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Studies on Impact of Various Packaging Materials on the Quality and Shelf-life of Mango (*Mangifera indica* l.) Fruit

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Mango (*Mangifera indica* L.) is a nutritionally rich and economically important fruit crop, with India being the largest global producer; however, significant postharvest losses and limited export share persist due to inadequate packaging and storage systems. Despite advances in packaging technologies, comparative evaluation of conventional and innovative, sustainable packaging materials under ambient conditions remains insufficient, necessitating focused research to improve shelf life and fruit quality. The study aims to evaluate the influence of varied packaging materials on the postharvest quality attributes and shelf life of mango fruits under ambient storage conditions. The present investigation was carried out during the year 2023-24 at Post-harvest Laboratory, Department of Horticulture of ITM University, Gwalior, Madhya Pradesh, India. The

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treatments comprised of the effect of different packaging materials on the quality and shelf life of mango fruits. The experiment was conducted in Completely Randomized Design (CRD) with eight treatments and three replications. The experiment consisted of eight treatments including T_0 (Control (No Packaging)), T_1 (Fibre Box),T_2 (Corrugated Fiber Box) T_3 (Container-1 (Soil Mud)), T_4 (Container-2 (Cow Dung +Soil Mud)), T_5 (Container-3 (Goat Dung + Soil Mud)), T_6 (Container-4 (Mushroom Residues + Soil Mud), T_7 (Container-5 (Cow Dung + Goat Dung + Mushroom Residues + Soil Mud) were used for this study. The lowest physiological loss in weight (2.49%) and decay loss (3.91%) at day 16, while maintaining the highest firmness (43.75 N), TSS (13.05 °Brix), Vitamin C (45.26 mg/100g), Vitamin A (42.50 µg/100g), reducing sugar (3.58%), total sugar (9.64%), and non-reducing sugar (6.05%) throughout storage. Sensory attributes colour, texture, and appearance were best retained under T_7 (score 8.67 at day 16 vs. 2.67 in Control). The maximum shelf life of 18 days was recorded under T7 (Cow Dung + Goat Dung + Mushroom Residues + Soil Mud), which was significantly superior to the control (12.67 days) and all other treatments under the agroclimatic conditions of Madhya Pradesh, India.

Keywords: Mango; packaging materials; postharvest quality; shelf life; physiological loss in weight; reducing sugar; firmness; sensory attributes.

1. Introduction

Mango (*Mangifera indica* L.), a member of the family Anacardiaceae having somatic chromosome number 2n = 40, ranks among the most economically significant fruit crops of tropical and subtropical regions worldwide (Mukherjee & Srivastava*,* 1979). The crop is believed to have originated in the South-East Asian or Indo-Myanmar region, where nearly 69 species of *Mangifera* have been reported (Kosterman *&* Bompard*,* 1993). The crop is cultivation on the Indian subcontinent has a history spanning over four millennia, a legacy that has earned it the celebrated designation of "King of Fruits." From a botanical standpoint, the mango fruit is a large, fleshy drupe consumed across different stages of maturity raw fruits find use in pickles and chutneys, while fully ripened fruits serve as the base for an extensive range of processed commodities including juices, purées, jams, nectars, and other value-added preparations (Hamdard *et al.*, 2004).

From a nutritional perspective, mango is an exceptionally rich source of dietary fibre, essential vitamins, minerals, and health-promoting bioactive constituents such as polyphenols, flavonoids, and antioxidants. Sucrose accounts for approximately half of the total sugar content, and the fruit contains substantial concentrations of α- and β-carotene, which function as key precursors of vitamin A (Saranwong *et al.*, 2004). Beyond its nutritional profile, mango is recognized for its therapeutic value in managing heat-related disorders, digestive disturbances, cardiovascular conditions, and certain forms of cancer. On a global scale, India stands as the foremost producer, contributing nearly 40% of world mango output from approximately 1.2 million hectares, with an annual production of around 11 million tonnes. Uttar Pradesh, Andhra Pradesh, Bihar, Maharashtra, and Karnataka are among the principal mango-producing states of the country.

Notwithstanding its dominant position in global production, India's mango exports remain disproportionately low at approximately 43,000 MT, constituting a mere 0.2% of total output. This paradox is largely a consequence of deficiencies in postharvest management, including inadequate packaging, handling, and storage infrastructure. Postharvest losses in mango are estimated to range between 17 and 36%, making it one of the most perishable of all commercially cultivated fruits. As a climacteric fruit, mango is characterized by a rapid and irreversible ripening process driven by a sharp increase in respiration rate and autocatalytic ethylene biosynthesis. This triggers a cascade of biochemical events including chlorophyll breakdown, cell wall dissolution, carotenoid synthesis, and the emergence of characteristic colour, taste, and aroma. Under prevailing ambient conditions, mature green fruits typically ripen within 9–12 days and may become unmarketable within 15 days of harvest, substantially constraining both domestic distribution and export potential (Gómez & Gómez*.,* 1984).

Packaging constitutes one of the most critical interventions in postharvest management, serving to shield fruits from mechanical injury, regulate moisture and gas exchange, and preserve overall sensory integrity. Among traditional packaging options, mud containers have long been employed owing to their inherent capacity for thermal insulation and passive ventilation, along with their low cost and biodegradability, making them particularly appropriate for rural and resource-constrained environments. The addition of cow dung to mud

containers confers enhanced antimicrobial properties and greater structural robustness, thereby reducing microbial spoilage and physiological weight loss. Goat dung–mud containers similarly improve microbial resistance and assist in maintaining fruit firmness, attributable to the fibrous and mineral-rich nature of goat dung (Singh *et al.,* 2013).

In recent years, mushroom residues abundant in β-glucans, phenolic compounds, and lignocellulosic matter have emerged as promising substrates for the development of biodegradable packaging materials with antioxidant, antimicrobial, and insulating functionalities (Haneef *et al.,* 2017; Jones *et al.,* 2018). On the commercial front, fiberboard and corrugated fiberboard (CFB) boxes continue to dominate packaging systems owing to their superior mechanical strength, ventilation capacity, and stackability, especially for long-distance transport and export operations (Tran, 2016).

In view of the considerable postharvest losses and constrained export competitiveness of Indian mangoes, a rigorous and comparative assessment of both conventional and innovative packaging systems is warranted. Developing packaging solutions that are simultaneously cost-effective, environmentally sustainable, and practically scalable holds the potential to significantly curtail losses, sustain fruit quality, and augment economic returns across the supply chain. The present investigation was accordingly designed to evaluate the influence of varied packaging materials on the postharvest quality attributes and shelf life of mango fruits under ambient storage conditions.

2. Materials and Methods

The experiment titled “Studies on impact of various packaging materials on the quaility and shelf-life of mango (*Mangifera indica* L.) fruit.” was carried out during the year 2023-24 at Post-harvest Laboratory, Department of Horticulture of ITM University, Gwalior, Madhya Pradesh, India. It involved ten-year-old mango plants planted at a spacing of 8m × 8m. The eight treatments details are T_0 (Control (No Packaging)), T_1 (Fibre Box),T_2 (Corrugated Fiber Box) T_3 (Container-1 (Soil Mud)), T_4 (Container-2 (Cow Dung +Soil Mud)), T_5 (Container-3 (Goat Dung + Soil Mud)), T_6 (Container-4 (Mushroom Residues + Soil Mud), T_7 (Container-5 (Cow Dung + Goat Dung + Mushroom Residues + Soil Mud). A Completely Randomized Design (CRD) with eight treatments and three replications was involved, and effect of different packaging materials on the quality and shelf life of mango fruits in year (2023-24) after harvesting of mature fruits.

2.1 Storage Conditions

Three fruits per treatment were packed and stored at ambient temperature (28–32°C). Observations were recorded on 0, 4, 8, 12 and 16 days. For biochemical analysis, pooled samples were taken from three fruits per replication. Data were recorded in a pre-designed observation sheet for further statistical analysis.

2.2 Physical Attributes

2.2.1 Physiological Loss in Weight (PLW)

Fruits were weighed periodically using an electronic balance.

$$PLW(\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} X100$$

2.2.2 Firmness

Measured with a digital penetrometer (8 mm probe) at the equatorial region; expressed in kg/cm² (mean of three readings).

2.2.3 Decay Loss (%)

Assessed by visual observation of fungal growth/rotting.

$$\text{Percentage of decay} = \frac{\text{No. of decayed fruits}}{\text{Total number of fruits}} \text{X100}$$

2.3 Biochemical Attributes

2.3.1 Total Soluble Solids (TSS, °Brix)

Determined using a hand refractometer (0–32% range) on fresh juice; corrected at 20°C (Ranganna, 1986).

2.3.2 pH

Determined using a digital pH meter. 10 g of pulp was homogenized with 50 mL distilled water, and pH was measured.

2.3.3 Titratable Acidity (%)

Titrated against N/10 NaOH using phenolphthalein indicator; expressed as anhydrous citric acid per 100 g (Ranganna, 1986).

$$\text{Acidity}(\%) = \frac{\text{Titrate value X Normality of NaOH X 64 X Volume made up}}{\text{Aliquot taken X Weight of sample taken X 1000}} \text{X } 100$$

2.3.4 Vitamin C (mg/100 g)

Estimated by titration against 2,6-dichlorophenol indophenol dye after extraction in 3% metaphosphoric acid (A.O.A.C., 1975).

$$\text{Dye factor} = \frac{0.5}{\text{Titrate volume of standard ascorbic acid}}$$

$$\text{Ascorbic acid } (\frac{\text{mg}}{100\text{g}}) = \frac{\text{Titre value X Dye factor X Volume made up X 100}}{\text{Aliquot taken X Weight of sample taken}}$$

2.3.5 Vitamin A (µg/100 g)

Determined by spectrophotometric method at 450 nm after saponification and extraction.

2.3.6 Reducing Sugar (%)

Estimated by Lane and Eynon (1923) method using Fehling's solution, titrated against 1% glucose with methyl blue indicator. The calculation was done with the help of following formula and results were expressed as per cent of reducing sugars:

$$\text{Reducing sugars } (\%) = \frac{\text{(Blank X Sample titrate value)X Volume made up}}{\text{Aliquot taken (3 ml)X Volume of sample taken (5 ml)}}$$

2.3.7 Total Invert Sugar (%)

Aliquot from reducing sugar extract hydrolyzed with HCl overnight, neutralized, and titrated by Lane and Eynon method. The results were expressed as per cent of total invert sugar:

$$\text{Total invert sugar } (\%) = \frac{\text{Blank titrate value X Sample titrate value X Volume made up}}{\text{Aliquot taken X Weight of sample taken}} \text{X100}$$

2.3.8 Total Sugar (%)

The sum of reducing sugars (%) and non-reducing sugar (%) was expressed as per cent of total sugars:

Total sugars (%) = Reducing sugars (%) + non-reducing sugar (%).
Determined using Lane and Eynon titration method.

2.3.9 Non-Reducing Sugar (%)

Non-reducing sugar was calculated with the help of following formulae:

Non-reducing sugar (%) = [Total invert sugar (%) – Reducing sugars (%)] x 0.95.

2.4 Sensory Characteristics

The sensory characteristics of products were judged by the panel of ten semi-trained member from the Department of Horticulture of ITM University, Gwalior, Madhya Pradesh, India. The panellists were asked to evaluate the product for different sensory attributes namely colour, flavour/taste, Body/texture, appearance, overall acceptability. Nine-point Hedonic scale and score Card method was used for evaluation of sensory characteristics of different products (Amerine *et al.,* 1965).

2.5 Statistical Analysis

The statistical tools using for analysis of sensory quality, and nutrient composition will be mean± SD. For analysis of collected information, suitable and appropriate statistical techniques would be applied interpretation would be drawn according to the results (Montgomery 2012).

3. Results and Discussion

The detailed results are interpreted in light of earlier findings to understand the mechanisms behind improved preservation and sensory acceptability under eco-friendly packaging systems.

3.1 Physiological Loss%

PLW increased progressively in all treatments across the storage period, which is attributable to continued transpiration and respiration after harvest a well-documented phenomenon in mango postharvest physiology. At 0 and 6 days, differences among treatments were non-significant. However, significant differences emerged at 12 and 16 days (CD = 0.41 and 0.39, respectively). At 16 days, T_7 (cow dung + goat dung + mushroom residues + soil mud) recorded the lowest PLW (2.49 ± 0.17%), differing significantly from all other treatments, which ranged from 2.98 to 3.23%. T5 (goat dung + soil mud) showed the highest PLW (3.23 ± 0.13%), followed by T6 (3.19 ± 0.25%) and T1 (3.11 ± 0.20%).

The superior performance of T_7 may be attributed to the insulating and moisture-buffering properties of the composite organic substrate, which likely reduced the vapour pressure deficit around the fruit, thereby minimizing moisture loss. Similar results were reported by earlier workers who observed reduced PLW in mango stored in organic material-lined containers compared to conventional packaging. The conventional packaging treatments (T1 – fibre box, T2 – CFB box) and control (T0) showed comparable PLW, suggesting no significant advantage of standard packaging over ambient storage at this storage duration. The present findings are also supported by previous studies conducted by Tripathi *et al.,* (2021).

3.2 Firmness (kg/cm²)

Firmness declined consistently across all treatments throughout the storage period, reflecting normal softening due to cell wall degradation and pectin solubilization during mango ripening a well-established postharvest phenomenon. Significant differences among treatments were observed at all storage intervals (CD = 3.21, 2.74, 3.03, and 2.62 at 0, 6, 12, and 16 days, respectively). T_7 (cow dung + goat dung + mushroom residues + soil mud) retained significantly higher firmness throughout storage, recording 50.17 ± 0.81 kg/cm² at 0 day and 43.75 ± 0.47 kg/cm² at 16 days markedly superior to all other treatments. In contrast, T1 (fibre box) showed the lowest firmness at 16 days (34.73 ± 2.25 kg/cm²), followed closely by T4 (34.60 ± 1.29 kg/cm²). T2 (CFB box) performed moderately better among conventional packaging treatments (37.90 ± 1.93 kg/cm² at 16 days).

Table 1. Effect of different packaging containers on physiological loss%, firmness (kg/cm²) and decay Loss (%) of mango during storage at various intervals

Treatments	Physiological loss%				Firmness (kg/cm²)				Decay Loss (%)			
	0 Day	6 day	12 day	16 day	0 Day	6 day	12 day	16 day	0 Day	6 day	12 day	16 day
T0	0.69 ± 0.24	1.48 ± 0.03	2.45 ± 0.09^{a}	3.02 ± 0.25^{a}	45.95 ± 1.65^{b}	41.71 ± 1.04^{bc}	38.60 ± 1.34^{bc}	35.36 ± 2.11^{bc}	0.26 ± 0.25	2.29 ± 0.35^{abc}	5.18 ± 0.27^{b}	.52 ± 0.81^{bc}
T1	0.56 ± 0.10	1.68 ± 0.26	2.39 ± 0.26^{a}	3.11 ± 0.20^{a}	43.55 ± 2.71^{b}	39.47 ± 2.44^{c}	37.07 ± 2.43^{bc}	34.73 ± 2.25^{c}	0.25 ± 0.44	2.39 ± 0.30^{abc}	4.97 ± 0.74^{b}	6.03 ± 0.42^{c}
T2	0.74 ± 0.14	1.74 ± 0.44	2.42 ± 0.24^{a}	2.99 ± 0.21^{a}	46.04 ± 3.53^{b}	43.49 ± 2.94^{b}	39.94 ± 3.04^{b}	37.90 ± 1.93^{b}	0.27 ± 0.13	2.92 ± 0.32^{a}	6.40 ± 0.27^{a}	7.85 ± 0.73^{a}
T3	0.52 ± 0.18	1.41 ± 0.11	2.44 ± 0.31^{a}	3.00 ± 0.34^{a}	44.88 ± 1.60^{b}	41.10 ± 1.22^{bc}	36.73 ± 2.00^{c}	35.04 ± 1.23^{c}	0.07 ± 0.06	3.06 ± 0.43^{a}	6.37 ± 0.40^{a}	7.70 ± 0.08^{a}
T4	0.57 ± 0.30	1.38 ± 0.26	2.44 ± 0.15^{a}	2.98 ± 0.19^{a}	44.47 ± 0.84^{b}	41.59 ± 0.70^{bc}	37.95 ± 0.73^{bc}	34.60 ± 1.29^{c}	0.16 ± 0.28	2.00 ± 0.18^{bc}	4.95 ± 0.42^{b}	6.97 ± 0.77^{ab}
T5	0.51 ± 0.23	1.52 ± 0.10	2.24 ± 0.28^{a}	3.23 ± 0.13^{a}	45.90 ± 0.69^{b}	43.25 ± 0.72^{b}	40.01 ± 1.09^{b}	36.32 ± 0.81^{bc}	0.20 ± 0.24	2.52 ± 0.26^{ab}	4.90 ± 0.76^{b}	6.18 ± 0.24^{bc}
T6	0.63 ± 0.04	1.46 ± 0.12	2.59 ± 0.17^{a}	3.19 ± 0.25^{a}	44.32 ± 0.70^{b}	41.34 ± 1.34^{bc}	37.00 ± 0.71^{bc}	35.35 ± 1.03^{bc}	0.09 ± 0.15	2.65 ± 0.33^{ab}	5.11 ± 0.23^{b}	6.53 ± 0.26^{bc}
T7	0.59 ± 0.20	1.28 ± 0.17	1.77 ± 0.30^{b}	2.49 ± 0.17^{b}	50.17 ± 0.81^{a}	48.72 ± 0.32^{a}	45.23 ± 1.16^{a}	43.75 ± 0.47^{a}	0.21 ± 0.18	1.65 ± 1.00^{c}	2.76 ± 0.49^{c}	3.91 ± 0.31^{d}
CD	NS	NS	0.41	0.39	3.21	2.74	3.03	2.62	NS	0.8	0.84	0.91
SE(m)	0.11	0.13	0.14	0.13	1.07	0.91	1.01	0.87	0.14	0.27	0.28	0.30
SE(d)	0.16	0.18	0.19	0.18	1.51	1.29	1.43	1.24	0.2	0.38	0.4	0.43

Note: T0 – Control, T1 - Fiber box, T2 - CFB box, T3 - Container-1 (Soil mud), T4 - Container-2 (Cow dung + soil mud), T5 - Container-3 (Goat dung + soil mud), T6 - Container-4 (Mushroom residues + soil mud), T7 - Container-5 (Cow dung + goat dung + mushroom Residues + soil mud)

Table 2 Effect of different packaging containers on Total Soluble Solids (TSS, °Brix), Titratable Acidity (%) of mango during storage at various intervals

Treatments	Total Soluble Solids (TSS, °Brix)				pH		Titratable Acidity (%)			
	0 Day	6 day	12 day	16 day	0 Day	16 day	0 Day	6 day	12 day	16 day
T0	10.32± 0.18	10.68 ± 0.15 ^{c}	11.20 ± 0.25 ^{c}	10.45 ± 0.88 ^{d}	4.21 ± 0.02^{bc}	4.26 ± 0.03^{bc}	0.59 ± 0.01^{bc}	0.55 ± 0.02	0.51 ± 0.01^{bcd}	0.49 ± 0.01^{bcd}
T1	10.69± 0.35	11.25 ± 0.32 ^{ab}	11.62 ± 0.26 ^{b}	12.15 ± 0.40 ^{b}	4.19 ± 0.02^{bc}	4.26 ± 0.01^{bc}	0.62 ± 0.01^{a}	0.57 ± 0.03	0.52 ± 0.01^{abc}	0.51 ± 0.01^{ab}
T2	10.52± 0.25	10.78 ± 0.20 ^{bc}	11.52 ± 0.27 ^{b}	12.26 ± 0.58 ^{b}	4.20 ± 0.02^{bc}	4.26 ± 0.01^{bc}	0.61 ± 0.00^{ab}	0.57 ± 0.02	0.52 ± 0.01^{abcd}	0.51 ± 0.02^{ab}
T3	10.51± 0.22	11.10 ± 0.23 ^{b}	11.65 ± 0.21 ^{b}	11.78 ± 0.28 ^{bc}	4.21 ± 0.02^{abc}	4.27 ± 0.01^{abc}	0.61 ± 0.02^{ab}	0.57 ± 0.03	0.53 ± 0.02^{ab}	0.51 ± 0.02^{ab}
T4	10.47± 0.27	10.92 ± 0.25 ^{bc}	11.50 ± 0.22 ^{b}	11.65 ± 0.31 ^{c}	4.22 ± 0.03^{ab}	4.28 ± 0.02^{ab}	0.57 ± 0.01^{c}	0.54 ± 0.02	0.49 ± 0.01^{cd}	0.48 ± 0.02^{cd}
T5	10.52± 0.24	11.08 ± 0.24 ^{b}	11.58 ± 0.33 ^{b}	11.84 ± 0.36 ^{bc}	4.22 ± 0.02^{abc}	4.27 ± 0.02^{abc}	0.62 ± 0.00^{ab}	0.56 ± 0.01	0.52 ± 0.01^{abcd}	0.50 ± 0.01^{abc}
T6	10.46± 0.31	10.95 ± 0.20 ^{bc}	11.60 ± 0.31 ^{b}	11.70 ± 0.35 ^{c}	4.18 ± 0.03^{c}	4.24 ± 0.03^{c}	0.62 ± 0.03^{a}	0.58 ± 0.03	0.54 ± 0.04^{a}	0.52 ± 0.03^{a}
T7	10.81 ± 0.14	11.55 ± 0.19 a	12.14 ± 0.28 a	13.05 ± 0.47 a	4.25 ± 0.01^{a}	4.30 ± 0.02^{a}	0.57 ± 0.00c	0.53 ± 0.02	0.49 ± 0.01d	0.47 ± 0.01d
CD	NS	0.32	0.32	0.32	0.04	0.03	0.03	NS	0.03	0.03
SE(m)	0.15	0.16	0.15	0.42	0.01	0.01	0.01	0.01	0.01	0.01
SE(d)	0.21	0.23	0.22	0.6	0.02	0.02	0.01	0.02	0.02	0.01

The significantly higher firmness retention in T_7 may be attributed to the combined buffering effect of the organic composite substrate, which likely moderated temperature fluctuations and maintained a favourable microenvironment around the fruit, thereby slowing ethylene-mediated ripening and cell wall-degrading enzyme activity. These findings are consistent with earlier studies reporting that organic material-based storage environments reduce metabolic activity and delay softening in climacteric fruits like mango. The observed results align with the findings of Singh and Pal (2013), Kumar *et al.* (2019), Larney and Angers, 2012).

3.3 Decay Loss %

Decay loss increased progressively in all treatments over the storage period, which is expected due to accelerated fungal activity and surface moisture loss under ambient conditions during prolonged storage. No significant differences were observed at 0 day. However, significant treatment effects were evident from 6 days onwards (CD = 0.80, 0.84, and 0.91 at 6, 12, and 16 days, respectively). T_7 (cow dung + goat dung + mushroom residues + soil mud) recorded the lowest decay loss throughout storage, with values of 1.65 ± 1.00, 2.76 ± 0.49, and 3.91 ± 0.31% at 6, 12, and 16 days, respectively significantly lower than all other treatments. On the other hand, T2 (CFB box) and T3 (soil mud) exhibited the highest decay loss at 16 days (7.85 ± 0.73% and 7.70 ± 0.08%, respectively), followed by T0 control (6.52 ± 0.81%). T1 (fibre box) recorded relatively lower decay among conventional treatments (6.03 ± 0.42%).

The markedly reduced decay in T_7 may be ascribed to the antimicrobial and moisture-regulating properties of the composite organic substrate. Constituents such as cow dung, goat dung, and mushroom residues are known to harbour beneficial microorganisms that may competitively suppress pathogenic fungi responsible for postharvest decay. Similar suppression of postharvest rot through organic substrate-based storage has been reported in earlier studies on tropical fruits. The higher decay in CFB box and soil mud treatments may be linked to moisture retention within enclosed or poorly ventilated environments, which favors fungal proliferation. These results are in agreement with the findings of Larney and Angers, (2012), Goss *et al.,* (2013), Droby *et al.* (2025) and Matisic *et al.,* (2024).

3.4 Total Soluble Solids (°Brix)

TSS increased progressively in all treatments throughout the storage period, reflecting the normal hydrolysis of complex carbohydrates into soluble sugars during mango ripening a characteristic feature of climacteric fruit maturation. No significant differences were recorded at 0 day. Significant treatment effects became apparent from 6 days onwards (CD = 0.32 at 6, 12, and 16 days). T_7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest TSS at all intervals, reaching 13.05 ± 0.47 °Brix at 16 days significantly superior to all other treatments. T0 (control) showed the lowest TSS at 16 days (10.45 ± 0.88 °Brix), indicating faster respiratory losses and irregular ripening under unprotected ambient conditions. Among conventional packaging treatments, T2 (CFB box) and T1 (fibre box) performed comparably (12.26 ± 0.58 and 12.15 ± 0.40 °Brix, respectively) at 16 days, followed by T3 (11.78 ± 0.28 °Brix) and T5 (11.84 ± 0.36 °Brix).

The consistently higher TSS in T_7 suggests a more uniform and sustained ripening process facilitated by the composite organic substrate, which likely moderated the storage microenvironment and slowed excessive respiratory carbon loss. The relatively lower TSS in control fruits may be attributed to unregulated water loss and faster metabolic activity under open ambient conditions. These findings are in agreement with earlier reports indicating that modified storage environments promote gradual sugar accumulation and better ripening uniformity in mango. These findings are in line with earlier reports by Ranganna (1986).

3.5 pH

pH increased slightly across all treatments from 0 to 16 days, consistent with the progressive breakdown of organic acids during mango ripening, which is a well-documented biochemical change in climacteric fruits. Significant differences among treatments were observed at both 0 day (CD = 0.04) and 16 days (CD = 0.03). T_7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest pH at both 0 day (4.25 ± 0.01) and 16 days (4.30 ± 0.02), differing significantly from most other treatments. T6 (mushroom residues + soil mud) recorded the lowest pH at both intervals (4.18 ± 0.03 and 4.24 ± 0.03, respectively), followed by T1 and T2 (4.26 ± 0.01 each at 16 days). Remaining treatments T0, T1, T2, T3, T4, and T5 showed comparable pH values with marginal differences.

The relatively higher pH in T_7 suggests slower acid catabolism, possibly due to the temperature-buffering and humidity-moderating properties of the composite organic substrate, which may have retarded metabolic activity and organic acid degradation. The lower pH in T6 may reflect slightly different microbial or substrate interactions affecting fruit metabolism. Overall, pH variation among treatments was narrow, indicating that storage method had a limited but statistically significant influence on acid dissipation during the 16-day storage period. Similar trends of gradual pH increase during ambient mango storage have been reported by several earlier workers. such as ammonium and calcium ions, through microbial mineralization. These findings corroborate with the results reported by Huang *et al.,* (2022), Hassan *et al*., (2020), Razali *et al.,* (2019), Singh *et al., (*2021), Larney and Angers, (2012) and Fetouh *et al. (*2020).

3.6 Titratable Acidity (%)

Titratable acidity declined consistently across all treatments throughout the storage period, reflecting the progressive oxidation and utilization of organic acids as respiratory substrates during mango ripening a characteristic biochemical change in climacteric fruits. Significant differences among treatments were observed at 0, 12, and 16 days (CD = 0.03 each), while differences at 6 days were non-significant. T6 (mushroom residues + soil mud) retained the highest acidity at 12 and 16 days (0.54 ± 0.04 and 0.52 ± 0.03%, respectively), followed by T1, T2, T3, and T5, which were statistically comparable. T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the lowest acidity throughout storage, reaching 0.47 ± 0.01% at 16 days significantly lower than most treatments. T4 (cow dung + soil mud) also showed comparably low acidity (0.48 ± 0.02%) at 16 days.

The faster acid decline in T7 is consistent with its higher TSS and pH values reported earlier, collectively indicating accelerated but uniform ripening in this treatment. The relatively higher acidity retention in T6 suggests a slower rate of organic acid catabolism, possibly due to the unique biochemical environment created by mushroom residues in the substrate. Higher initial acidity in T1 and T6 (0.62%) at 0 day may reflect slight variability in initial fruit maturity. These findings are in conformity with earlier reports of progressive acidity decline during ambient storage of mango. Similar trends were reported by Singh and Sethi (2017), Kader, (2002), Larney and Angers (2012).

3.7 Vitamin- C (mg/100g)

Vitamin C content declined progressively in all treatments throughout the storage period, which is attributed to oxidative degradation of ascorbic acid during ripening and prolonged ambient storage a commonly reported trend in mango postharvest studies. No significant differences were observed at 0 day. Significant treatment effects emerged from 6 days onwards (CD = 1.46, 1.80, and 1.93 at 6, 12, and 16 days, respectively). T7 (cow dung + goat dung + mushroom residues + soil mud) retained significantly higher Vitamin C throughout storage, recording 47.76 ± 0.60, 46.28 ± 0.21, and 45.26 ± 0.39 mg/100 g at 6, 12, and 16 days, respectively markedly superior to all other treatments. In contrast, T4 (cow dung + soil mud) showed the lowest Vitamin C retention at 16 days (33.87 ± 0.49 mg/100 g), followed by T1 (34.44 ± 1.41 mg/100 g) and T2 (34.95 ± 1.26 mg/100 g). All remaining treatments T0, T3, T5, and T6 were statistically comparable at 16 days, ranging between 35.32 and 35.61 mg/100 g.

The significantly superior Vitamin C retention in T7 may be attributed to the antioxidant-rich microenvironment created by the composite organic substrate, which likely reduced oxidative stress on the fruit surface and slowed ascorbic acid oxidation. Organic amendments such as cow dung, goat dung, and mushroom residues are known to release bioactive phenolic and enzymatic compounds that may confer an indirect protective effect against oxidative degradation. These findings corroborate earlier reports emphasizing the role of modified storage environments in preserving ascorbic acid content in climacteric fruits during postharvest handling. Similar findings were reported by Sundaram *et al.* (2020).

3.8 Vitamin -A (ug/100g)

Vitamin A content declined gradually across all treatments throughout the storage period, which is consistent with the oxidative degradation of carotenoids during prolonged ambient storage a well-reported postharvest phenomenon in mango. Significant differences among treatments were observed at all storage intervals (CD = 3.66, 3.54, 3.74, and 3.73 at 0, 6, 12, and 16 days, respectively). T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest Vitamin A content throughout storage, with values of 45.20, 44.20, 43.20, and 42.50 µg/100 g at 0, 6, 12, and 16 days, respectively significantly superior to all other treatments. T1

(fibre box) showed the lowest Vitamin A retention at all intervals, recording 35.13 ± 2.90 µg/100 g at 16 days. T6 (mushroom residues + soil mud) and T2 (CFB box) performed comparably and ranked second, recording 39.57 ± 1.82 and 39.00 ± 0.40 µg/100 g at 16 days, respectively. Treatments T0, T3, T4, and T5 were statistically at par throughout storage, ranging between 37.07 and 37.73 µg/100 g at 16 days.

The superior carotenoid retention in T7 may be attributed to the protective microenvironment generated by the composite organic substrate, which likely moderated temperature extremes and reduced photo-oxidative degradation of carotenoids. Mushroom residues and animal dung constituents in T7 may also contribute antioxidant compounds that inhibit carotenoid oxidation. The relatively poor performance of T1 may be linked to inadequate insulation within fibre boxes, exposing fruits to greater temperature fluctuation and accelerated pigment degradation. These findings are consistent with earlier studies reporting enhanced carotenoid retention in mango under modified or insulated storage conditions. The present findings are also supported by previous studies conducted by Sharma *et al.,* (2022), Pathak et al., (2021), Thakur *& Bajagain,* (2020), Gupta *et al.,* (2012).

3.9 Reducing Sugar (%)

Reducing sugar content increased progressively in all treatments throughout the storage period, reflecting the hydrolysis of starch and non-reducing sugars into reducing sugars during the ripening process a characteristic biochemical transformation in climacteric fruits such as mango. Significant differences among treatments were observed at all storage intervals (CD = 0.13, 0.09, 0.09, and 0.10 at 0, 6, 12, and 16 days, respectively). T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest reducing sugar content throughout storage, with values of 2.70 ± 0.02, 3.03 ± 0.02, 3.36 ± 0.00, and 3.58 ± 0.03% at 0, 6, 12, and 16 days, respectively significantly superior to all other treatments at every interval. All remaining treatments T0, T1, T2, T3, T4, T5, and T6 were statistically at par throughout the storage period, ranging between 3.38 and 3.43% at 16 days.

The consistently higher reducing sugar accumulation in T7 may be attributed to the favourable ripening microenvironment created by the composite organic substrate, which likely promoted uniform and sustained starch hydrolysis through enhanced amylolytic enzyme activity. The regulated temperature and humidity conditions within T7 containers may have facilitated optimal enzymatic conversion of complex carbohydrates into simple sugars. These findings are in agreement with the higher TSS values recorded in T7, collectively indicating superior and well-coordinated ripening. Similar trends of progressive reducing sugar accumulation during ambient mango storage have been reported by earlier workers. Similar findings have been reported by Larney and Angers (2012).

3.10 Total Sugar (%)

Total sugar content increased progressively in all treatments throughout the storage period, reflecting the cumulative accumulation of both reducing and non-reducing sugars during starch hydrolysis and ripening a well-established biochemical pattern in climacteric fruits. Significant differences among treatments were observed at all storage intervals (CD = 0.19, 0.15, 0.15, and 0.15 at 0, 6, 12, and 16 days, respectively). T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest total sugar content throughout storage, with values of 9.12 ± 0.03, 9.30 ± 0.06, 9.50 ± 0.04, and 9.64 ± 0.02% at 0, 6, 12, and 16 days, respectively significantly superior to all other treatments at every interval. All remaining treatments T0 through T6 were statistically at par throughout storage, ranging between 9.02 and 9.14% at 16 days, with T6 (9.14 ± 0.02%) and T1 (9.14 ± 0.13%) marginally higher among this group.

The consistently higher total sugar accumulation in T7 is in conformity with the higher reducing sugar and TSS values reported earlier, collectively confirming superior and well-coordinated ripening facilitated by the composite organic substrate. The regulated microenvironment within T7 containers likely promoted optimal amylolytic and invertase enzyme activity, resulting in greater carbohydrate conversion. The statistical parity among all other treatments suggests that neither conventional packaging nor single-component organic substrates conferred any significant advantage in sugar accumulation over the storage period. These findings are consistent with earlier reports on total sugar dynamics during ambient storage of mango. These findings corroborate with the results reported by Larney and Angers, (2012).

Table 3. Effect of different packaging containers on Vitamin- C (mg/100g), Vitamin -A (ug/100g) and Reducing sugar of mango during storage at various intervals

Treatments	Vitamin- C (mg/100g)				Vitamin -A (ug/100g)				Reducing sugar			
	0 Day	6 day	12 day	16 day	0 Day	6 day	12 day	16 day	0 Day	6 day	12 day	16 day
T0	49.93 ± 0.51	45.06 ± 0.42^{b}	40.59 ± 1.02^{b}	35.61 ± 1.01^{b}	39.63 ± 0.51^{bc}	38.70 ± 0.78^{bc}	37.97 ± 0.58^{bc}	37.33 ± 0.40^{bc}	2.48 ± 0.11^{b}	2.85 ± 0.04^{b}	3.15 ± 0.03^{b}	3.38 ± 0.02^{b}
T1	49.94 ± 0.16	45.54 ± 0.94^{b}	39.65 ± 2.09^{b}	34.44 ± 1.41^{b}	37.83 ± 2.65^{c}	36.77 ± 2.93^{c}	35.43 ± 2.64^{c}	35.13 ± 2.90^{c}	2.53 ± 0.03^{b}	2.86 ± 0.03^{b}	3.23 ± 0.05^{b}	3.43 ± 0.06^{b}
T2	49.32 ± 0.14	44.89 ± 0.54^{b}	40.21 ± 0.66^{b}	34.95 ± 1.26^{b}	41.83 ± 0.15^{ab}	40.90 ± 0.10^{ab}	39.37 ± 0.25^{b}	39.00 ± 0.40^{ab}	2.46 ± 0.08^{b}	2.82 ± 0.02^{b}	3.15 ± 0.07^{b}	3.38 ± 0.09^{b}
T3	50.23 ± 0.65	45.17 ± 1.05^{b}	39.73 ± 0.76^{b}	35.45 ± 1.45^{b}	39.83 ± 1.36^{bc}	38.80 ± 1.39^{bc}	37.57 ± 1.42^{bc}	37.07 ± 1.07^{bc}	2.47 ± 0.05^{b}	2.82 ± 0.08^{b}	3.15 ± 0.07^{b}	3.42 ± 0.07^{b}
T4	50.23 ± 1.24	44.39 ± 1.16^{b}	39.15 ± 0.90^{b}	33.87 ± 0.49^{b}	39.77 ± 4.04^{bc}	39.13 ± 3.69^{bc}	37.67 ± 4.08^{bc}	37.33 ± 3.73^{bc}	2.52 ± 0.11^{b}	2.84 ± 0.06^{b}	3.16 ± 0.02^{b}	3.39 ± 0.04^{b}
T5	49.82 ± 1.16	44.16 ± 1.07^{b}	39.36 ± 0.62^{b}	35.32 ± 0.69^{b}	40.23 ± 2.50^{bc}	39.20 ± 2.34^{bc}	38.23 ± 2.50^{bc}	37.73 ± 3.18^{bc}	2.53 ± 0.06^{b}	2.84 ± 0.06^{b}	3.18 ± 0.03^{b}	3.39 ± 0.06^{b}
T6	49.62 ± 0.32	44.59 ± 0.59^{b}	39.69 ± 1.02^{b}	35.34 ± 1.54^{b}	42.43 ± 2.01^{ab}	40.90 ± 1.83^{ab}	39.93 ± 2.27^{ab}	39.57 ± 1.82^{ab}	2.52 ± 0.07^{b}	2.85 ± 0.07^{b}	3.17 ± 0.08^{b}	3.40 ± 0.08^{b00}
T7	49.80 ± 0.32	47.76 ± 0.60^{a}	46.28 ± 0.21^{a}	45.26 ± 0.39^{a}	45.20 ± 0.00a	44.20 ± 0.00a	43.20 ± 0.00a	42.50 ± 0.00a	2.70 ± 0.02a	3.03 ± 0.02a	3.36 ± 0.00a	3.58 ± 0.03a
CD	NS	1.46	1.8	1.93	3.66	3.54	3.74	3.73	0.13	0.09	0.09	0.1
SE(m)	0.40	0.49	0.60	0.64	1.22	1.18	1.25	1.25	0.04	0.03	0.03	0.03
SE(d)	0.56	0.69	0.85	0.91	1.73	1.67	1.77	1.76	0.06	0.04	0.04	0.05

Table 4. Effect of different packaging containers on Total Sugar (%) and non-reducing sugar of mango during storage at various intervals

Treatments	Total Sugar (%)				Non-Reducing Sugar (%)			
	0 Day	6 day	12 day	16 day	0 Day	6 day	12 day	16 day
T0	8.44 ± 0.17^{b}	8.73 ± 0.11^{b}	8.84 ± 0.11^{c}	9.05 ± 0.06^{b}	5.96 ± 0.12^{b}	5.88 ± 0.12^{b}	5.69 ± 0.09^{c}	5.67 ± 0.06^{b}
T1	8.51 ± 0.12^{b}	8.74 ± 0.03^{b}	8.96 ± 0.13^{bc}	9.14 ± 0.13^{b}	5.98 ± 0.09^{b}	5.88 ± 0.01^{b}	5.73 ± 0.08^{bc}	5.71 ± 0.10^{b}
T2	8.50 ± 0.08^{b}	8.72 ± 0.10^{b}	8.99 ± 0.08^{bc}	9.09 ± 0.08^{b}	6.04 ± 0.04^{b}	5.90 ± 0.09^{b}	5.84 ± 0.04^{b}	5.71 ± 0.06^{b}
T3	8.45 ± 0.09^{b}	8.71 ± 0.12^{b}	8.90 ± 0.14^{bc}	9.04 ± 0.11^{b}	5.98 ± 0.10^{b}	5.89 ± 0.12^{b}	5.75 ± 0.14^{bc}	5.63 ± 0.10^{b}
T4	8.47 ± 0.16^{b}	8.69 ± 0.13^{b}	8.91 ± 0.07^{bc}	9.02 ± 0.15^{b}	5.95 ± 0.05^{b}	5.85 ± 0.08^{b}	5.75 ± 0.06^{bc}	5.63 ± 0.11^{b}
T5	8.48 ± 0.08^{b}	8.69 ± 0.01^{b}	8.91 ± 0.03^{bc}	9.06 ± 0.04^{b}	5.95 ± 0.09^{b}	5.85 ± 0.06^{b}	5.73 ± 0.05^{bc}	5.67 ± 0.07^{b}
T6	8.53 ± 0.08^{b}	8.80 ± 0.05^{b}	9.01 ± 0.05^{b}	9.14 ± 0.02^{b}	6.01 ± 0.14^{b}	5.94 ± 0.12^{b}	5.84 ± 0.04^{b}	5.74 ± 0.10^{b}
T7	9.12 ± 0.03^{a}	9.30 ± 0.06^{a}	9.50 ± 0.04^{a}	9.64 ± 0.02^{a}	6.42 ± 0.03^{a}	6.27 ± 0.05^{a}	6.15 ± 0.04^{a}	6.05 ± 0.01^{a}
CD	0.19	0.15	0.15	0.15	0.15	0.15	0.13	0.14
SE(m)	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.05
SE(d)	0.09	0.07	0.07	0.07	0.07	0.07	0.06	0.07

Table 5. Effect of different packaging containers on Sensory Attributes and Shelf life- days of mango during storage at various intervals

Treatments	Sensory Attributes						Shelf life- days
	Colour	Texture	Appearance	Colour	Texture	Appearance	
	0 Day			16 day			
T0	8.67 ± 0.58	8.67 ± 0.58	8.67 ± 0.58	3.67 ± 0.58^{f}	2.67 ± 0.58^{e}	2.67 ± 0.58^{f}	12.67 ± 1.15^{c}
T1	8.33 ± 0.58	8.33 ± 0.58	8.33 ± 0.58	5.00 ± 0.00^{de}	4.67 ± 0.58^{d}	4.67 ± 0.58^{de}	15.67 ± 0.58^{b}
T2	8.33 ± 0.58	8.33 ± 0.58	8.33 ± 0.58	5.67 ± 0.58^{cd}	5.67 ± 0.58^{c}	5.33 ± 0.58^{cd}	14.00 ± 1.73bc
T3	8.00 ± 0.00	8.00 ± 0.00	8.00 ± 0.00	4.67 ± 0.58^{e}	4.67 ± 0.58^{d}	4.33 ± 0.58^{e}	13.00 ± 1.00c
T4	8.33 ± 0.58	8.33 ± 0.58	8.33 ± 0.58	6.67 ± 0.58^{b}	6.33 ± 0.58^{bc}	6.67 ± 0.58^{b}	14.00 ± 1.00bc
T5	8.67 ± 0.58	8.67 ± 0.58	8.67 ± 0.58	6.67 ± 0.58b	6.67 ± 0.58b	6.33 ± 0.58b	13.67 ± 0.58c
T6	8.33 ± 0.58	8.33 ± 0.58	8.33 ± 0.58	6.33 ± 0.58bc	6.00 ± 0.00bc	6.00 ± 0.00bc	14.00 ± 1.00bc
T7	9.00 ± 0.00	9.00 ± 0.00	9.00 ± 0.00	8.67 ± 0.58a	8.67 ± 0.58a	8.67 ± 0.58a	18.00 ± 1.00a
CD	-	-	-	0.93	0.93	0.93	1.84
SE(m)	0.29	0.29	0.29	0.31	0.31	0.31	0.61
SE(d)	0.41	0.41	0.41	0.44	0.44	0.44	0.87

3.11 Non-Reducing Sugar (%)

Non-reducing sugar content declined gradually across all treatments throughout the storage period, reflecting the progressive hydrolysis of sucrose into reducing sugars during mango ripening a normal biochemical event associated with invertase enzyme activity in climacteric fruits. Significant differences among treatments were observed at all storage intervals (CD = 0.15, 0.15, 0.13, and 0.14 at 0, 6, 12, and 16 days, respectively).

T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest non-reducing sugar content throughout storage, with values of 6.42 ± 0.03, 6.27 ± 0.05, 6.15 ± 0.04, and 6.05 ± 0.01% at 0, 6, 12, and 16 days, respectively significantly superior to all other treatments at every interval. All remaining treatments T0 through T6 were statistically at par throughout storage, ranging between 5.63 and 5.74% at 16 days. Among this group, T6 (mushroom residues + soil mud) marginally retained higher non-reducing sugar (5.74 ± 0.10%) while T3 and T4 recorded the lowest values (5.63% each) at 16 days.

The higher non-reducing sugar content in T7 at all intervals, despite its simultaneously higher reducing sugar accumulation, suggests a greater overall carbohydrate reserve in fruits stored under the composite organic substrate. The regulated microenvironment of T7 likely slowed invertase-mediated sucrose hydrolysis while maintaining active ripening metabolism. These findings complement the total sugar and reducing sugar data reported earlier, collectively confirming the biochemical superiority of T7 in sustaining carbohydrate metabolism during postharvest storage. Similar declining trends in non-reducing sugars during ambient mango storage have been reported by previous workers. Non-reducing sugars, mainly sucrose, tend to decrease over time due to enzymatic hydrolysis by invertase, leading to an increase in reducing sugars such as glucose and fructose (Tomar *et al.,* 2018). Similar findings were reported by Singh *et al.* (2020), Larney and Angers, (2012).

3.12 Sensory Attributes (Colour, Texture, and Appearance)

At 0 day, no significant differences were observed among treatments for any sensory attribute, indicating uniform initial fruit quality across all treatments. Scores ranged between 8.00 and 9.00, reflecting freshly harvested, well-matured fruits acceptable to panellists across all storage conditions. At 16 days, significant differences emerged among treatments for all three attributes (CD = 0.93 each).

T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the highest scores for colour (8.67 ± 0.58), texture (8.67 ± 0.58), and appearance (8.67 ± 0.58) at 16 days significantly superior to all other treatments and closely comparable to initial scores, indicating excellent sensory quality retention. T0 (control) recorded the lowest scores at 16 days for all attributes (colour: 3.67 ± 0.58, texture: 2.67 ± 0.58, appearance: 2.67 ± 0.58), reflecting rapid sensory deterioration under unprotected ambient storage. Among other treatments, T4 and T5 performed comparably (6.33–6.67) and ranked second, followed by T6 (6.00–6.33), T2 (5.33–5.67), T1 (4.67–5.00), and T3 (4.33–4.67).

The superior sensory retention in T7 may be attributed to the composite organic substrate's ability to moderate temperature, maintain adequate humidity, and reduce physical stress on fruits, thereby retarding surface shrivelling, discoloration, and textural softening. The sharp decline in control fruits underscores the importance of appropriate storage environments in maintaining postharvest sensory quality. These findings are consistent with earlier reports emphasizing the role of modified storage conditions in preserving the visual and tactile quality of mango during ambient storage. The present findings are also supported by previous studies conducted by Larney and Angers, (2012), Kader, (2002) and Mahajan *et al.* (2014,2011).

3.13 Shelf Life (Days)

Significant differences in shelf life were observed among treatments (CD = 1.84), indicating that storage method had a meaningful influence on the postharvest longevity of mango cv. Langra under ambient conditions. T7 (cow dung + goat dung + mushroom residues + soil mud) recorded the maximum shelf life of 18.00 ± 1.00 days significantly superior to all other treatments. T1 (fibre box) ranked second with 15.67 ± 0.58 days, differing significantly from T7 but performing better than most remaining treatments. T2, T4, and T6 were statistically at par with each other (14.00 days each), followed by T5 (13.67 ± 0.58 days) and T3 (13.00 ± 1.00 days). T0 (control) recorded the shortest shelf life (12.67 ± 1.15 days), being statistically comparable to T3 and T5.

The markedly extended shelf life in T7 may be attributed to the synergistic effect of all constituent organic materials cow dung, goat dung, mushroom residues, and soil mud which collectively created a thermally buffered, humidity-regulated, and antimicrobial microenvironment around the stored fruits. This likely retarded respiration rate, ethylene-mediated ripening, moisture loss, and fungal decay simultaneously, as evidenced by the superior performance of T7 across all physical, biochemical, and sensory parameters reported earlier. The poor shelf life of control fruits further underscores the vulnerability of mango to rapid postharvest deterioration under unprotected ambient storage. These findings strongly suggest that composite organic substrate-based storage containers represent a low-cost, eco-friendly, and effective postharvest management strategy for extending mango shelf life at the farm or rural level. The present findings are also supported by previous studies conducted by Larney and Angers, (2012), Sivakumar and Bautista-Baños, (2014).

4. Summary and Conclusion

The present investigation assessed the influence of various eco-friendly organic substrate-based storage treatments on the postharvest quality attributes of mango cv. Langra stored under ambient conditions for 16 days. Treatments comprised conventional packaging (fibre box and CFB box), individual organic substrates (soil mud, cow dung, goat dung, and mushroom residues), and a composite organic substrate, and were evaluated for PLW, firmness, decay loss, TSS, pH, titratable acidity, Vitamin C, Vitamin A, sugar fractions, sensory attributes, and shelf life. Among all treatments, T7 (cow dung + goat dung + mushroom residues + soil mud) demonstrated markedly superior performance, registering minimum PLW (2.49%) and decay loss (3.91%), along with maximum firmness (43.75 kg/cm²), TSS (13.05 °Brix), Vitamin C (45.26 mg/100g), Vitamin A (42.50 µg/100g), reducing sugar (3.58%), total sugar (9.64%), and highest sensory scores at the end of storage. The unpackaged control (T0) recorded the poorest quality retention, while standard packaging treatments (T1 and T2) offered no notable benefit over single-component organic substrates. T7, comprising a composite blend of cow dung, goat dung, mushroom residues, and soil mud, emerged as the most effective postharvest storage treatment, extending the shelf life of mango cv. Langra to 18.00 ± 1.00 days under ambient conditions. The combined thermal insulation, moisture regulation, and antimicrobial activity of this substrate synergistically slowed respiration, delayed ethylene-driven ripening, minimized weight loss, and suppressed fungal decay, thereby maintaining superior nutritional and organoleptic quality. Given its low input cost and ease of preparation, this approach offers a practical and sustainable postharvest solution suitable for resource-limited farming settings. Validation across diverse cultivars, seasons, and agro-climatic zones is recommended for broader application.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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