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Swatantra Yadav
Chandra Shekhar Azad
University of Agriculture and
Technology, Kanpur, Uttar
Pradesh, India

VK Tripathi
Chandra Shekhar Azad
University of Agriculture and
Technology, Kanpur, Uttar
Pradesh, India

AK Trivedi
ICAR-Central Institute for
Subtropical Horticulture,
Lucknow, Uttar Pradesh,
India

Corresponding Author:
AK Trivedi
ICAR-Central Institute for
Subtropical Horticulture,
Lucknow, Uttar Pradesh,
India

Preharvest fruit bagging with different-coloured bags modulates postharvest quality and storage behaviour of mango (*Mangifera indica* L.) cv. Dashehari

Swatantra Yadav, VK Tripathi and AK Trivedi

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Abstract

A two-year field experiment was conducted during 2023-24 and 2024-25 to investigate the influence of preharvest fruit bagging with different-coloured bags on the physicochemical and biochemical quality attributes of mango (*Mangifera indica* L.) cv. Dashehari during postharvest storage. Fruits were bagged at the lemon-size stage using green, red, brown, and white bags, while unbagged fruits served as the control. Fruits were harvested at physiological maturity and evaluated at 0, 3, 6, 9, and 12 days after harvest for changes in physical, physicochemical, and biochemical quality attributes. Preharvest bagging significantly improved fruit quality and delayed quality deterioration during storage compared with unbagged control fruits. Among the treatments, green bagging (T₂) exhibited the most favourable overall response. At 12 days after harvest, fruits from the green-bag treatment recorded the highest fruit weight (276.33 g), fruit volume (272.50 cm³), firmness (1.57 kg cm⁻²), specific gravity (1.02), total soluble solids (19.73 °Brix), titratable acidity (0.26%), total sugars (16.52%), and reducing sugars (6.81%). The same treatment also maintained comparatively lower physiological loss in weight (15.79%) and vitamin C content of 29.48 mg 100 g⁻¹ at the end of storage. These findings demonstrate that preharvest fruit bagging, particularly with green-coloured bags, can effectively enhance and maintain the postharvest quality of Dashehari mango. The practice offers a simple, low-cost, and potentially scalable preharvest intervention for improving fruit quality and extending marketable storage life.

Keywords: *Mangifera indica* L., Dashehari, preharvest bagging, coloured bags, postharvest quality, physicochemical characteristics, biochemical quality, shelf life

Introduction

Mango (*Mangifera indica* L.), popularly known as the "King of Fruits," is among the most significant commercial fruit crops. Anacardiaceae family and chromosome no. is (2n = 40) (Tharanathan *et al.*, 2006) [26]. It is best suitable for tropical and subtropical climates and can be grown in all areas of the country, up to an elevation of 600 meters. Required deep, fertile, and well-draining soils, such as sandy loam, loam, and alluvial types. A pH level of 5.5 to 7.5 is predominantly best suited for strong root growth, nutrient absorption, and fruit production (Usha *et al.*, 2015) [27]. And throughout the cultivation period, high humidity and temperatures ranging from 24 to 30 °C are ideal. The most suitable annual precipitation range for mango cultivation is between 890 and 1015 mm (Adak *et al.*, 2016) [2].

Originally native to the Indo-Burma region, a mango cultivation is growing globally, including India, China, Thailand, Mexico, Pakistan, the Philippines, Indonesia, Brazil, Nigeria, and Egypt being the predominant mango-producing country (Rajan *et al.*, 2019) [19]. In Indian production hubs include Uttar Pradesh, Andhra Pradesh, Telangana, Karnataka, Bihar, Gujarat, and Maharashtra (Thakor *et al.*, 2019) [25].

Fresh mango pulp is an excellent nutritional source of essential micronutrients, particularly provitamin A, vitamin C, vitamin E, and necessary dietary fibres. It contains optimum quantity of carbohydrates, organic acids, and essential minerals such as potassium, magnesium, and calcium (Zafar *et al.*, 2017) [31]. Mango is used in a variety of value-added processes. Immature green fruits are commonly used in culinary preparations such as traditional pickling, chutneys. Ripe fruits are processed commercially into canned pulp, purees, concentrated juices, nectars, jams, and jellies. (Bhusari *et al.*, 2025) [6]

Fruit bagging is a traditional horticulture technique that was especially cultivated in Japan and China for the preservation of quality crops. Subsequently, it disseminated to additional fruit-exporting developing nations, such as India, South Korea, Australia, and countries in Southeast Asia. The approach can be applied to fruits including mango, apple, pear, peach, grape, guava, pomegranate, citrus, persimmon, and loquat. (Ali *et al.*, 2021) ^[3]. In mango cultivation, bagging covers the fruits against pests, infections, sun exposure, and physical injury, while improving their visual attractiveness and quality (Kumar *et al.*, 2021) ^[15].

Pre-harvest fruit bagging is an environmentally friendly physical protection practice that can help increase the post-harvest shelf life of mangos. Bagging individual fruits during development protects them from insect pests, fungal spores, dust, and extreme environmental conditions. It also alters the microenvironment around the fruit by controlling temperature, humidity, and light penetration, impacting fruit development and ripening. Bagging can help prevent sunburn, cracking, latex staining, and surface flaws, leading in higher-quality fruit after harvest. (Kumar *et al.*, 2021) ^[15] While storage, bagged fruits may experience reduced moisture loss, slowed softening, and slower ripening and senescence. Maintaining better fruit firmness and physicochemical and biochemical quality can help to postpone quality decline and extend mango fruit marketability. Bagging effectiveness may vary depending on bag color, material, and number of layers, as these factors alter the microclimate around the fruit (Sharma *et al.*, 2016) ^[23]. Therefore, pre-harvest fruit bagging has the potential to significantly reduce post-harvest losses, preserve fruit quality throughout storage, and increase mango fruit shelf life and commercial value.

While extensive studies on various mango bagging materials, nothing is known about the effect of colourful bags on the physiology, biochemical composition, and post-harvest quality of the Dashehari variety in North Indian settings. Differences in bag colours can affect light penetration, temperature, and relative humidity inside the bag, influencing fruit development, ripening characteristics, and quality (Ali *et al.*, 2021) ^[3]. Investigating the effect of colored paper bags on the physicochemical and biochemical properties of mangoes can help in developing appropriate bagging strategies for the growth of premium export-quality fruits (Sharma, 2020) ^[22]. Thus, the present research was conducted aiming to evaluate the influence of pre-harvest bagging on the physicochemical characteristics and quality of the mango cv. Dashehari.

Materials and methodology

Experimental Site

The current study was carried out in the years 2023-24 and 2024-25 in the experimental orchard at ICAR-Central Institute for Subtropical Horticulture, located in Rehmanpura, Kakori, Lucknow, Uttar Pradesh, India. The laboratory of the same institute conducted the physicochemical and enzymatic assessments of the fruits. The experimental location is situated at 26°50'21.4" N latitude and 80°55'23.27" E longitude, at an elevation of roughly 123 m above mean sea level. This location experiences a humid subtropical climate characterized by three different seasons: the monsoon period from June to September, winter from November to March, and summer from April to June. The region experiences approximately 940 mm of

yearly precipitation, predominantly during the monsoon season, with temperatures frequently soaring to 45 °C in May and June, and declining to 8 °C-25 °C in January; summer humidity is typically moderate but can escalate to 70-80% in July.

Experimental Material and Treatment Details

The experiment was conducted on healthy and uniformly maintained 15-year-old trees of Mango cultivar Dashehari planted at of 5 × 5 m spacing. It was structured using a randomized block design that included five treatments and four replications. The total number of plants was 40, and each replication had two trees. The treatments included [T₁ (No. bag), T₂ (Green bag), T₃ (Red bag), T₄ (Brown bag), and T₅ (White bag)] comprising to different colours of bag with an inner black layer of 44 gsm and an outer coloured layer of 55 gsm. Each bag size (length 33.5 cm × width 20 cm). Fruit bagging was used after the fruit was about the size of a lemon, which was four to six weeks after it was set. A total of 100 fruits from each tree were randomly selected and uniformly bagged in all four directions of the canopy, with 25 fruits bagged for each. The bags were securely tied to ensure the protection of the fruits. Bagging tasks were carried out using ladders, tables, and necessary field support equipment. The enclosed fruits were examined on a regular basis during the experiment and harvested when they reached physiological maturity, which was around 55-60 days after bagging, for the shelf-life study.

Observations Recorded

The observations related to physical parameters were recorded at the time of harvest using standard procedures. Days to maturity were calculated by subtracting the date of bagging from the date of harvest maturity. Fruit weight was measured with the help of a digital weighing balance expressed in gram. Fruit volume was measured by the water displacement method and expressed in cubic centimetres. Fruit firmness was measured with the help of penetrometers and expressed in kg/cm² and specific gravity was measured by fruit weight divided by fruit volume and expressed in centimetres. Physiological loss in weight was calculated by record the initially measured and subsequent weights of the same fruits during storage and expressing the weight loss as a percentage of the initial fruit weight. TSS was measured using an Erma hand refractometer. Acidity was measured by the titration method, and reducing sugar was estimated by Folin and Wu's method as reported in AOAC (1975) ^[4]. Total sugar was estimated by the anthrone method (Hedge and Hofreiter, 1962) ^[10]. Data variance analysis was performed using SAS software ver. 9.1.

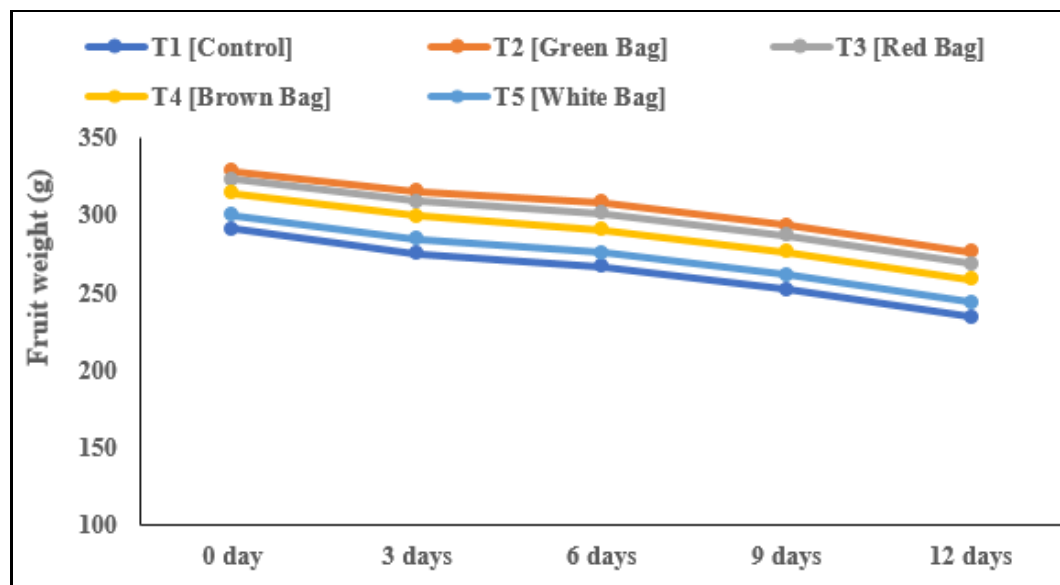
Results and Discussion

Fruit weight (g)

The pooled data revealed that fruit weight decreased progressively with advancement of storage from 0 to 12 days, while bagging treatments significantly influenced fruit weight. At 0 day, the maximum fruit weight was recorded under T₂ (Green Bag) (328.31 g), followed by T₃ (322.90 g), T₄ (314.02 g), T₅ (299.94 g) and T₁ (Control) (291.28 g); the same trend was maintained up to 12 days, when T₂ recorded the maximum fruit weight (276.33 g) and T₁ the minimum (234.19 g) (Fig 1). The reduction in fruit weight during storage may be attributed mainly to moisture loss through transpiration and respiratory metabolism. Better weight

retention under green bagging may be associated with modification of the fruit microenvironment and reduced moisture loss. Similar findings have been reported in bagged mango fruits, where bagging improved postharvest performance by reducing weight loss and maintaining firmness and other quality attributes (Hofman *et al.*,

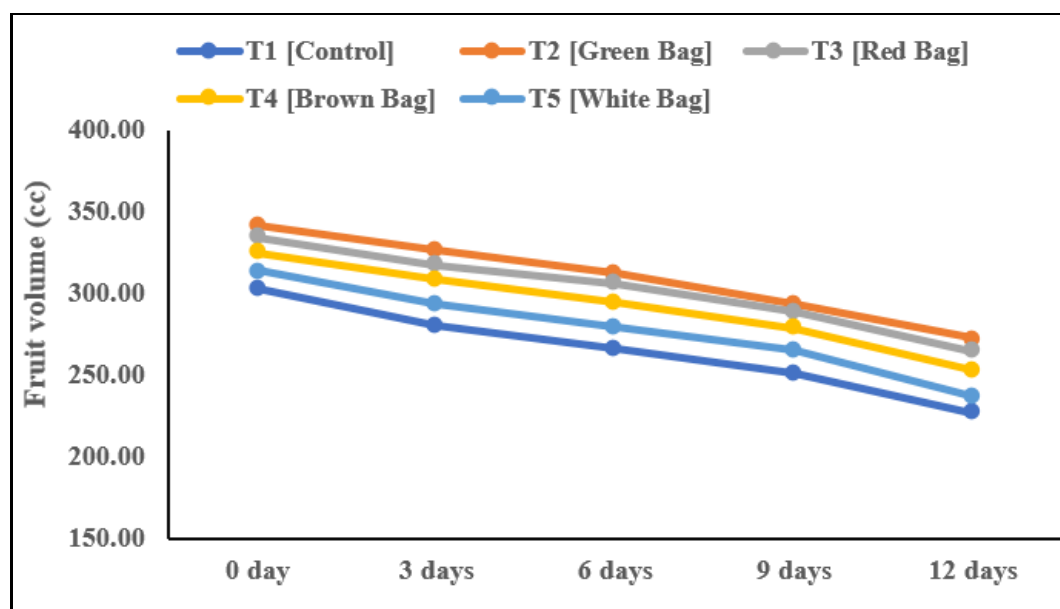
1997 and Wu *et al.*, 2013) ^[11, 28], Comparable enhancement of fruit weight following bagging has been reported for several mango cultivars, including Alphonso (Kireeti *et al.*, 2016; Haldankar *et al.*, 2015 and Ramez *et al.*, 2024) ^[14, 9, 20] in Himsagar.



Fruit volume (cc)

The pooled data showed a continuous decline in fruit volume with increasing storage duration, with significant differences among bagging treatments. At 0 day, T₂ (Green Bag) recorded the maximum fruit volume (341.25 cc), followed by T₃ (334.38 cc), T₄ (325.00 cc), T₅ (313.75 cc) and T₁ (Control) (303.13 cc). At 12 days, T₂ maintained the highest fruit volume (272.50 cc), whereas T₁ recorded the

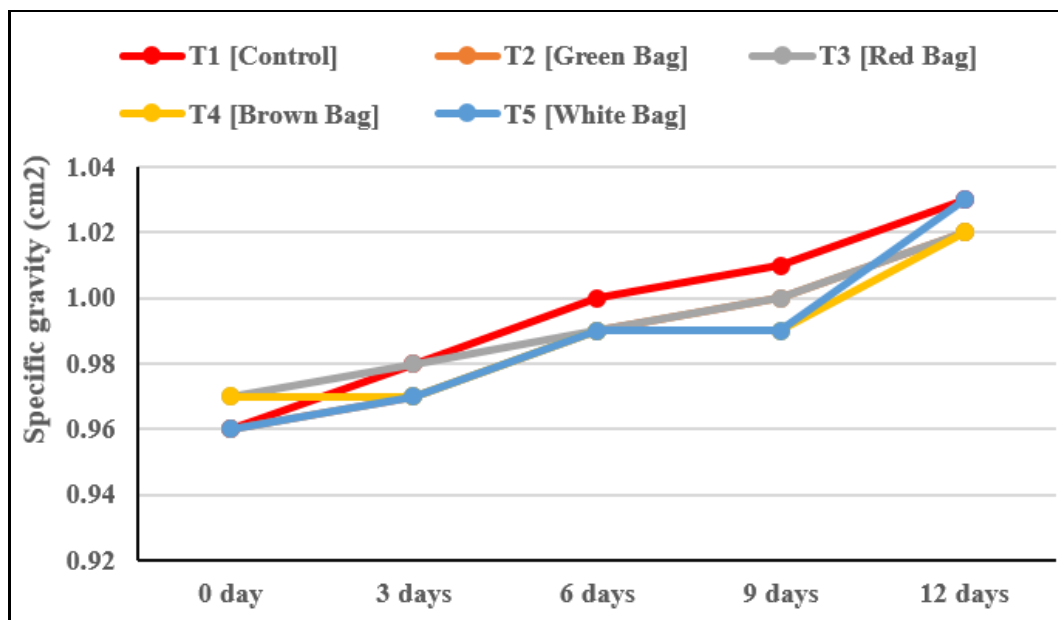
lowest (226.88 cc) (Fig 2). The reduction in fruit volume may be related to progressive moisture loss, tissue dehydration and physiological changes during ripening and storage. The comparatively maximum retention under green bagging suggests that modification of the fruit microenvironment reduced moisture loss and delayed physical deterioration (Yu *et al.*, 2022; Wu *et al.*, 2013 and Ali *et al.*, 2021) ^[30, 3, 28].



Specific gravity (cm2)

Specific gravity showed a slight increasing trend during storage in all treatments, although differences among treatments were non-significant up to 9 days, while a significant difference was observed at 12 days. The values increased from 0.96-0.97 at harvest to 1.02-1.03 at 12 days, with T₁ and T₅ recording the highest value (1.03) and T₂, T₃ and T₄ recording 1.02 (Fig 3). The increase in specific

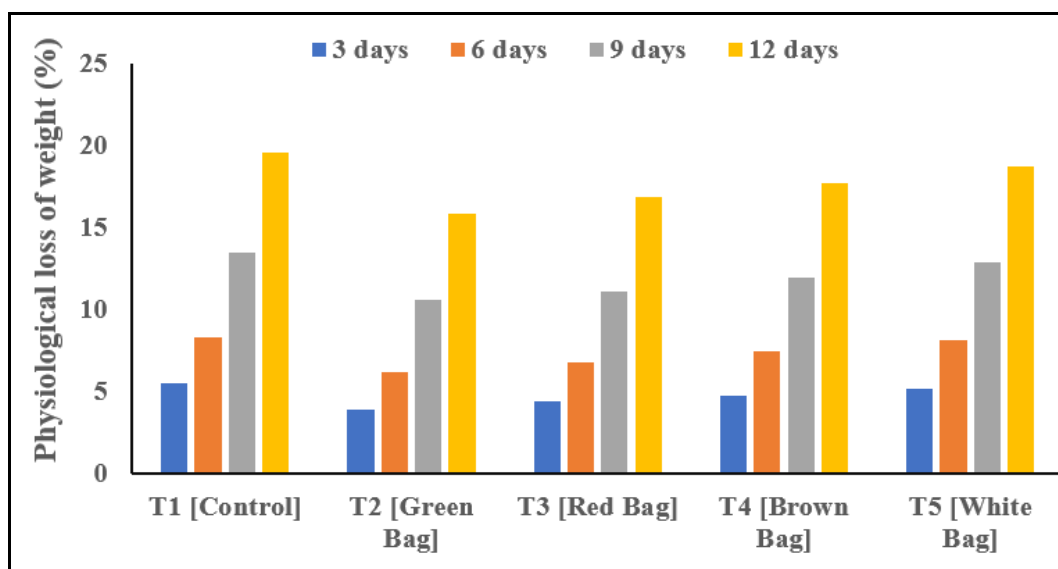
gravity may be associated with changes in the relative proportions of fruit mass and volume during ripening and dehydration. Since the treatment effect was largely non-significant, bagging colour appeared to have comparatively little influence on specific gravity during the early storage period (Hofman *et al.*, 1997; Yu *et al.*, 2022 and Hussain *et al.*, 2024) ^[11, 30, 12].



Physiological loss of weight (%)

Physiological loss in weight increased progressively with storage duration in all treatments, with significant differences among treatments. At 3 days, the lowest weight loss was recorded under T₂ (Green Bag) (3.87%), followed by T₃ (4.39%), T₄ (4.72%), T₅ (5.11%) and T₁ (Control) (5.50%). At 12 days, T₂ recorded the minimum physiological loss in weight (15.79%), whereas the

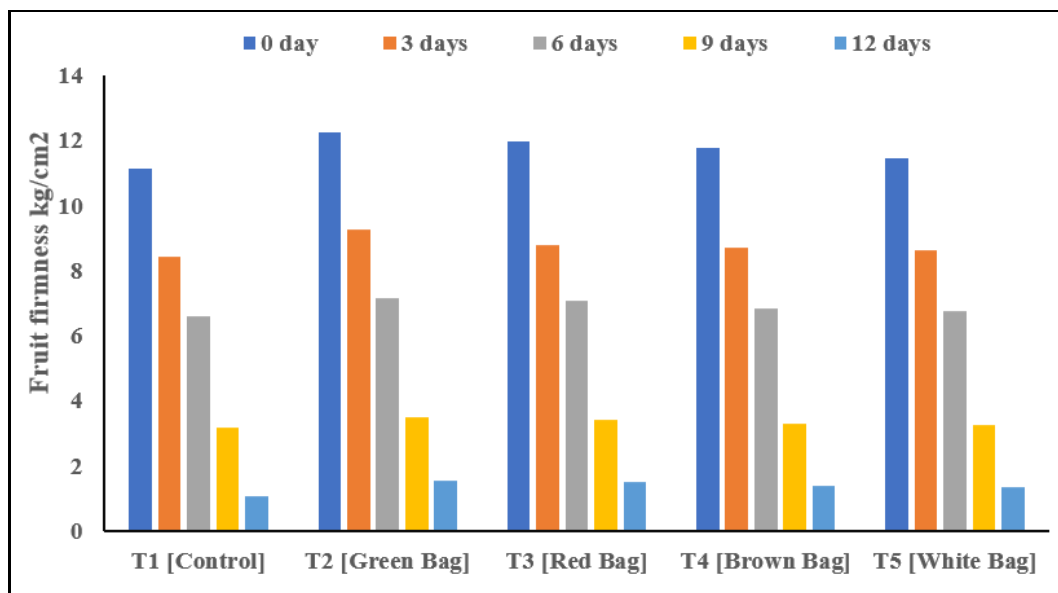
maximum was recorded in T₁ (19.59%) (Fig 4). The lower weight loss under green bagging may be attributed to reduced transpiration and moisture loss caused by modification of the microenvironment around the fruit. Bagging has previously been reported to slow postharvest weight loss and improve fruit quality by reducing water loss and metabolic deterioration (Begum *et al.*, 2023 and Nadeem *et al.*, 2022) [5, 16].



Fruit firmness kg/cm²

Fruit firmness decreased markedly with increasing storage duration in all treatments. At 0 day, the highest firmness was recorded in T₂ (Green Bag) (12.24 kg cm⁻²), followed by T₃ (11.98), T₄ (11.76), T₅ (11.46) and T₁ (11.14 kg cm⁻²). At 12 days, T₂ maintained the highest firmness (1.57 kg cm⁻²), whereas T₁ recorded the lowest (1.10 kg cm⁻²) (Fig 5). The decline in firmness may be associated with ripening-related

degradation of cell-wall components and loss of cellular integrity. The comparatively greater firmness retention under bagging, particularly green bagging, indicates delayed softening and physiological deterioration. Similar findings have been reported in bagged mango fruits, where bagging helped maintain higher fruit firmness during storage (Brummell *et al.*, 2004; Zhao *et al.*, 2026 and Negi *et al.*, 2008) [8, 32, 17].



Total soluble solids (° Brix)

TSS increased progressively during storage in each treatment, indicated advancement of fruit ripening. At 0 day, TSS ranged from 10.61°Brix in T₂ to 11.08°Brix in T₁, while at 12 days the highest TSS was recorded in T₂ (19.73°Brix), followed by T₃ (19.65), T₄ (19.45), T₅ (19.15) and T₁ (18.88°Brix) (Table 1). The increase in TSS during storage may be attributed to hydrolysis of complex carbohydrates and conversion of starch and other polysaccharides into soluble sugars during ripening. Bagging, particularly green bagging, appeared to support the maintenance of higher TSS at the later storage stage. Similar increases in soluble solids during fruit ripening and improved postharvest quality of bagged mango have been reported previously (Singh *et al.*, 2005; Abida *et al.*, 2026 and Rahman *et al.*, 2026) [24, 1, 18].

Treatments	0 day	3 days	6 days	9 days	12 days
T ₁ [Control]	11.08	12.74	15.19	18.81	18.88
T ₂ [Green Bag]	10.61	12.06	14.48	17.6	19.73
T ₃ [Red Bag]	10.78	12.29	14.72	17.82	19.65
T ₄ [Brown Bag]	10.83	12.42	14.88	18.35	19.45
T ₅ [White Bag]	11.00	12.56	13.97	18.64	19.15
C.D. at 5%	0.18	0.22	0.24	0.38	0.37
SE(m)±	11.08	12.74	15.19	18.81	18.88

Acidity (%)

Fruit acidity generally declined during storage in all treatments, indicating progressive ripening and utilization of organic acids during respiration. The highest acidity at 0 day was recorded under T₂ (Green Bag) (1.53%), followed by T₃ (1.48%), T₄ (1.40%), T₅ (1.38%) and T₁ (1.32%). At 12 days, acidity decreased to 0.26% in T₂, while T₁, T₃, T₄ and

T₅ recorded 0.32, 0.27, 0.28 and 0.30%, respectively (Table 2). The decline in acidity may be associated with the utilization of organic acids as respiratory substrates during ripening. Similar decreases in titratable acidity during postharvest ripening have been documented in mango and other climacteric fruits. Similar findings have been reported by (Brecht *et al.*, 2009; Khatun *et al.*, 2024 and Runkua, 2016) [7, 13, 21].

Treatments	0 day	3 days	6 days	9 days	12 days
T ₁ [Control]	1.32	0.9	0.77	0.25	0.32
T ₂ [Green Bag]	1.53	1.1	0.95	0.52	0.26
T ₃ [Red Bag]	1.48	1.04	0.93	0.43	0.27
T ₄ [Brown Bag]	1.40	1.0	0.91	0.38	0.28
T ₅ [White Bag]	1.38	0.96	0.83	0.29	0.30
C.D. at 5%	1.32	0.9	0.77	0.25	0.32
SE(m)±	0.02	0.02	0.03	0.01	0.01

Ascorbic acid (mg/100 g)

Ascorbic acid content minimises progressively during storage in each treatment. The maximum initial data was recorded in T₂ (Green Bag) (93.30 mg 100 g⁻¹), followed by T₃ (92.22), T₄ (92.16), T₁ (88.92) and T₅ (90.26 mg 100 g⁻¹). At 12 days, T₂ retained the highest ascorbic acid content (30.28 mg 100 g⁻¹), whereas T₁ recorded the lowest value (27.22 mg 100 g⁻¹) (Table 3). The decline in ascorbic acid during storage may be attributed to oxidation of ascorbic acid and its utilization during metabolic processes. Better retention under green bagging may indicate comparatively slower physiological deterioration and oxidation. Similar retention of vitamin C in bagged fruits during storage has been reported by (Begum *et al.*, 2023; Singh *et al.*, 2005; Ali *et al.*, 2021) [5, 24, 3].

Treatments	0 day	3 days	6 days	9 days	12 days
T ₁ [Control]	88.92	69.83	56.41	39.48	27.22
T ₂ [Green Bag]	93.3	74.24	59.56	41.55	30.28
T ₃ [Red Bag]	92.22	73.15	58.78	41.34	29.67
T ₄ [Brown Bag]	92.16	72.72	57.86	40.72	29.06
T ₅ [White Bag]	90.26	72.59	56.75	40.31	28.04
C.D. at 5%	1.53	1.34	1.14	1.02	0.52
SE(m)±	0.49	0.43	0.37	0.33	0.17

Total sugar (%)

Total sugar content increased progressively during storage up to 9 days in all treatments, followed by a slight decline in T₁, T₃, T₄ and T₅ at 12 days, whereas T₂ continued to increase. At 0 day, total sugar ranged from 5.53% in T₂ to 5.98% in T₁. At 12 days, the highest value was recorded in T₂ (16.52%), followed by T₃ (16.32%), T₄ (16.16%), T₅ (15.45%) and T₁ (15.22%) (Table 4). The increase in total sugars may be attributed to conversion of starch and other complex carbohydrates into soluble sugars during ripening. The subsequent decline in some treatments at 12 days may indicate utilization of sugars as respiratory substrates at advanced storage stages. Similar changes in sugars accompanying fruit ripening have been reported in postharvest fruits. (Ali *et al.*, 2021; Yashoda *et al.*, 2006; Hussain *et al.*, 2024 and Begum *et al.*, 2023) [3, 29, 12, 5].

Treatments	0 day	3 days	6 days	9 days	12 days
T ₁ [Control]	5.98	8.92	12.17	15.93	15.22
T ₂ [Green Bag]	5.53	8.29	11.54	14.66	16.52
T ₃ [Red Bag]	5.70	8.60	11.74	15.37	16.32
T ₄ [Brown Bag]	5.83	8.71	11.93	15.53	16.16
T ₅ [White Bag]	5.89	8.7	12.03	15.76	15.45
C.D. at 5%	0.09	0.14	0.26	0.44	0.39
SE(m)±	0.03	0.05	0.08	0.14	0.13

Reducing sugar (%)

Reducing sugar content increased progressively with storage duration in all treatments. At 0 day, the values ranged from 1.18% in T₂ to 1.60% in T₁ while at 12 days the maximum reducing sugar was recorded in T₁ (7.93%), followed by T₅ (7.73%), T₄ (7.63%), T₃ (7.11%) and T₂ (6.81%) (Table 5). The increase in reducing sugars during storage may be attributed to hydrolysis of starch and other polysaccharides into simpler sugars during ripening. The comparatively lower accumulation under green bagging may suggest slower carbohydrate hydrolysis and delayed ripening compared with the control. Similar biochemical changes, including changes in soluble sugars during fruit ripening, have been reported during postharvest storage (Yu *et al.*, 2022; Khatun *et al.*, 2024 and Wu *et al.*, 2013) [30, 13, 28].

Treatments	0 day	3 days	6 days	9 days	12 days
T ₁ [Control]	1.6	3.85	6.43	7.44	7.93
T ₂ [Green Bag]	1.18	3.4	5.91	6.67	6.81
T ₃ [Red Bag]	1.28	3.54	6.04	6.71	7.11
T ₄ [Brown Bag]	1.36	3.65	6.14	6.71	7.63
T ₅ [White Bag]	1.48	3.74	6.35	7.31	7.73
C.D. at 5%	0.04	0.11	0.13	0.16	0.15
SE(m)±	0.01	0.04	0.04	0.05	0.05

Conclusion

The present study revealed that pre-harvest fruit bagging positively influenced the postharvest quality and storage behaviour of mango fruits. During storage, fruit weight, volume and firmness decreased, while physiological loss in weight increased. Among the treatments, green bagging (T₂) performed best, maintaining maximum fruit weight, volume, firmness, TSS and total sugars, with the lowest physiological loss in weight at 12 days. Overall, green bagging was the most effective treatment for reducing postharvest deterioration, maintaining fruit quality and improving storage life up to 12 days.

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