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Effect of Different Packaging Materials on Physico-Chemical Characteristics of Guava

Talib Hussain Rind[1], Maria Abro*[1], Kaleem Kakar[2], Muhzzam Anwar[3], Mohammad Asif[1], Amir Ali[4], Muhammad Nawaz Baloch[1], Ghulam Hussain Bugti[5], Farhan Ali Jatoi[1]

[1]Department of Horticulture, Sindh Agriculture University Tandojam, Sindh, Pakistan
[2]Agriculture Extension Killah Abdullah, Balochistan, Pakistan
[3]Department of Horticulture, Balochistan Agriculture College Quetta, Pakistan
[4]Institute of Horticultural Sciences, University of Agriculture, Faisalabad
[5]Department of Agronomy, Sindh Agriculture University Tandojam, Sindh, Pakistan

*Corresponding Author email: *mariaabro2k19@gmail.com*

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ABSTRACT

Postharvest losses in guava are largely influenced by improper packaging, which affects fruit quality under ambient conditions. Therefore, the present study was conducted to evaluate the effect of different packaging materials on physico-chemical characteristics of guava (Psidium guajava L.) at the Department of Horticulture, Sindh Agriculture University, Tandojam, during 2015. The experiment was laid out in a Completely Randomized Design (CRD) with two varieties, Shimla Gola and Allahabad, and four packaging materials viz. wooden crates, paper bags, plastic bags and gunny bags, each replicated three times. The fruits were stored at room temperature (24 ± 2°C), and observations were recorded on fruit weight, pH, moisture content, total soluble solids (TSS), ash content, and fruit diameter. The results revealed that the Allahabad variety significantly performed better in most parameters, showing higher fruit weight (115.16 g), moisture content (27.75%), TSS (6.33 °Brix), ash content (0.46%), and fruit diameter (2.30 cm) under wooden crates, while the highest pH (5.54) was recorded under gunny bags, compared to Shimla Gola. In Shimla Gola, comparatively lower values were recorded; the maximum fruit weight (92.26 g), pH (5.44), fruit diameter (2.13 cm), and TSS (4.49 °Brix) were observed under paper bags, while moisture content (26.64%) was recorded under both paper and gunny bags, and ash content (0.36%) was highest under wooden crates. Among packaging materials, wooden crates showed superior performance for Allahabad for most quality attributes, while paper bags performed relatively better for Shimla Gola for fruit weight, TSS, and fruit diameter. In contrast, gunny bags generally recorded the lowest values for most parameters in both varieties. It is concluded that packaging materials significantly influence postharvest quality of guava, and the Allahabad variety packed in wooden crates maintained better physico-chemical quality under ambient storage conditions.

Keywords: Guava, packaging materials, wooden crates, physico-chemical properties, storage.

INTRODUCTION

Guava is widely cultivated in India, Pakistan, Bangladesh, Indonesia, South America, and other tropical and subtropical regions (Kumar et al., 2022; Rehman & Khan, 2022). Among the leading guava-producing countries, Pakistan holds the second position in terms of production (Ali et al., 2025: Gangappa et al., 2022; Khan et al., 2020). The crop has a high adaptability to most agro-climatic conditions and soil types and low cost of production and high yield potential, which makes it a highly profitable fruit crop to the growers (Roy et al., 2023). Guava is also a significant fruit crop in Pakistan, especially in Punjab and Sindh areas, and is consumed locally and exported to other countries (Shah et al., 2022). Guava has a short shelf life, being a climacteric fruit, and it is very perishable, although it is of great economic and nutritional value (Gill, 2016). Following harvest, the guava fruits experience swift physiological and biochemical modifications with a high rate of respiration and ethylene synthesis that stimulate ripening and senescence (Deepthi, 2017). The changes cause the fruit texture to become soft, lose their firmness, chlorophyll to be degraded, skin color altered, and their nutritional value diminished (Chen et al., 2024). Also, it is highly prone to microbial spoilage due to high moisture content in guava, causing high post-harvest losses during storage and transportation (Yadav et al., 2022).In developing countries, the problem of post-harvest losses of fruits and vegetables is significant, with the loss rate reaching 20-40 percent because of poor handling, storage, and packaging (Rajapaksha et al., 2021). Poor management after harvesting fruits does not only lower the marketable fruits and vegetables but also the income and the food security of farmers (Tadesse, 2022). Hence, better post-harvest management practices, especially the packaging is necessary to preserve the quality of fruits and prolong shelf life.Packaging is essential in maintaining quality of fresh fruits as it helps preserve them against mechanical damages, moisture, and formation of modified atmosphere surrounding the produce (Lin et al., 2023). Polyethylene bags, corrugated fiberboard boxes, perforated films, and biodegradable packaging have been extensively used as different packaging materials to improve storage life and preserve quality properties of fruits (Meti et al., 2024; Yousaf et al., 2024). These substances determine the gaseous structure internally (O2, CO2) and consequently the respiration rate, ethylene production, and metabolic activities of fruits (Yadav et al., 2022).The application of plastic films and modified atmosphere packaging (MAP) has been identified to reduce physiological weight loss, retard ripening and retain firmness and nutritional value of guava fruits (Mangararaj et al., 2014). The packaging materials also aid in the reduction of external contamination and microbial growth, thus enhancing safety and shelf life of the produce (Fadiji et al., 2023). The packaging effectiveness, however, is determined by the nature of the material, its ability to allow gases and moisture to penetrate it and by storage conditions. The physico-chemical properties of guava such as total soluble solids (TSS), titratable acidity, pH, ascorbic acid content, firmness of fruits, and weight loss are significant properties of fruit quality and consumer acceptance (Kamboj et al., 2025). Post-harvest handling practices, especially packaging and storage conditions, play a crucial role in determining these parameters (Al-Dairi et al., 2021). Proper packaging can delay biochemical processes like sugar buildup, acid decadence, and vitamin loss and thus extend the quality of fruits (Nagaraj et al., 2026). Despite various research studies carried out on post-harvest management of fruits, the efficacy of various packaging material remains to be tested. Appropriate packaging material is important to minimize losses after harvesting, preserve quality and improve market value of guava fruits. Thus, the current research was carried out to address the impact of various packaging materials on physico-chemical properties of guava fruit at ambient storage conditions

MATERIAL AND METHODS

Experimental Design and Treatments: The setup of the experiment was based on Completely Randomized Design (CRD) and had three replications. The study consisted of two factors: guava varieties and packaging materials. Two guava varieties Shimla Gola and Allahabad were tested by applying four packaging treatments such as wooden crates, paper bags, plastic bags and gunny bags. Experimental error was minimized by randomly assigning all treatments to experimental units.

Experimental Site and Material: The experiment was carried out in 2015 at the Department of Horticulture, Sindh Agriculture University, Tandojam, under laboratory conditions. The samples of half-mature guava fruits of test varieties were picked from Delhi Farm, Tandojam. The fruits were carried to the laboratory with a lot of care to ensure that they were not damaged mechanically.

Fruit Preparation and Packaging: The gathered fruits were cleaned with distilled water to eliminate dust and other contaminants and dried under a muslin cloth. The fruits were washed and sorted in homogenous sizes. The fruits were then divided into different groups according to the packaging treatments. The groups were packed separately in wooden crates, paper bags, plastic bags, and gunny bags for 5 days (Figure A).

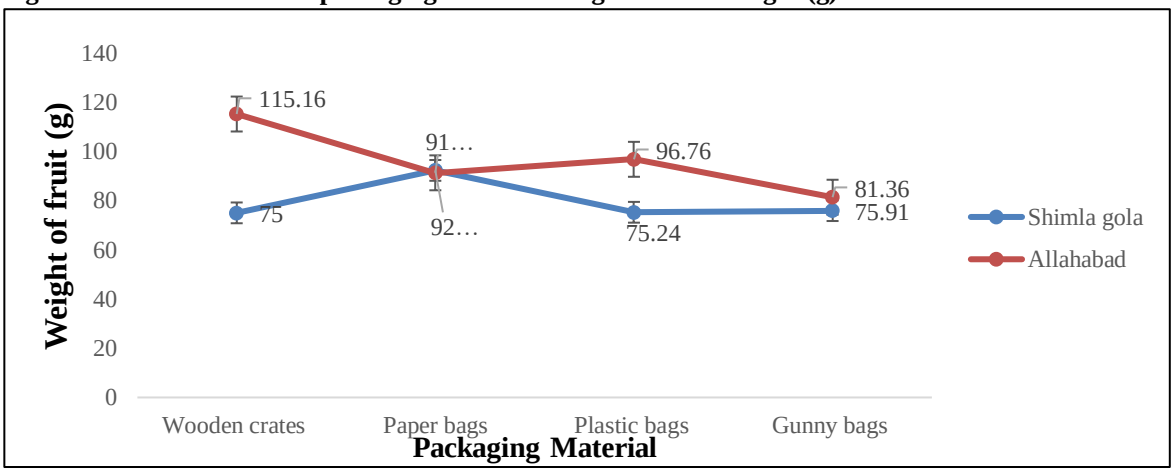
Figure (A)

Storage Conditions: The packed fruits were kept at ambient room temperature (24 ± 2 °C) to determine the impact of packaging materials on the quality characteristics of fruits.
Observations recorded: Data were recorded on various physico-chemical parameters. Fruit weight (g) was taken by using a digital weighing balance. Fruit diameter (cm) was measured with the help of a vernier caliper. The pH of fruit juice was determined using a calibrated digital pH meter. Total soluble solids (TSS) were measured using a hand refractometer and expressed as °Brix. Moisture content (%) was determined by the oven-drying method. A known weight of fresh fruit sample was taken and dried in a hot air oven at 70-80°C until a constant weight was obtained. The moisture content was calculated using the following formula: Moisture content (%) = (Fresh weight - Dry weight) / Fresh weight × 100. Ash content (%) was determined by the dry ashing method. A known weight of dried sample was placed in a crucible and ignited in a muffle furnace at 550-600°C for 4-6 hours until ash was formed. The ash content was calculated using the following formula: Ash content (%) = (Weight of ash / Original sample weight) × 100
Statistical Analysis: The recorded data were subjected to analysis of variance (ANOVA) using software Statistix version 8.1. The treatment means were compared using the Least Significant Difference (LSD) test at 5% probability level to determine significant differences among treatments.

RESULTS

Weight of Fruit (g): Wide variation was noticed pertaining to weight of fruit between varieties and packaging material (Fig. 1).The maximum fruit weight (115.16 g) was observed in Allahabad packaged in wooden crates followed by plastic bags (96.76 g) and paper bags (91.27 g), respectively. The fruits of Allahabad variety packed in gunny bags showed minimum fruit weight (81.36 g). However, this was not the case with Shimla Gola (Fig. 1) with the highest fruit weight (92.26 g) being recorded in paper bags, followed by gunny bags (75.91 g) and plastic bags (75.24 g) and lowest fruit weight (75 g) was found in wooden crates. Results, however, reveal that packaging materials had different effects on weight retention in both the varieties, with Allahabad exhibiting relatively higher fruit weight maintenance when stored in wooden crates, whereas, Shimla Gola exhibited higher weight maintenance when packed in paper bags.

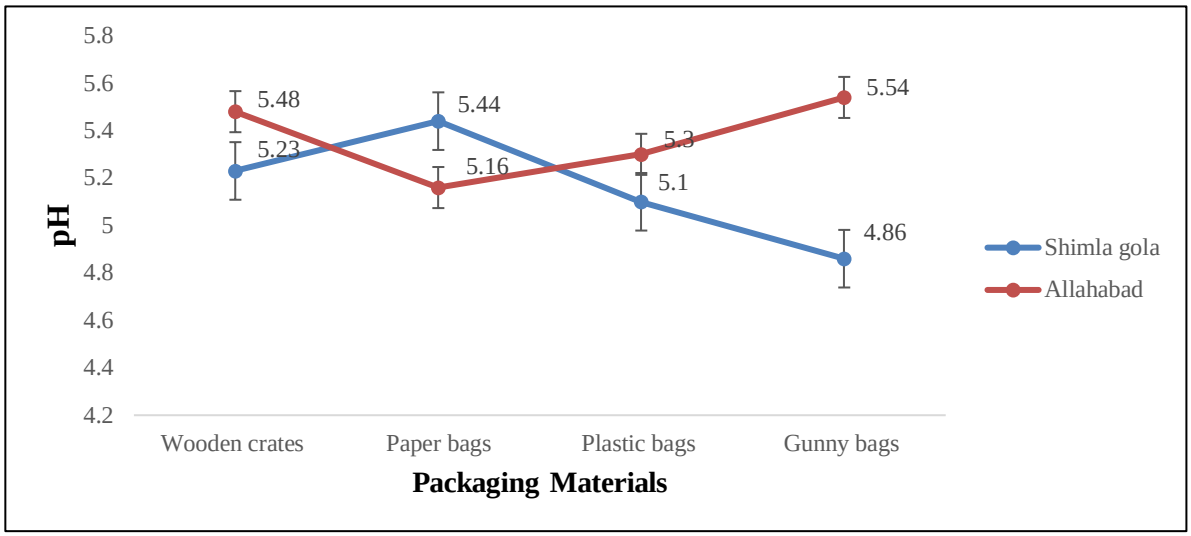
Figure 1. Effect of different packaging materials on guava fruit weight (g)



	Varieties	Treatment	T X V
SE	**2.887**	**4.0829**	**5.7741**
LSD @ 5%	**6.1921**	**8.7569**	**12.384**

pH of Fruit Juice: Fruit juice pH of guava varieties was affected by different packing materials and guava varieties during storage (Fig. 2).. The results showed that fruits of Allahabad registered the highest pH (5.54) when packed in gunny bags, followed by wooden crates (5.48) and plastic bags (5.30), while the lowest pH (5.16) was observed in paper bags. In Shimla Gola, the highest pH (5.44) was observed when fruits were packed in paper bags, followed by wooden crates (5.23) and plastic bags (5.10), whereas the lowest pH (4.86) was recorded in gunny bags. Overall, Allahabad showed comparatively higher pH values under most treatments that indicates slightly lower acidity than Shimla Gola during storage under different packaging conditions.

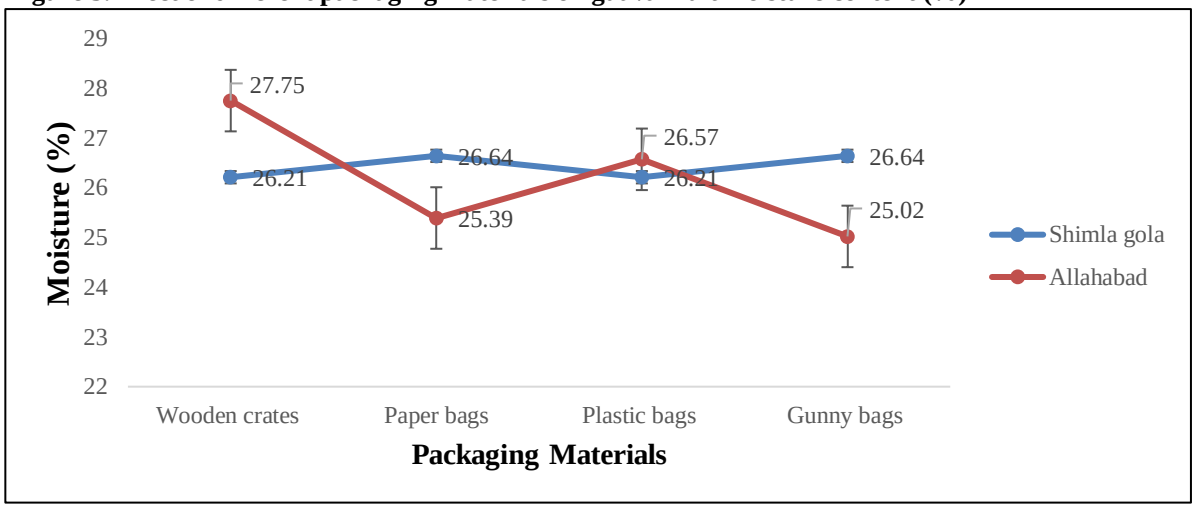
Figure 2.Influence of different packaging materials on guava fruit pH



	Varieties	Treatment	T X V
SE	**0.1238**	**0.175**	**0.2475**
LSD @ 50%	**-**	**-**	**-**

Moisture Content (%): Moisture content of guava varieties was affected by different packing materials during storage (Fig. 3). Distinct treatment-wise variations were observed in both varieties, indicating differences in water retention ability under various packaging conditions. The results revealed that in Allahabad, the highest moisture content (27.75%) was recorded in wooden crates, followed by plastic bags (26.57%), while the lowest moisture content (25.02%) was observed in gunny bags. In Shimla Gola, the greatest moisture content (26.64) was obtained in paper bags and gunny bags and had similar values with wooden crates and plastic bags (26.21). Nonetheless, Allahabad had a relatively high moisture retention than Shimla Gola with most treatments, which showed good preservation of fruit water content during storage under specific packaging material.

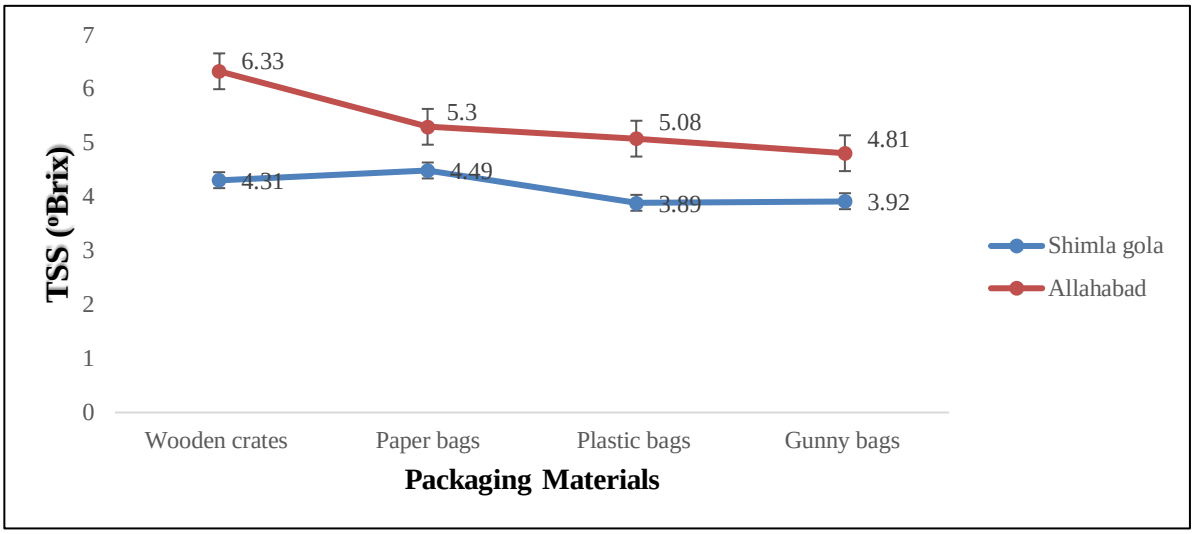
Figure 3.Effect of different packaging materials on guava fruit moisture content (%)



	Varieties	Treatment	T X V
SE	**1.2392**	**1.7525**	**2.4785**
LSD @ 5%	**-**	**-**	**-**

Total Soluble Solids (TSS, °Brix): Various packing materials substantially influenced the total soluble solids (TSS) of guava fruit juice of both varieties. . The results indicated that in Allahabad, the TSS was highest when fruits were packed in wooden crates (6.33 °Brix), followed by paper bags (5.30 °Brix) and plastic bags (5.08 °Brix) and the lowest TSS (4.81 °Brix) was observed in gunny bags. In Shimla Gola, the highest TSS (4.49 °Brix) was observed in paper bags, followed by wooden crates (4.31 °Brix), whereas the lowest TSS (3.89 °Brix) was recorded in plastic bags. Taken together, Allahabad maintained comparatively higher TSS values than Shimla Gola under most packaging treatments during storage**.**

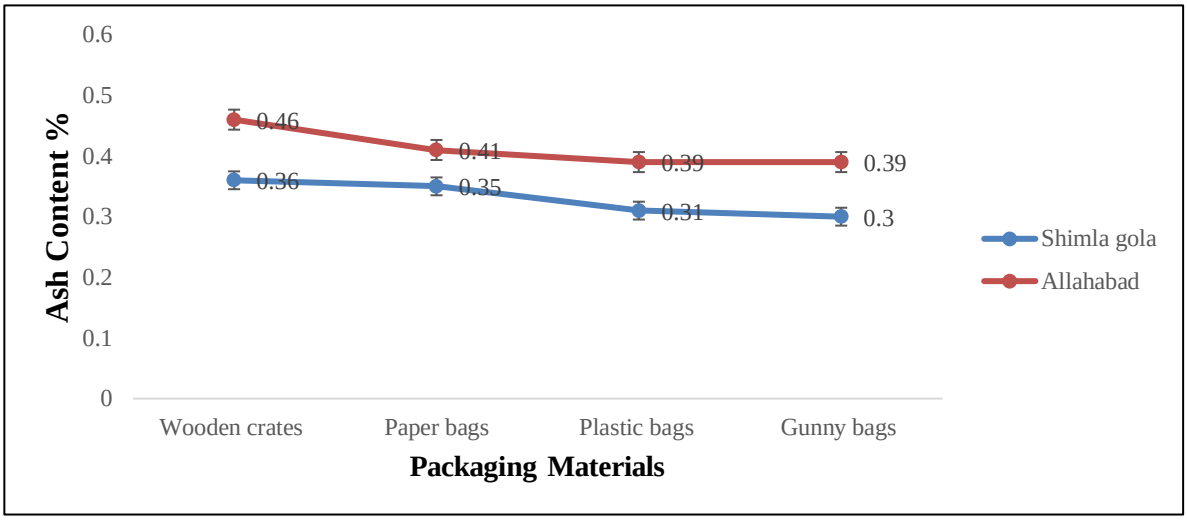
Figure 4.Response of guava fruit total soluble solids (TSS) (°Brix) to different packaging materials



	Varieties	Treatment	T X V
SE	**0.3434**	**0.4856**	**0.6868**
LSD @ 5%	**0.7365**	**-**	**1.4729**

Ash Content (%): Ash content of fruits of both varieties was significantly affected by different packing materials during storage (Fig. 5). The results showed that in Allahabad, the highest ash content (0.46%) was recorded when fruits were paced in in wooden crates, followed by paper bags (0.41%), while the lowest ash content (0.39%) was observed in plastic bags and gunny bags. In Shimla Gola, the highest ash content (0.36%) was observed in wooden crates, followed by paper bags (0.35%), whereas the lowest ash content (0.30%) was recorded in gunny bags. Allahabad as a whole had relatively high amounts of ash compared to Shimla Gola in most packaging materials.

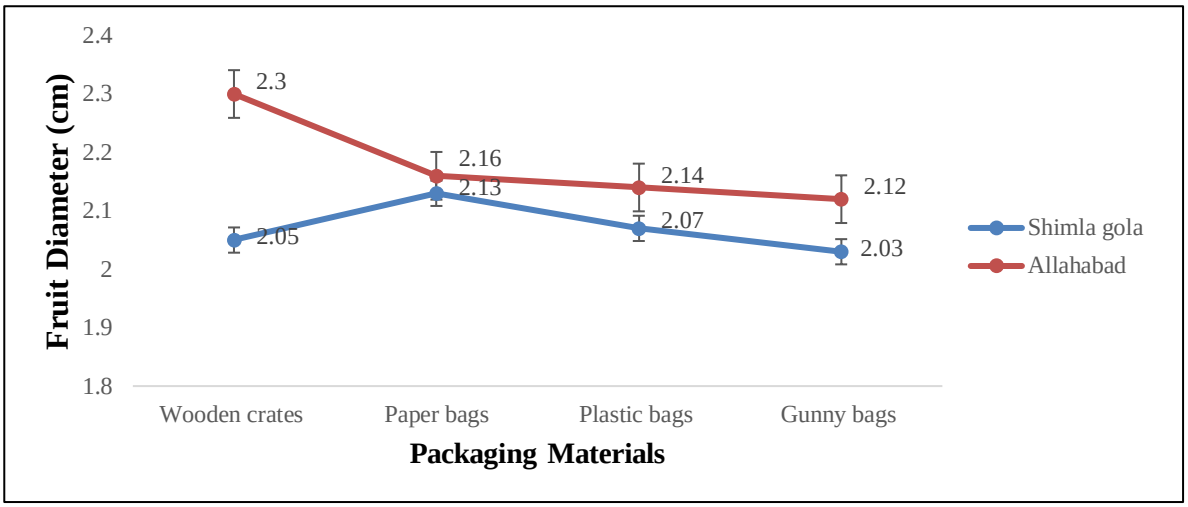
Figure 5.Influence of different packaging materials on guava fruit ash content (%)



	Varieties	Treatment	T X V
SE	**0.0294**	**0.0415**	**0.0587**
LSD @ 5%	**0.063**	**0.0891**	**0.126**

Fruit Diameter (cm): The packing materials notably influenced fruit diameter of guava varieties during storage (Fig. 6). The findings with regards to Allahabad variety showed that the maximum fruit diameter (2.30 cm) was registered when fruits were placed in wooden crates, paper bags (2.16 cm), and plastic bags (2.14 cm), and the minimum fruit diameter (2.12 cm) was noted in gunny bags. The maximum fruit diameter (2.13 cm) was obtained in paper bags, then plastic bags (2.07 cm) and wooden crates (2.05 cm), and the minimum fruit diameter (2.03 cm) was observed in gunny bags. On average, Allahabad had a relatively large fruit diameter in comparison with Shimla Gola across packaging materials, demonstrating better genetic potential in maintaining the fruit vigour and size during storage.

Figure 6. Comparative effect of different packaging material on guava fruit diameter (cm)



	Varieties	Treatment	T X V
SE	**0.0158**	**0.0223**	**0.0315**
LSD @ 5%	**0.0338**	**0.0478**	**0.0677**

DISCUSSION

The climacteric nature of guava, high rate of respiration and high moisture loss under ambient conditions has contributed to postharvest deterioration and is considered a major challenge in guava. Packaging is important in controlling such physiological and biochemical processes by altering the internal microenvironment of the fruit. In the current research, the various packaging materials had a major impact on physico-chemical properties of guava, indicating that appropriate packaging can effectively delay the process of quality degradation and increase shelf life of fruit. The results of the current study proved that packaging materials had a significant impact on the weight of fruits, with noticeable differences recorded between guava varieties. Wooden crates were found to be most efficient in preserving higher fruit weight in Allahabad, whereas paper bags demonstrated better performance in Shimla Gola, suggesting that varietal characteristics such as peel structure and respiration rate play a significant role in determining the response to storage condition (Chen et al., 2024). The enhanced weight retention under applied packaging material can be associated with reduced physiological weight loss, mainly from low transpiration and respiration processes (Yadavet al., 2022). A good packaging provides a favorable microenvironment by controlling humidity and gaseous exchange thus reducing loss of moisture (Yadav et al., 2022). Likewise, Yousaf et al. (2024) also found that packaged guava fruits can maintain a better quality because of the controlled respiration and less ethylene content. The higher performance of wooden crates could be associated with sufficient ventilation, which could prevent condensation and excessive respiration (Molla et al., 2023) It is worth mentioning here that performance of shimla variety of guava was better when packed in paper bag. This could be attributed to thae fact the use of paper bags probably ensured a modest humidity level, proving beneficial for Shimla Gola. Conversely, the reduced weight of the fruit was observed when packed in gunny and plastic bags, respectively. This could be attributed to the high loss of moisture and low exchange of gases in gunny and plastic bags respectively resulting in high physiological stress and loss of fruit weight respectively. Marked variation in pH of fruit juice was noted in the study, The difference in pH of fruit juice is a biochemical alteration that takes place in the storage and was largely dependent on packaging material as well as the varietal difference. In this study

the elevated pH of fruit juice was observed in Allahabad when packed in gunny bag and wooden crates, In contrast, the rise in pH of fruit juice of Shimla Gola was noticed when fruits were packed in paper bag. This reflects different response guava cultivars to packaging environment (Pisciotta et al., 2020). The augment in pH is mainly linked with the breakdown of organic acids during respiration resulting in decrease of acidity (Teixeira et al., 2016). The comparatively elevated pH recorded in some treatments suggests an accelerated metabolic activity and a fast utilization of organic acids during storage (Londaverde et al., 2020). Recent research has revealed that packaging materials markedly affect the internal gas environment, regulating oxygen and carbon dioxide concentrations, and, thus, influencing respiration rate and acid metabolism (Gull et al., 2024). Gunny bags might have facilitated higher respiration rates in the current study leading to greater degradation of organic acids, whereas paper bags and wooden crates probably offered more balanced microenvironment, resulting in moderate pH changes (Hanani et al., 2023). The moisture content is a major factor affecting the freshness and shelf life of fruits and the current study has revealed that it was greatly affected both by packaging materials and varieties. Higher moisture retention in wooden crates for Allahabad reveals that these packaging material offered favorable microenvironment with sufficient ventilation and humidity (Molla et al., 2023). In contrast, Shimla Gola showed greater moisture retention in paper and gunny bags, reflecting a different varietal response to moisture regulation. Maintaining adequate moisture is essential for delaying senescence and prolongs shelf life, since greater water loss leads to shriveling and reduces marketability of fruits (Twede et al., 2014; Anusha et al., 2024). The relative dryness observed in gunny bags for Allahabad can be associated with their high porosity, which increases transpiration rate and accelerates drying process (Vijayalakshmi, 2017). Conversely, plastic bags may decrease moisture loss but restrict gas exchange and cause condensation, resulting in reasonable moisture retention (Hanani et al., 2023). These results align with recent research indicating that permeable packaging enhances water loss, while materials that retain a balanced internal environment assist maintain moisture and extend shelf life (Qu et al., 2022). The total soluble solids (TSS) is key traits that determines sweetness in the fruits and affecting the consumer acceptability, is markedly influenced by both packaging material and varieties in the present research. Higher TSS noted in wooden crates and paper bags for Allahabad suggest better retention and accumulation of soluble sugars (Twede et al., 2014), while the maximum TSS recorded in paper bags for Shimla Gola indicates a comparatively favorable microenvironment for sugar retention (Panigrahi et al., 2021). The rise in TSS during storage may be associated with breakdown of complex carbohydrates into simple sugars during ripening process (Kaur et al., 2013; Vu et al., 2023). In addition, proper packaging environment can regulate respiration and metabolic rate, thus augmenting sugar concentration and preserving higher TSS levels (Gull et al., 2024). The findings of present study regarding TSS suggests that both packaging material and genetic potential of variety play significant role in determining TSS maintenance during storage

In the current experiment, packaging materials and varieties had a substantial impact on the ash content that reflect the mineral composition of fruit. Maximum ash content in both varieties was found when fruits were packed in wooden crates; where as lower values of ash content of both varieties were observed in plastic and gunny bags. This may be attributed to the fact that improved mineral retention was achieved in wooden crates since they might have provided sufficient ventilation with little loss of moisture and thus led to reduce metabolic degradation (Siedt et al., 2023). Likewise, Yousaf et al. (2024) also found that proper packaging materials are effective in preserving nutrient stability by reducing biochemical losses and preserving fruit quality. The relative low ash composition in fruits packed in gunny bags, particularly for Shimla Gola, could be attributed to the porous nature of the bags that hastens the process of losing moisture and related mineral losses (Bhatla & Kathpalia, 2023; Subedi, 2023).

The packaging materials and varieties also showed a significant effect on fruit diameter in the current study.(Lufu et al., 2024). The larger fruit diameter was noted in wooden crates for Allahabad and in paper bags for Shimla Gola that indicated highly varied response of varieties to packing environment (Lufu et al., 2024; Pisciotta, et al., 2020). The improved fruit diameter in wooden crate might have associated with the fact that wooden crates may have offered sufficient ventilation with regulation of moisture. Likewise, paper bags might have maintained optimum humidity, which helped to preserve the size better during storage. On the contrary, the reduced fruit diameter observed in gunny bags might be attributed to their porous nature which increases the rate of transpiration, resulting in rapid dehydration and subsequent shrinkage of fruit tissues (Giannakourou & Tsironi, 2021; Tucker et al., 2017). The results align with the existing literature that indicates that the proper packaging retards the process of structural degradation and assist preserves the firmness and size of fruits during storage (Liu et al., 2025).

CONCLUSION

The present research clearly shows that packaging materials significantly affected the postharvest quality of guava by influencing the important physico-chemical parameters. Among the tested treatments, wooden crates were found to be most effective packaging material especially for the Allahabad variety under ambient storage conditions. The paper bags performed relatively better for *Shimla Gola* for fruit weight, TSS, and fruit diameter. In contrast, gunny bags generally recorded the lowest values for most parameters in both

varieties Future studies needs to be done by integrating conventional packaging material with latest technologies such as usage of edible coatings and modified atmosphere packaging to further extend shelf life and improve the quality of guava.

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AUTHOR CONTRIBUTIONS
All authors contributed equally to the conception, execution, and preparation of this research work.

COMPETING OF INTEREST
The authors declare that they have no competing interests or conflicts of interest.

REFERENCES

Ali, M., Wagan, H., Ali, A., Hussain, T., &Bibi, H. (2025). Agribusiness Value Chain Analysis of Guava from Producer Perspectives in Taluka and District Larkana Sindh Pakistan. *The Asian Bulletin of Big Data Management*, ***5*(3)**, 63-86.

Anusha, M., Sri, K. R., Lokesh, M., Deepthi, N. M., &Malleswari, M. D. (2024). Postharvest management techniques for improved shelf life of horticultural crops: A review. *Journal of Experimental Agriculture International*, ***46*(11)**, 362-380.

Al-Dairi, M., Pathare, P. B., & Al-Yahyai, R. (2021). Chemical and nutritional quality changes of tomato during postharvest transportation and storage. *Journal of the Saudi Society of Agricultural Sciences*, ***20*(6)**, 401-408.

Bhatla, S. C., &Kathpalia, R. (2023). Essential and functional mineral elements. In *Plant physiology, development and metabolism* (pp. 25-49). Singapore: Springer Nature Singapore.

Chen, N., Wei, W., Yang, Y., Chen, L., Shan, W., Chen, J., ...& Wu, C. (2024). Postharvest physiology and handling of guava fruit. *Foods*, ***13*(5)**, 805.

Deepthi, V. P. (2017). Physiological and biochemical changes during fruit growth, maturity and ripening of guava: A review. *J. PostHarvestTechnol*, ***5***, 1-6.

Fadiji, T., Rashvand, M., Daramola, M. O., &Iwarere, S. A. (2023). A review on antimicrobial packaging for extending the shelf life of food. *Processes*, ***11*(2)**, 590.

Gangappa, N. D., Singh, C., Verma, M. K., Thakre, M., Sevanthi, A. M., Singh, R., ...&Nagaraja, A. (2022). Assessing the genetic diversity of guava germplasm characterized by morpho-biochemical traits. *Frontiers in nutrition*, ***9***, 1017680.

Giannakourou, M. C., &Tsironi, T. N. (2021). Application of processing and packaging hurdles for fresh-cut fruits and vegetables preservation. *Foods*, *10*(4), 830.

Gill, K. B. S. (2016). Techniques for extending shelf life of guava fruits: a review. In *International Symposia on Tropical and Temperate Horticulture-ISTTH2016 1205* (pp. 959-969).

Gull, S., Ejaz, S., Ali, S., Ali, M. M., Sardar, H., Azam, M., ...&Almutairi, M. H. (2024). Xanthan gum-based edible coating effectively preserve postharvest quality of 'Gola'guava fruits by regulating physiological and biochemical processes. *BMC Plant Biology*, ***24*(1)**, 450.

Hanani, Z. N., Sonawane, A. D., & Mahajan, P. V. (2023). Impact of humidity, temperature and condensation on O2 and CO2 transmission rate of modified atmosphere packages. *Food Packaging and Shelf Life*, ***39***, 101132.

Kamboj, K., Kaur, G., Kaur Kang, K., Kumar Arora, N., & Singh Brar, J. (2025). Comparative Study on Morphological and Physiological Changes During Fruit Development in Three Guava (*Psidiumguajava* L.) Cultivars. *Applied Fruit Science*, ***67*(5)**, 315.

Kapoor, S., Gandhi, N., & Kapoor, A. (2020). Guava (*Psidiumguajava*). In *Antioxidants in Fruits: Properties and Health Benefits* (pp. 227-249). Singapore: Springer Singapore.

Kaur, K., Dhillon, W. S., & Mahajan, B. V. C. (2013). Effect of different packaging materials and storage intervals on physical and biochemical characteristics of pear. *Journal of food science and technology*, ***50*(1)**, 147-152.

Khan, D., Ullah, A., Bibi, Z., Ullah, I., Zulfiqar, M., & Khan, Z. U. (2020). Forecasting area and production of guava in Pakistan: An econometric analysis. *Sarhad Journal of Agriculture*, ***36*(1)**, 272-281.

Kumar, M., Kapoor, S., Dhumal, S., Tkaczewska, J., Changan, S., Saurabh, V., ...&Bhuyan, D. J. (2022). Guava (*Psidiumquajava* L.) seed: A low-volume, high-value byproduct for human health and the food industry. *Food Chemistry*, *386*, 132694.

Landaverde, A. C., Shreckhise, J. H., &Altland, J. E. (2020). Storage procedures affect pH, electrical conductivity, and nutrient concentrations of pour-through leachate from pine bark and peat-based substrates. *HortScience*, ***55*(10)**, 1597-1604.

Lin, M., Fawole, O. A., Saeys, W., Wu, D., Wang, J., Opara, U. L., ...& Chen, K. (2023). Mechanical damages and packaging methods along the fresh fruit supply chain: A review. *Critical Reviews in Food Science and Nutrition*, ***63*****(30)**, 10283-10302.

Liu, F., Hai, M., Mei, B., Yi, L., &Xie, S. (2025). How does mechanical damage affect the preservability of postharvest fruits and vegetables?. *LWT*, 118781.

Lufu, R., Ambaw, A., &Opara, U. L. (2024). Assessing weight loss control strategies in pomegranate (Punicagranatum L.) fruit: plastic packaging and surface waxing. *Sustainable Food Technology*, ***2*****(1)**, 175-188.

Mangaraj, S., Goswami, T. K., Giri, S. K., &Joshy, C. G. (2014). Design and development of modified atmosphere packaging system for guava (cv. Baruipur). *Journal of Food Science and Technology*, ***51*****(11)**, 2925-2946.

Meti, S. C., Vyshnavi, A., Patil, P., Khayum, A., Siddiqua, A., Shekar, R. R., & Kaur, R. (2024). ADVANCEMENTS IN FRUIT PACKAGING TECHNOLOGY: A REVIEW. *Plant Archives (09725210)*, ***24*****(2)**.

Molla, S. W., Delele, M. A., Mekonen, T. N., &Tsige, A. A. (2023). Model-based design and development of horticultural produce crate from bamboo. *Cogent Food & Agriculture*, *9*(1), 2202051.

Mosie, T., &Woldetsadik, P. (2018). *Effect of Plastic Packaging and Storage Environment on Shelf Life and Quality of Some Peach (Prunuspersica L.) Genotypes at Holeta, Central Ethiopia* (Doctoral dissertation, Haramayauniversity).

Munir, A., Khan, S. M., Jamal, A., Mihoub, A., Saeed, M. F., Ahmad, S., ...&Alharbi, K. (2022). Effect of different packaging storage techniques on physiological and chemical changes in Citrus sinensis L. *Adv. Food Sci*, ***44*****(2)**, 45-53.

Nagaraja, S. K., Kumar, P., R, K., Nabi, S. U., Mir, J. I., Verma, M. K., ... &Mansoor, S. (2026). A Comprehensive Review of Biochemical Insights and Advanced Packaging Technologies for Shelf-Life Enhancement of Temperate Fruits. *Biosensors*, ***16*****(2)**, 94.

Nagaraja, A., Nayan, D. G., Thakre, M., Vasugi, C., Selvakumar, R., & Singh, S. K. (2025). Genetic Diversity of Guava (*Psidiumguajava* L.) and Sustainable Utilization. In *Genetic Diversity of Fruits and Nuts* (pp. 128-145). CRC Press.

Naseer, S., Hussain, S., Naeem, N., Pervaiz, M., & Rahman, M. (2018). The phytochemistry and medicinal value of *Psidiumguajava* (guava). *Clinical phytoscience*, ***4*****(1)**, 32.

Omayio, G. D. (2021). *Production, Utilization and Processing of Kenyan Guavas: Development Of Nutrient-Enriched Guava Nectars From Local Varieties* (Doctoral dissertation, UNIVERSITY OF NAIROBI).

Panigrahi, C., Shaikh, A. E. Y., Bag, B. B., Mishra, H. N., & De, S. (2021). A technological review on processing of sugarcane juice: Spoilage, preservation, storage, and packaging aspects. *Journal of Food Process Engineering*, ***44*****(6)**, e13706.

Pisciotta, A., Planeta, D., Giacosa, S., Paissoni, M. A., Di Lorenzo, R., & Rolle, L. (2020). Quality of grapes grown inside paper bags in Mediterranean area. *Agronomy*, *10*(6), 792.

Qu, P., Zhang, M., Fan, K., &Guo, Z. (2022). Microporous modified atmosphere packaging to extend shelf life of fresh foods: A review. *Critical Reviews in Food Science and Nutrition*, ***62*****(1)**, 51-65.

Rajapaksha, L., Gunathilake, D. M. C. C., Pathirana, S. M., & Fernando, T. (2021). Reducing post-harvest losses in fruits and vegetables for ensuring food security—Case of Sri Lanka. *MOJ Food Process Technols*, ***9*****(1)**, 7-16.

Rehman, M. A. U., & Khan, I. (2022). Medicinal and pharmacological potential of Guava leaf powder, A Review. *International Journal of Natural Medicine and Health Sciences*, ***1*****(2)**.

Roy, T., Kalambukattu, J. G., Biswas, S. S., & Kumar, S. (2023). Agro-climatic variability in climate change scenario: adaptive approach and sustainability. In *Ecological footprints of climate change: Adaptive approaches and sustainability* (pp. 313-348). Cham: Springer International Publishing.

Shah, M. H., Rafique, R., Almas, M., Usman, M., Yasin, S., &Bibi, S. (2022). A Review: Fruit Production Industry of Pakistan Trends, Issues and Way Forward. *Pakistan Journal of Agricultural Research*, ***35*****(3)**.

Shi, Y., Zhang, W., & Zhou, G. (2020). Effects of different moisture-permeable packaging on the quality of aging beef compared with wet aging and dry aging. *Foods*, ***9*****(5)**, 649.

Siedt, M., Teggers, E. M., Linnemann, V., Schäffer, A., & van Dongen, J. T. (2023). Microbial degradation of plant residues rapidly causes long-lasting hypoxia in soil upon irrigation and affects leaching of nitrogen and metals. *Soil Systems*, *7*(2), **62**.

Subedi, T. (2023). An assessment of mineral contents in fruits. *Prithvi Academic Journal*, 21-31.

Tadesse, K. T. (2024). The role of post-harvest management in ensuring food security in a changing world. *Journal of Clinical Research and Case Studies*, ***2*****(3)**, 1-14.

Twede, D., Selke, S. E., Kamdem, D. P., & Shires, D. (2014). *Cartons, crates and corrugated board: handbook of paper and wood packaging technology*. DEStech Publications, Inc.

Teixeira, G. H., Júnior, L. C. C., Ferraudo, A. S., &Durigan, J. F. (2016). Quality of guava (*Psidiumguajava* L. cv. Pedro Sato) fruit stored in low-O2 controlled atmospheres is negatively affected by increasing levels of CO2. *Postharvest Biology and Technology*, *111*, 62-68.

Tucker, G., Yin, X., Zhang, A., Wang, M., Zhu, Q., Liu, X., ...& Grierson, D. (2017). Ethylene and fruit softening. *Food Quality and Safety*, ***1*(4)**, 253-267.

Vijayalakshmi, N. (2017). Influence Of Packaging Materials And Desiccant On Storability Of Kernel And Pod Of Summer Groundnut (*ArachisHypogaea* L.).

Vikram, B., Gautam, D. K., Tondihal, M. S., Chaturvedi, S., Verma, S., Yadav, H. C., ...&Nayak, T. (2024). Revolutionizing guava food processing: a fresh perspective. *International Journal of Environment and Climate Change*, ***14*(2)**, 14-22.

Vu, N. D., Nguyen, V. M., & Tran, T. T. (2023). Effects of pH, total soluble solids, and pectin concentration on color, texture, vitamin C, and sensory quality of mango fruit bar. *International Journal of Food Science*, *2023***(1)**, 6618300.

Yousaf, A. A., Abbasi, K. S., &Faiz, M. (2024). Post-harvest quality assessment of guava fruit (*Psidiumguajava.* L.) CV.'Gola'in response to different packaging materials. *International Journal of Postharvest Technology and Innovation*, ***9*(2)**, 93-109.

Yousaf, A. A., Abbasi, K. S., Ibrahim, M. S., Sohail, A., Faiz, M., &Khadim, M. (2024). Storage stability assessment of guava fruit (*Psidiumguajava* L.) cv.'Gola'in response to different packaging materials. *Sustainable Food Technology*, ***2*(1)**, 210-221.

Yadav, A., Kumar, N., Upadhyay, A., Fawole, O. A., Mahawar, M. K., Jalgaonkar, K., ...&Mekhemar, M. (2022). Recent advances in novel packaging technologies for shelf-life extension of guava fruits for retaining health benefits for longer duration. *Plants*, ***11*(4)**, 547.