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Original Research Article

INFLUENCE OF STORAGE TEMPERATURE ON MORPHOLOGICAL AND PHYSIOLOGICAL TRANSFORMATIONS AND SHELF LIFE OF MANGO CV. SUFAID CHAUNSA

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Abstract *Mango, scientifically known as Mangifera indica L., is highly popular in Pakistan and around the globe known for its abundant provitamins and other phytochemical elements. Being a climacteric fruit, mangoes ripen quickly after being harvested. Commercial growers typically harvest mangoes when they reach their horticultural maturity to maintain the fruit's quality. Temperature is a crucial environmental factor affecting mangoes quality, as these tropical fruits do not respond well to storage at low temperatures. Therefore, this study aimed to examine the impact of different storage conditions on the physiological and biochemical qualities of the shelf life of cv. Sufaid Chaunsa mangoes. During the study, the mangoes were stored in cold storage facilities at 8°C, 12°C, and 16°C with 90% relative humidity. The storage containers consisted of plastic baskets covered with white paper, and the mangoes were assessed for weight loss, texture properties, chilling injury, titratable acidity, sensory characteristics, total soluble salts and external appearance every 7 days throughout the storage period till 28 days. The results indicated that storing mangoes at 12°C extended their shelflife by up to 21 days, shows better results. Utilizing the storing conditions set at 12°C effectively reduced suitable water loss, maintained chemical changes and other sensory characteristics. Additionally, storing the mangoes at 12°C was sufficient to prolong their storage life until 21 days. It was observed that the quality of mangoes deteriorated after being stored for 21 days at 16°C.*

Keywords: Post-harvest; morphological; physiological; storage temperature; environmental factors

Introduction

Mango, scientifically known as Mangifera indica L., is a highly regarded fruit belonging to the Anacardiaceae family. It is often called the "king of fruits" due to its exceptional flavor, enticing aroma, and delightful taste (Azam *et al.*, 2020). Pakistan, being a large part of the country and situated in a subtropical region, has a significant economic reliance on mango cultivation. Mangoes can be grown nationwide and are immensely popular, surpassing other fruits. Sufaid Chaunsa is late season maturing exportable mango cultivar which cover and area of 14% cultivation in Punjab (Iqbal et al., 2022). However, mangoes present a challenge for long-distance marketing due to their climacteric nature, high respiration rate, and relatively short postharvest life (Murtaza *et al.*, 2020). Mangoes are not only cherished for their taste but also valued for their diverse range of phytochemicals and nutritional content (Dubey *et al.*, 2021). In a 100g serving, mangoes contain 83.46g of water, providing 60 kcal of energy. They have 0.82g of protein, 0.38g of total lipid (fat), 14.9g of carbohydrates, 1.6g of dietary fiber, and 13.6g of total sugar. Mangoes also contain various essential minerals, including sodium (1mg), calcium (11mg), potassium (168mg), iron (0.16mg), zinc (0.09mg), magnesium (10mg), and phosphorus (14mg) (Naik and Bhatt, 2017; Iqbal *et al.*, 2022a). Additionally, they are a rich source of vitamins. The fatty acid composition includes 0.092g of saturated fatty acids, 0.140g of total monounsaturated fatty acids (Ahmed *et al.*, 2020), and 0.071g of total polyunsaturated fatty acids (Medany *et al.*, 2009). Chitosan is a natural alkaline cationic polymer well-known for its complex double helix structure (Reshma and Simi, 2019; Ali *et al.*, 2021). It is widely found in the cell walls of lower arthropods such as shrimp, crabs, and crustaceans, as well as in lower plants like algae and fungi (Zaghum *et al.*, 2021). One of the notable characteristics of chitosan is its antibacterial properties, which are attributed to the abundant amino groups on its surface (Kiran *et al.*, 2021). Furthermore, its unique membrane structure enhances the resistance of fruits and vegetables to abiotic stress and helps prevent oxidative aging (Zaghum *et al.*, 2022). Maintaining low temperatures during fruit storage is beneficial for delaying spoilage, inhibiting microbial growth, and minimizing metabolic variations (Ghaffar *et al.*, 2022). However, certain products are susceptible to chilling injury and rapid deterioration when stored at temperatures below the chilling threshold (Iqbal *et al.*, 2022b). Temperature management plays a critical role in extending the postharvest shelf life of mangoes (Helmey *et al.*, 2021; Kiran *et al.*, 2022). Typically, mangoes are stored within the 8 to 13 °C (Kumar *et al.*, 2013; Suparyanto dan Rosad (2015, 2020). Maintaining a relative humidity of around 90 to 95% during the postharvest handling of mangoes is essential to minimize water loss (Neware *et al.*, 2017). Fruit quality significantly influences consumer acceptance, particularly in international markets (Murtaza *et al.*, 2020). Therefore, controlling and maintaining the quality of mangoes during export is crucial. Decay and quality deterioration are common postharvest issues faced during the export of mangoes (Iqbal *et al.*, 2021). Additionally, since mangoes are harvested during a specific season, typically from May to June, they are often released simultaneously, leading to oversupply concerns (Minja *et al.*, 2017; Bibi *et al.*, 2019). Therefore, this research aimed to examine how different storage conditions impact the physical, physiological, and chemical characteristics, and longevity of Sufaid Chaunsa mangoes.

Material and methods

Elements and raw material

Mangoes of cv. Sufaid Chaunsa used in this study was obtained from an orchard of Mango Research Station, Shujabad, Multan, Pakistan. The mangoes were swiftly transported to the horticulture laboratory shortly after being harvested on 12.07.2021, with a transit time of no longer than two hours. To ensure uniformity, the mangoes underwent sorting based on their specific gravity using the water immersion method. By submerging the mangoes in a bucket of water, those that floated, indicating insufficient development, were discarded. Only mangoes exhibiting 100% green peel color, free from any sort of blemishes, uniform size were selected for inclusion in this experiment.

Storage Conditions

The mangoes were partitioned into five distinct groups, comprising five replicates in each group. Subsequently, the harvested fruits were carefully arranged inside plastic boxes that adhered to their respective treatment specifications, with dimensions of 37 cm × 55.5 cm × 30.5 cm. The treatments consisted of the following conditions: 1) mangoes stored continuously at 8°C, 2) mangoes stored at 12°C, and 3) mangoes stored at 16°C and maintained relative humidity 90% until the end of the storage period at the storage facility installed at MG Food, Kabirwala. The quality assessment of the stored fruit was conducted at 0, 7, 14, 21 and 28 days of storage.

Weight loss

Before storage, each treatment's fruits were individually labeled and weighed to determine their initial weight. This enabled the measurement of weight loss during the storage period. Throughout the entire storage duration, the same set of fruits was consistently weighed regularly during the sampling process. The weight loss results were then expressed as a percentage.

$$Weight\ loss(\%) = \frac{\text{Initial weight (g)} - \text{Weight at removal (g)}}{\text{Initial weight (g)}}\ x\ 100$$

Chilling Injury Index

When the fruit exhibited visible symptoms of chilling injury (CI) in the form of sunken lesions, it was categorized as having CI manifestation. Chilling injury (CI) was evaluated by employing the CI index. This metric quantified the extent of sunken lesions as a percentage of the overall surface area affected. The CI index scale ranged from 5 to 1, with 5 indicating no abnormality (0% affected), 4 representing trace symptoms (1-10% concerned), 3 denoting moderate symptoms with a blotchy appearance (11-25% affected), 2 indicating moderate to severe symptoms (26-50% affected), and 1 representing severe symptoms >50% affected (Brecht and Nunes, 2012).

Total soluble solids (TSS)

Total soluble solids (TSS) measure the concentration of soluble substances in fruit. To ascertain the total soluble solids (TSS) content, a small quantity of fruit juice was extracted and subjected to analysis utilizing a digital refractometer calibrated within a scale range of 0 to 45 degrees Brix. The TSS value is reported as a percentage, representing the total soluble solids in the fruit.

Titratable Acidity

Titratable acidity is determined using a pH meter. To conduct the measurement, 5 ml of mango juice and 45 ml of distilled water are combined in a beaker. Subsequently, the mixture was expeditiously filtered, with the simultaneous addition of 0.1 N NaOH solution from a burette, until the solution attained a pH level of 8.2. The titratable acidity was then determined by calculating the percentage of citric acid per 100 ml of mango juice.

Texture Profile Analysis (TPA)

Mango texture was evaluated using a TA-XT2 texture analyzer manufactured by Stable Microsystems in Surrey, UK. The texture profile analysis (TPA) method was utilized to analyze the textural attributes. A cylindrical probe with a diameter of 12.7 mm (P/0.5) was employed to penetrate the fruit to a depth of 6 mm. The texture analyzer was configured in compression mode with a constant 1 mm/sec speed. The fruit was compressed at its center, and the resulting force was quantified and expressed in Newton (N).

Sensory Properties

Following a ripening period of 21 and 28 days in storage, sensory evaluation of the fruit was carried out. Trained panelists utilized a nine-point hedonic scale to assess the mango's taste, aroma, flavor, and overall acceptability. The samples were rated on a scale ranging from 1 to 9, where a rating of 9 indicated "extremely favorable," 1 indicated "extremely unfavorable," and the intermediate numbers represented different levels of preference or dislike.

Statistical Analysis

The data about mango qualities throughout the storage duration were subjected to statistical analysis utilizing a completely randomized design consisting of five replicates. Variance (ANOVA) was analyzed to assess the significance of the observed differences. Additionally, Pearson's correlation coefficients were computed to investigate the associations between various independent variables (such as external appearance, weight loss, and skin color) and dependent variables (including chilling injury index, total soluble solids (TSS), hardness, and overall characteristics based on sensory evaluations) at both the 21-day and 28-day storage intervals.

Result and discussion

External Appearance

During the early stages of storage, the overall appearance of most mangoes was of high quality, receiving a score of 5 (Fig. 1). However, when mangoes were stored at a temperature of 8°C, they experienced an escalation in the occurrence of darkened and bruised skin. On the other hand, mangoes stored at 12°C began to manifest symptoms of anthracnose disease on the peel. Notably, the mangoes stored at 8°C displayed bruises after a storage period of 14 days. Subsequently, after 28 days of storage, mangoes stored at 8°C exhibited the onset of anthracnose on the peel, while those stored at 12°C displayed signs of scorching at the pedicel. By the conclusion of the 28-day storage period, mangoes stored at both 8°C and 12°C exhibited manifestations of anthracnose and scorching at the poles, accompanied by wilting symptoms observed throughout the fruit. Therefore, using a storage temperature 12°C can extend the shelf-life of mangoes for up to 21 days, as shown in Figure 1.

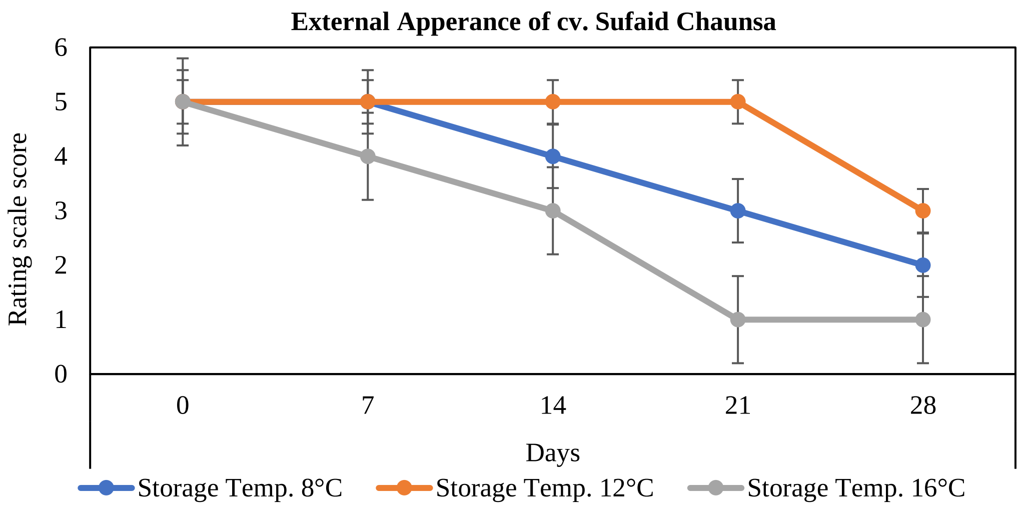

Fig. 1. Effect of mango cv. Sufaid Chaunsa on external appearance during different storage periods at temperatures of 8°C, 12°C, and 16°C.

Chilling Injury

The initial indication of chilling injury was the emergence of small brown spots on the mango skin, which spread and darkened the skin significantly. By the 14th day of storage, mangoes stored at 8°C exhibited a more rapid development of chilling injury, with more pronounced symptoms than those stored at 8°C, and 12°C. However, by the end of the 28-day storage period, samples kept at 8°C and 12°C displayed the least severe chilling injury symptoms as shown in Figure 2.

[Citation Kiran, S., Raza, S., Bibi, F., Mustafa, G., Iqbal, M., Bukhari, S.I.U.S., Imran, M., Iqbal, A., Khan, A.H., Iqbal, J., Mahmood, N., Majeed, T. (2023). Influence of storage temperature on morphological and physiological transformations and shelf life of Mango cv. Sufaid Chaunsa.. *Biol. Clin. Sci. Res. J.*, **2023**:*337*. doi: https://doi.org/10.54112/bcsrj.v2023i1.337]

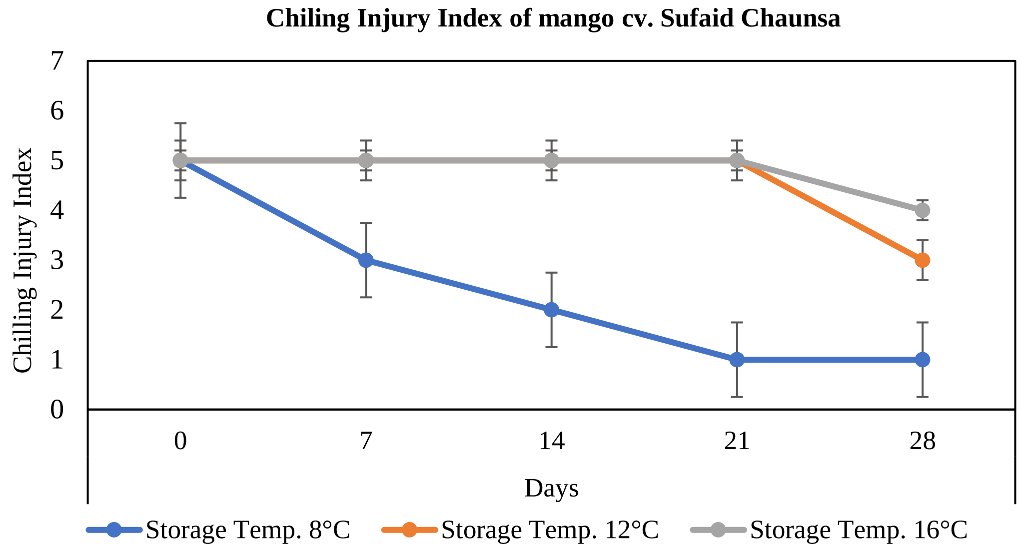

Fig. 2. Effect of Mango cv. Sufaid Chaunsa on chilling injury during different storage periods at temperatures of 8°C, 12°C, and 16°C.

Weight (water) Loss

The duration of storage and temperature had a significant impact on the weight loss of mangoes ($p < 0.05$) (table 1). As the storage time increased, the weight loss also increased. The most effective weight loss control was observed in mangoes stored at 8°C and 12°C, with losses of 9% and 17%, respectively. However, mangoes stored at 16°C for 28 days experienced a higher weight loss, reaching 21% as shown in figure 3.

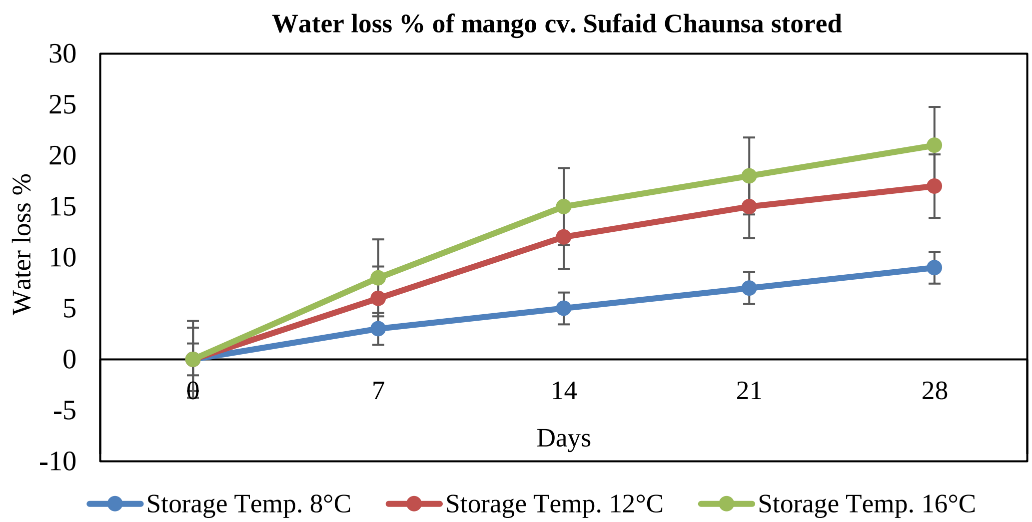

Fig. 3. Effect of Mango cv. Sufaid Chaunsa on water loss% during different storage periods at temperatures of 8°C, 12°C, and 16°C.

Total Soluble Solids

The findings revealed a significant change in the total soluble solid (TSS) content throughout the storage period (Fig. 4). As the shelf life extended, there was an increase in TSS content, reaching 16%, 22% and 23% at 8°C, 12°C, and 16°C, respectively. However, minimal changes were observed in mangoes stored at 8°C as shown in Figure 4. Higher storage temperatures were associated with higher TSS content compared to lower storage temperatures.

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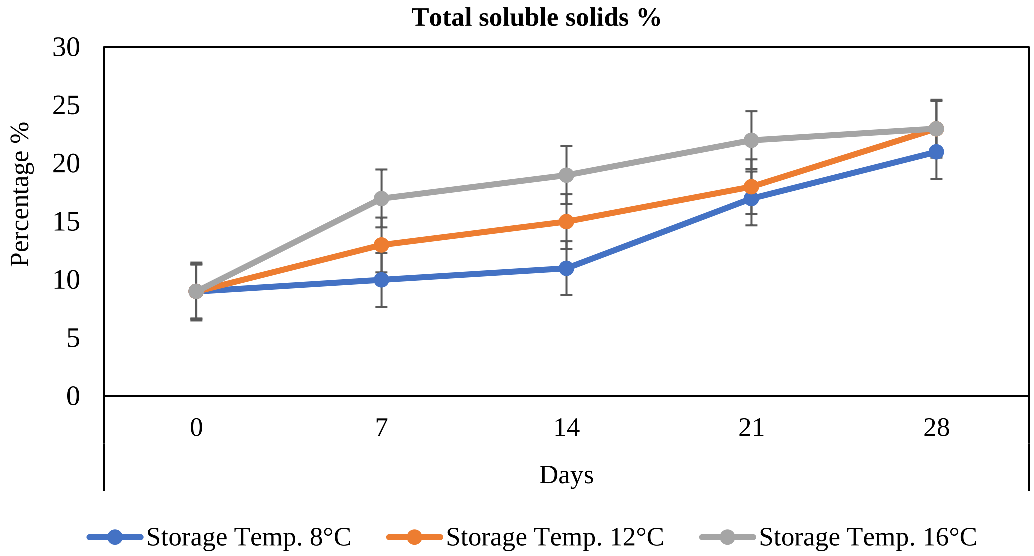

Fig. 4. Effect of Mango cv. Sufaid Chaunsa on Total soluble solid % during different storage periods at temperatures of 8°C, 12°C, and 16°C.

Titratable Acidity

Figure 5 illustrates the titratable acidity (TA) changes observed in mangoes stored under varying temperature conditions. The results revealed a steady decline in TA across all treatment groups. Notably, mangoes stored at 8°C experienced a reduction of 1.54% in TA by the conclusion of the storage period. Similarly, mangoes stored at 8°C, 12°C, and 16°C exhibited significant decreases in TA, measuring 1.3, 1.5, and 0.9, respectively, on the final day of storage. This observation aligns with previous research that demonstrated a loss of vitamin C in mango pulp during bulk storage [11].

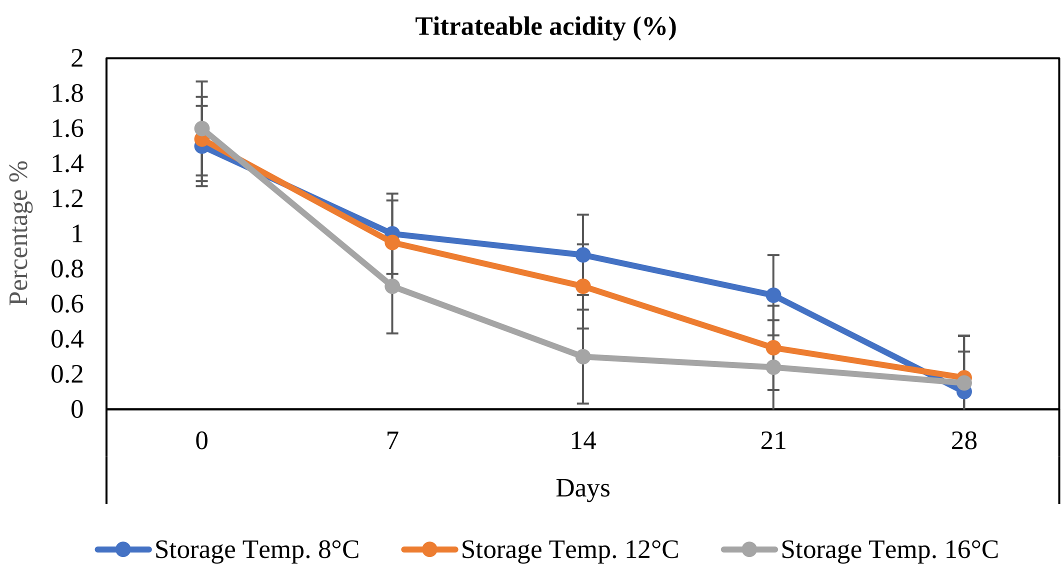

Fig. 5. Effect of Mango cv. Sufaid Chaunsa on Titratable acidity % during different storage periods at temperatures of 8°C, 12°C, and 16°C.

Texture Properties

The initial compression force, indicative of mango hardness, softness, tenacity, and strength, is a significant parameter. The findings demonstrate a significant decrease in mango hardness throughout the storage period (Fig. 8). Among the storage temperatures, mangoes stored at 8°C exhibited the highest retention of hardness. On the final day of storage (day 28), the hardness values of mangoes stored at 8°C, 12°C and 16°C were 230, 160, and 0, respectively. Likewise, gumminess displayed a significant reduction throughout the storage duration.

Notably, storing mangoes at 8°C resulted in the least alteration in gumminess. By the conclusion of the 28-day storage period, the gumminess values for mangoes stored at 8°C, 12°C, and 16°C were recorded as 180, 150, and 0, respectively.

The trend observed in chewiness during storage followed the same pattern as hardness and gumminess. On the final day of storage (day 28), the chewiness values of mangoes stored at 8°C, 12°C, and 16°C were 180, 130, and 0, respectively.

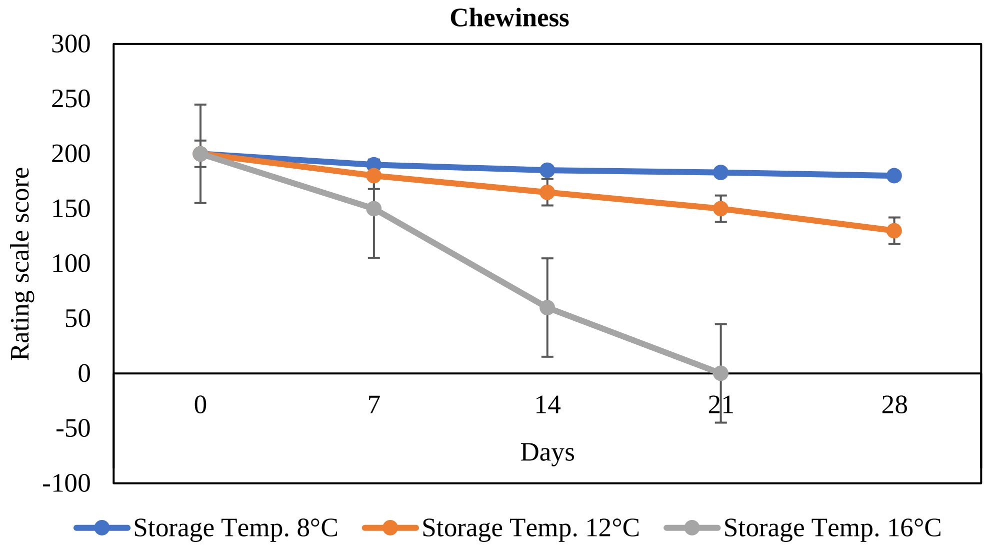

Fig. 6. Effect of Mango cv. Sufaid Chaunsa on texture (chewiness) during different storage periods at temperatures of 8°C, 12°C, and 16°C.

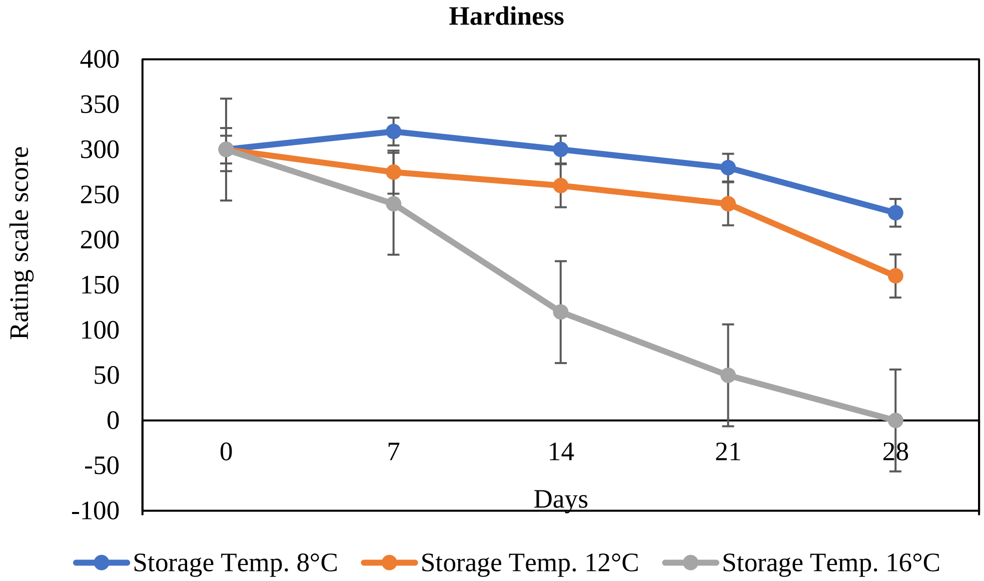

Fig. 6. Effect of Mango cv. Sufaid Chaunsa on texture (hardiness) during different storage periods at temperatures of 8°C, 12°C, and 16°C.

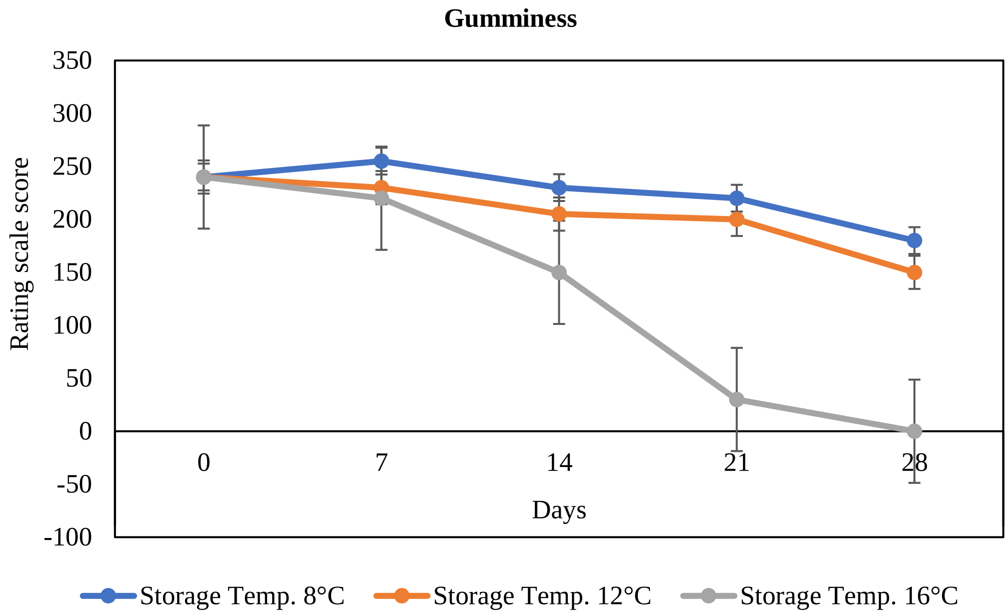

Fig. 7. Effect of Mango cv. Sufaid Chaunsa on texture (Gumminess) during different storage periods at temperatures of 8°C, 12°C, and 16°C.

Sensory characteristics

A sensory evaluation was conducted to evaluate the quality attributes of the mangoes, including flavor, color, odor, texture, and overall characteristics. The findings revealed a significant decline in sensory attributes of the mangoes throughout the storage period, as depicted in Figure 9. Specifically, in terms of flavor, the statistical analysis of the hedonic test indicated that mangoes stored at 8°C attained the highest score of 7.8 points on the 21st day of storage. Similarly, on the 28th day of storage, mangoes stored at 8°C achieved the highest score of 5.6 points. By the end of the storage period, mangoes at 8°C received the highest flavor score of 6.0 points, surpassing the other treatments. The same pattern was observed for color, odor, texture, and overall characteristics. At the culmination of storage, mangoes stored at 8°C exhibited the highest sensory acceptance in terms of color, taste, and aroma compared to the other treatments.

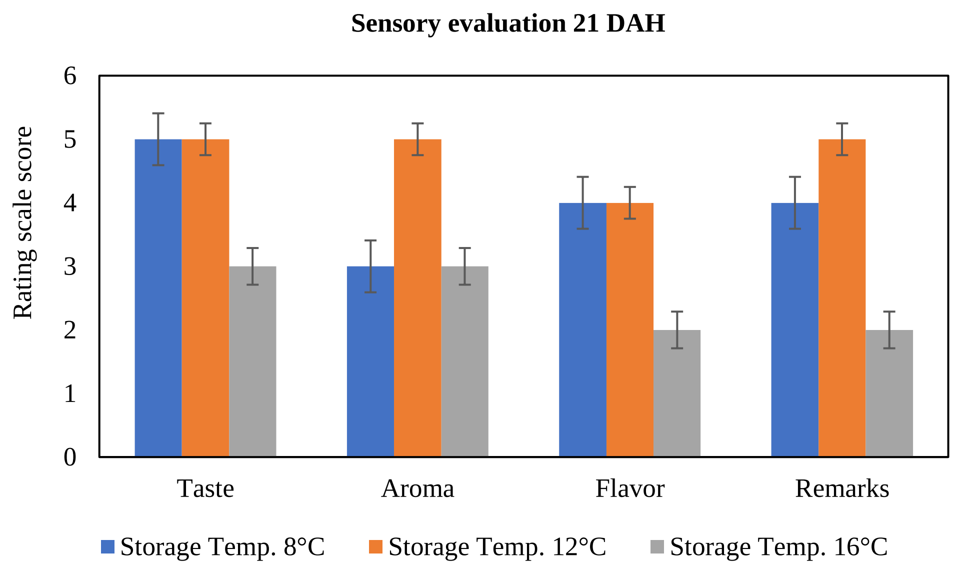

Fig. 8. Effect of Mango cv. Sufaid Chaunsa on sensory evaluation at temperatures of 8°C, 12°C, and 16°C after 21 DAH.

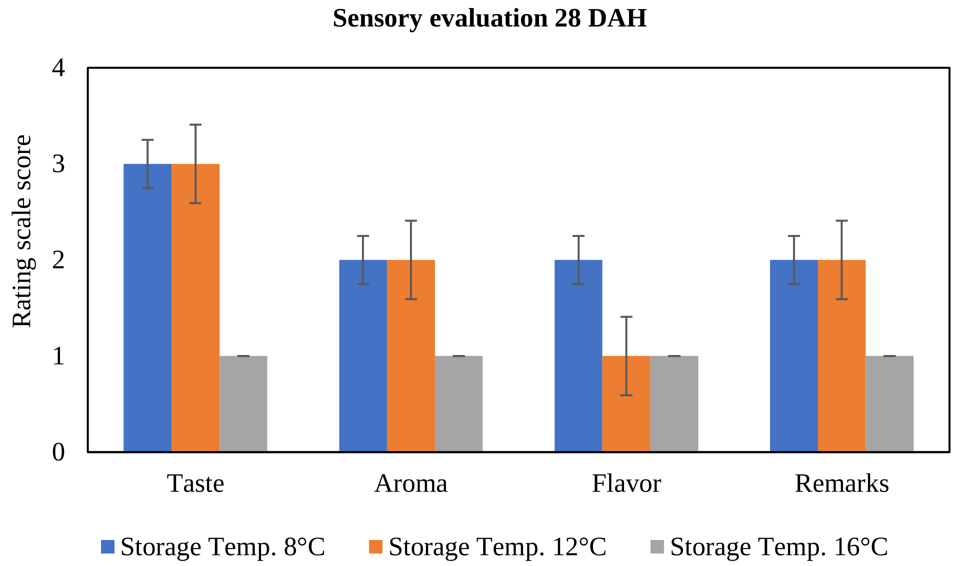

Fig. 9. Effect of Mango cv. Sufaid Chaunsa on sensory evaluation at temperatures of 8°C, 12°C, and 16°C after 28 DAH.

Table 1. Pearson correlations between all variables

Variables	External Appearance	Chilling	Water loss	TSS	TA	Chewiness	Hardiness	Gumminess
Chilling	0.74*							
Water loss	0.7*	0.45						
TSS	0.3	0.64	0.72*					
TA	0.51	0.35	0.77*	0.8*				
Chewiness	0.33	0.72*	0.5	0.47	0.54			
Hardiness	0.45	0.77*	0.62	0.34	0.37	0.75*		
Gumminess	0.57	0.32	0.48	0.6	0.36	0.71*	0.75*	
Sensory Evaluation	0.7*	0.75*	0.75*	0.8*	0.82*	0.7*	0.78*	0.78*

≥0.7 is significant "" & ≤ 0.7 is non-significant values*

Pearson Correlation

Table 1 presents the interrelationships among various parameters, including chilling injury, external appearance, weight loss, total soluble solids (TSS), titratable acidity (TA), texture properties, and sensory properties of mangoes across different treatments. Significant positive correlations were observed between chilling injury and TSS, chewiness, and sensory properties. This indicates that as chilling injury increased, there was also an increase in TSS content, chewiness, and sensory attributes. Weight loss correlated with TSS, TA, external appearance, and sensory evaluation. This implies that weight loss was associated with changes in TSS content, titratable acidity, external appearance, and sensory perceptions of the mangoes. Moreover, the texture profile parameters demonstrated a positive correlation with chilling injury, suggesting that changes in texture properties were linked to the severity of chilling injury experienced by the mangoes.

Conclusion

The results indicated that storing mangoes at 12°C extended their shelf life by up to 21 days, showing better results than other temperatures. Storing the mangoes at 12°C reduced water loss, maintained chemical changes, and preserved sensory characteristics. In contrast, storing mangoes at 16°C resulted in a quality deterioration after 21 days. Mangoes stored at 8°C exhibited increased dark and bruised skin, while those stored at 12°C developed anthracnose disease on the peel. Mangoes stored at 8°C also exhibited more rapid chilling injury development than those stored at 8°C and 12°C. However, by the end of the 28-day storage period, samples kept at 8°C and 12°C displayed the least severe chilling injury symptoms. The total soluble solids (TSS) content increased with the extended shelf life, reaching 16%, 22%, and 23% at 8°C, 12°C, and 16°C, respectively. This indicates that the sweetness of the mangoes intensified during storage. Regarding flavor, mangoes stored at 8°C received the highest score in the hedonic test on the 21st and 28th day of storage, achieving a flavor score of 7.8 and 5.6 points, respectively. At the end of the storage period, mangoes at 8°C surpassed the other treatments and received the highest flavor score of 6.0 points. The storage of cv. Sufaid Chaunsa mangoes at 12°C were the most effective temperature for extending their shelf life. This temperature helped maintain the fruit's quality by reducing water loss, preserving sensory characteristics, and minimizing chilling injury. However, it should be noted that storing mangoes at lower temperatures (8°C) may result in skin darkening, bruising, and the development of anthracnose disease on the peel. Overall, the findings of this study provide valuable insights for commercial growers and stakeholders involved in mango storage and quality maintenance.

Conflict of interest

The authors declared absence of conflict of interest

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