Max F1 (days)	Avatar TY F1 (days)	Treatment mean (days)
Control	25.67	29.00	27.33 d
Carbonized rice hull	33.33	31.67	32.50 a
Rice hull ash	33.33	30.00	31.67 ab
Milled rice hull	33.33	30.00	31.67 abc
Rice bran	28.00	30.00	29.00 abcd
Variety mean	30.73	30.13	

### Chemical Properties

Sugar content was significantly affected by rice hull-based by-products. Rice bran recorded the highest mean sugar content at 3.43 degrees Brix, comparable with carbonized rice hull at 3.37 and milled rice hull at 3.13. The control recorded the lowest at 2.85 degrees Brix. The increase in sugar content may be associated with continued ripening and the conversion of complex carbohydrates into simple sugars during storage (Mouhamed & Kasnazany, 2024; Tadesse et al., 2012).

Total soluble solids and pH were not significantly affected by variety, rice hull-based treatments, or their interaction. TSS values ranged from 1.80 to 2.12 degrees Brix by treatment mean, lower than common fresh tomato values, indicating relatively low soluble solids in the fruit samples. The low TSS may be due to high moisture content, genotype-related differences, and storage conditions that slowed

carbohydrate conversion (Desalegn et al., 2020; Kabaş et al., 2024). The pH values ranged from 3.78 to 4.76 by treatment mean, indicating that acidity levels were generally maintained across treatments.

Table 7. *Chemical Properties of Tomato Fruits as Affected by Rice Hull-Based By-Products*

Rice hull-based by-product	Sugar content (degrees Brix)	TSS (degrees Brix)	pH
Control	2.85 c	1.88	4.37
Carbonized rice hull	3.37 ab	1.83	4.76
Rice hull ash	2.98 bc	1.95	4.23
Milled rice hull	3.13 abc	2.12	3.78
Rice bran	3.43 a	1.80	3.83

### Visual Quality Rating and Decay Incidence

Visual quality rating was not significantly affected by variety or treatment as main effects, although the interaction was significant. Carbonized rice hull recorded the highest numerical mean VQR at 5.65, while rice bran recorded the lowest at 4.85. Visual quality reflects consumer-relevant characteristics such as color, freshness, firmness, and visible defects.

Decay incidence was significantly affected by rice hull-based by-products and by the interaction between variety and treatment. Diamante Max F1 had lower mean decay incidence at 20.33% than Avatar TY F1 at 29.67%. Carbonized rice hull recorded the lowest treatment mean decay incidence at 10.83%, while rice bran had the highest at 43.33%. The best combination was Diamante Max F1 with carbonized rice hull, which recorded only 6.67% decay. The reduced decay may be attributed to moisture regulation, physical protection, and suppression of microbial activity. Firmer varieties and treatments that delay ripening reduce tissue susceptibility to pathogens (Oladipo et al., 2025; Peralta-Ruiz et al., 2020).

Table 8. *Decay Incidence of Tomato Fruits as Affected by Variety and Rice Hull-Based By-Products*

Rice hull-based by-product	Diamante Max F1 (%)	Avatar TY F1 (%)	Treatment mean (%)
Control	8.33	25.00	16.67
Carbonized rice hull	6.67	15.00	10.83
Rice hull ash	16.67	20.00	18.33
Milled rice hull	55.00	16.67	35.83
Rice bran	15.00	71.67	43.33
Variety mean	20.33	29.67	

### Cost and Return Analysis

Economic analysis showed that profitability varied by variety and treatment. For Diamante Max F1, carbonized rice hull produced the highest net income at Php 13,230.00 and an ROI of 39.20%, indicating that the improvement in marketable yield offset the added treatment cost. For Avatar TY F1, the control recorded the highest ROI at 39.92% because of lower production cost, despite lower postharvest improvement compared with carbonized rice hull. Rice hull ash, milled rice hull, and rice bran generally produced negative ROI values under the study conditions because of higher treatment costs and reduced marketable yields. These findings show that postharvest effectiveness and profitability do not always produce the same ranking; therefore, treatment selection must consider both quality objectives and cost-efficiency.

Table 9. *Cost and Return Analysis per 1,000 kg of Tomato Fruits*

Variety	Treatment	Cost (Php)	Marketable fruits (kg)	Gross income (Php)	Net income (Php)	ROI (%)
---------	-----------	------------	------------------------	--------------------	------------------	---------

Diamante Max F1	Control	25,000.00	567.00	34,020.00	9,020.00	36.08
Diamante Max F1	Carbonized rice hull	33,750.00	783.00	46,980.00	13,230.00	39.20
Diamante Max F1	Rice hull ash	57,750.00	517.00	31,020.00	-26,730.00	-46.29
Diamante Max F1	Milled rice hull	63,750.00	283.00	16,980.00	-46,770.00	-73.36
Diamante Max F1	Rice bran	93,750.00	650.00	39,000.00	-54,750.00	-58.40
Avatar TY F1	Control	25,000.00	583.00	34,980.00	9,980.00	39.92
Avatar TY F1	Carbonized rice hull	33,750.00	650.00	39,000.00	5,250.00	15.56
Avatar TY F1	Rice hull ash	57,750.00	350.00	21,000.00	-36,750.00	-63.64
Avatar TY F1	Milled rice hull	63,750.00	617.00	37,020.00	-26,730.00	-41.93
Avatar TY F1	Rice bran	93,750.00	233.00	13,980.00	-79,770.00	-85.09

## CONCLUSION

The study concludes that tomato variety and rice hull-based storage materials influence tomato postharvest performance differently. Diamante Max F1 showed better storage quality than Avatar TY F1 because it ripened more slowly, lost less weight, developed color more gradually, and had lower decay incidence. However, variety did not significantly affect firmness, total soluble solids, pH, and visual quality rating.

Among the rice hull-based by-products, carbonized rice hull was the most effective treatment for improving tomato storage performance. It delayed ripening, reduced weight loss, increased marketable fruits, lowered non-marketable fruits, extended storage life, and minimized decay incidence. The combination of Diamante Max F1 and carbonized rice hull produced the best postharvest result, particularly in reducing weight loss and decay while increasing marketable yield. In economic terms, however, the highest ROI was obtained from Avatar TY F1 under the control treatment because it involved lower production cost, while Diamante Max F1 with carbonized rice hull produced the highest net income and ROI within the Diamante variety. Therefore, carbonized rice hull is most suitable when the goal is quality preservation and reduction of postharvest loss, while profitability depends on treatment cost and variety-specific marketable yield.

## Recommendation

The use of carbonized rice hull is recommended as a storage medium for tomato fruits because it effectively delays ripening, reduces weight loss, increases the proportion of marketable fruits, extends storage life, and minimizes decay. It is particularly recommended for Diamante Max F1, which responded most favorably to this treatment in terms of storage quality and resistance to deterioration.

Farmers, traders, and agripreneurs may adopt carbonized rice hull as a low-cost, locally available, and eco-friendly postharvest storage option, especially in areas where rice hull is abundant. Rice hull ash, milled rice hull, and rice bran may be explored further as alternative materials, but their cost-effectiveness should be carefully considered because they produced weaker economic outcomes under the conditions of this study. Further studies should test other tomato varieties, storage environments, treatment ratios, sanitation protocols, and longer monitoring periods to refine practical recommendations for commercial and farm-level use.

## References

- Abhirami, P., & Modupalli, N. (2020). Novel post-harvest intervention using rice bran wax edible coating for shelf-life enhancement of tomato (*Solanum lycopersicum*). *Journal of Food Processing and Preservation*. <https://doi.org/10.1111/jfpp.14989>
- Bakpa, E., Maalekuu, B., Tandoh, P. K., & Aculey, P. (2018). Effect of ash-based storage media on the physical quality characteristics and shelf life of three cultivars of tomato (*Lycopersicon esculentum* Mill.) grown in the greenhouse. *Asian Journal of Agricultural and Horticultural Research*, 2, 1-10. <https://doi.org/10.9734/AJAHR/2018/45808>
- Charoensuk, P., Chaiwong, S., Suwunwong, T., Halley, P. J., & Suwantong, O. (2024). Preparation and utilization of biochar from agricultural wastes as ethylene absorber for Gros Michel banana ripening. *Industrial Crops and Products*, 222, 119860. <https://doi.org/10.1016/j.indcrop.2024.119860>
- Collins, E. J., Bowyer, C., Tsouza, A., & Chopra, M. (2022). Tomatoes: An extensive review of the associated health impacts of tomatoes and factors that can affect their cultivation. *Biology*, 11(2), 239. <https://doi.org/10.3390/biology11020239>
- Desalegn, K., Ayalew, A., & Woldetsadik, K. (2020). Effect of irrigation levels on yield and quality of tomato (*Solanum lycopersicum* L.). *African Journal of Agricultural Research*, 15(5), 679-687. <https://doi.org/10.5897/AJAR2019.14658>
- FAO. (2016). FAOSTAT statistical database. Food and Agriculture Organization of the United Nations.
- Fich, E. A., Segado, P., & Rose, J. K. C. (2020). Transpiration from tomato fruit occurs primarily via trichome-associated transcuticular pores. *Plant Physiology*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC7723074/>
- Friedman, M. (2013). Rice brans, rice bran oils, and rice hulls: Composition, food and industrial uses, and bioactivities in humans, animals, and cells. *Journal of Agricultural and Food Chemistry*, 61(45), 10626-10641. <https://doi.org/10.1021/jf403635v>
- Haider, Z., Nawab, A., Alam, F., Lutfi, Z., & Hasnain, A. (2020). The effect of rice husk based ethylene scavengers on the postharvest quality of tomato fruits. *International Journal of Biology and Biotechnology*, 17(4), 765-775.
- International Rice Research Institute. (2017). Rice knowledge bank: Rice hull utilization. <https://www.knowledgebank.irri.org>
- Kabaş, O., Ozdemir, A. E., & Gundogdu, M. (2024). Influence of cultivar and storage conditions on quality attributes of tomato fruits. *Applied Sciences*, 14(17), 7741. <https://doi.org/10.3390/app14177741>
- Kader, A. A. (2016). Postharvest handling practices and treatment methods for tomato. *Journal of Food Quality*, 2016, Article 6436945. <https://doi.org/10.1155/2016/6436945>
- Li, S., Chen, K., Grierson, D., & Yin, X. (2019). Roles of RIN and ethylene in tomato fruit ripening. *Journal of Experimental Botany*, 70(15), 3845-3857. <https://doi.org/10.1093/jxb/erz196>
- Liu, G., et al. (2023). Effects of hydroxyethyl cellulose and sulfated rice bran polysaccharide coating on quality maintenance of cherry tomatoes during storage. *Foods*, 12(17), 3156. <https://doi.org/10.3390/foods12173156>
- Mahesh, K., et al. (2023). Postharvest quality and shelf-life behavior of tomato under storage conditions. *Advances in Agricultural Sciences*.
- Mapiemfu-Lamare, D., Agwa, M. H., Nangsingnyuy, T. B., Ndimanjeh, H., Bihchang-Ngwa, L., Suh, C., & Eku, N. T. (2025). Field and post-harvest efficacy of calcium and carbonized rice husk on fungal diseases and shelf-life of tomato (*Solanum lycopersicum* L.). *Journal of Agriculture and Food Research*, 19, 101657. <https://doi.org/10.1016/j.jafr.2025.101657>
- Mouhamed, B. A., & Kasnazany, S. A. S. (2024). Impact of harvesting stages and postharvest treatments on the quality and storability of tomato fruits (*Solanum lycopersicum* L.). *Coatings*, 14(9), 1143. <https://doi.org/10.3390/coatings14091143>
- Nguyen, N. T., Tran, N. T., Phan, T. P., Nguyen, A. T., Nguyen, M. X. T., Nguyen, N. N., Ko, Y. H., Nguyen, D. H., Van, T. T. T., & Hoang, D. (2022). The extraction of lignocelluloses and silica from rice husk using a single biorefinery process and their characteristics. *Journal of Industrial and Engineering Chemistry*, 108, 150-158. <https://doi.org/10.1016/j.jiec.2021.12.032>
- Oladipo, E. K., et al. (2025). Postharvest losses of tomato: Causes, spoilage mechanisms and preservation strategies. *Food Research International*. <https://doi.org/10.1016/j.foodres.2025.113716>

- Peralta-Ruiz, Y., Hernandez-Munoz, P., Almenar, E., & Gavara, R. (2020). Reduction of postharvest quality loss and microbiological decay of tomato fruit using antimicrobial coatings. *Foods*, 9(9), 1217. <https://doi.org/10.3390/foods9091217>
- Quinet, M., Angosto, T., Yuste-Lisbona, F. J., Blanchard-Gros, R., Bigot, S., Martinez, J. P., & Lutts, S. (2019). Tomato fruit development and metabolism. *Frontiers in Plant Science*, 10, 1554. <https://doi.org/10.3389/fpls.2019.01554>
- Saltveit, M. E. (2019). Respiratory metabolism and ethylene responses in postharvest fruits. In *Postharvest biology and technology of fruits and vegetables*.
- Tadesse, T., Workneh, T. S., & Woldetsadik, K. (2012). Effect of varieties on changes in sugar content and marketability of tomato stored under ambient conditions. *African Journal of Agricultural Research*, 7(45), 6064-6070.
- Tiamiyu, S. A., et al. (2023). Postharvest losses of fruits and vegetables in developing countries: Causes and solutions. *Journal of Postharvest Technology*.
- Yu, Y., et al. (2023). Ethylene regulation and fruit ripening mechanisms in climacteric fruits. *Frontiers in Plant Science*.
- Zhang, X., et al. (2021). Biochar and agricultural waste materials for postharvest preservation: A review. *Journal of Cleaner Production*.
- Zhang, Y., et al. (2023). Bioactive compounds and antioxidant activities in tomato fruit. *Plants*, 12(16), 2947. <https://doi.org/10.3390/plants12162947>