



RESEARCH ARTICLE

Effect of packaging materials on shelf-life and quality attributes of strawberry [*Fragaria × ananassa* (Duchesne ex Weston) Duchesne ex Rozier] under ambient storage

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Abstract

Strawberry (*Fragaria × ananassa* (Duchesne ex Weston) Duchesne ex Rozier) is a highly perishable non-climacteric fruit harvested at full ripeness, making postharvest management critical. Its high respiration rate and soft texture lead to rapid postharvest deterioration and a limited shelf life. They also experience high postharvest losses due to water loss, fungal growth, mechanical damage and physiological decline. This study evaluated the effectiveness of various packing materials in maintaining strawberry quality and extending shelf life. Strawberry fruits were packaged in punnets, cardboard boxes, paper bags, aluminium foil, biaxially oriented polypropylene (BOPP) covers and polyethylene zip-lock bags. Samples were stored at 19 ± 1 °C and 60 ± 5 % relative humidity under ambient conditions. Following packing, observations were made at 0, 2 and 4 days. Polyethylene terephthalate (PET) punnets showed superior performance by minimising physiological weight loss and preserving firmness, while maintaining key quality attributes including total soluble sugars, sugars, vitamin C, phenolics, flavonoids, anthocyanins, antioxidant activity, titratable acidity (TA) and pH. Compared to the unpacked control, PET punnets were the most effective packaging system for preserving postharvest quality under ambient conditions.

Keywords: biaxially oriented polypropylene; packaging materials; polyethylene terephthalate punnet; polyethylene bags; postharvest quality; strawberry

Introduction

Strawberry (*Fragaria × ananassa* (Duchesne ex Weston) Duchesne ex Rozier) is widely consumed, a soft fruit valued for its characteristic colour, flavour, texture and high contents of vitamins, phenolics and antioxidants (1). It is consumed both fresh and processed in products such as juices, desserts, dairy formulations and preserves (2). Strawberry cultivation has expanded globally due to increasing consumer demand and advances in production practices (3). According to Food and Agriculture Organization (FAO), global production has reached approximately 9.3 million tonnes, including China, US, Mexico, Turkey and Egypt (4). In India, strawberry cultivation is expanding in temperate and subtropical regions such as Maharashtra, Himachal Pradesh and Jammu and Kashmir. India produced approximately 23000 metric tonnes over an area of 1200 hectares (5).

A major challenge in strawberry production is its perishability, resulting in significant postharvest losses. Due to the high respiration rate, soft skin and susceptibility to microbial infection, strawberries have a very short shelf life of only 2–5 days under ambient conditions (6). As per the Indian Council of Agricultural Research (ICAR) and other postharvest research, strawberry cultivation globally experiences 30 % to 40 % postharvest losses annually and 35–45 % in India, depending on supply chain

efficiency and storage conditions. These losses can be due to improper packaging, inadequate cold chain infrastructure, improper handling and microbial spoilage. Such losses have major economic ramifications, disturbing supply chain participants and producers alike (7).

To address these issues and extend shelf life, demand for scientifically developed packaging materials is increasing daily. Packaging acts as a barrier to moisture loss, microbial attack and mechanical damage, thereby maintaining fruit quality. Nowadays, biodegradable films, nanocomposite-based packaging and modified atmosphere packaging (MAP) are widely used to preserve freshness, reduce respiration rates and maintain nutritional and sensory attributes. However, comparative evaluation of commonly used packaging materials under ambient storage conditions remains limited (8). Despite advancements in packaging technologies, limited studies have systematically compared commonly used packaging materials under ambient storage conditions for strawberries. Moreover, integrated evaluations of key quality attributes and short-term shelf-life performance remain insufficient, particularly under practical supply chain conditions.

This study aims to investigate the effect of various types of packaging materials (i) to standardise the best packaging material, (ii) to study the effect of different packaging materials on

physiological parameters and (iii) to study the effect of different packaging materials on qualitative parameters.

This study evaluates widely available packaging materials under ambient storage conditions, making the findings more applicable to routine handling and small-scale farming systems than those of previous researchers, who investigated advanced bio-nanocomposite packaging under modified atmosphere conditions (9). The study focuses on short-term storage responses of freshly harvested strawberries, linking packaging type with physicochemical quality changes under practical market conditions in Punjab, India.

Materials and Methods

The present investigation was conducted at the post-harvest laboratory of the Department of Horticulture, Lovely Professional University, Punjab, during the year 2022–23. Fresh, uniform and disease-free strawberry fruits at full ripeness were harvested in February. The experimental fruits were procured from consistently healthy plants chosen from the Ludhiana farm. Fruits were purchased in a transparent punnet and transported to the laboratory to prevent loss of fruit quality. The experiment consisted of 7 treatments: T1 (Paper bags), T2 (polyethylene ziplock bags), T3 (biaxially oriented polypropylene (BOPP) film bags), T4 (Punnets), T5 (Aluminium foil), T6 (Cardboard boxes) and T7 (unpacked control). Freshly harvested fruits were used to analyse the zero data observations. Periodically, fruit samples were removed from the lab and tested for various physicochemical properties at 0, 2 and 4 days after packing. Three replications were taken to assess various physical and biochemical assays under study.

Physiological parameter

Moisture content (%) was determined using the Association of Official Analytical Chemists (AOAC) method (10, 11). Length is measured from the top of the fruit to the bottom of the fruit with the help of a vernier calliper, according to Sicari et al. (12). Girth was measured from side to side at the thickest part of the fruit with the help of a Vernier calliper (12). Firmness is measured using a penetrometer, which determines the maximum penetration force (N) required to break tissue with a 5 mm-diameter flat probe (13).

Biochemical parameters

Total soluble solids (TSS, °Brix) of the fruit is measured with the help of a refractometer suggested by Adams et al. (14). Total sugar (%), reducing sugar (%) and non-reducing sugar (%) are obtained according to the AOAC method (10), as described by Food Safety and Standards Authority of India (FSSAI) (15). Vitamin C content [mg per 100 g fresh weight (FW)] was estimated using the metaphosphoric acid extraction method followed by spectrophotometric analysis at 750 nm (16).

The reaction mixture comprises 400 µL of strawberry liquid, 200 µL of 3 % metaphosphoric acid solution and 200 µL of diluted Folin's reagent (1 : 5, v/v), for a final volume of 2 mL. After a 10 min incubation, absorbance was measured at 750 nm using a UV-Vis spectrophotometer. The concentration of ascorbic acid was determined and expressed as mg of ascorbic acid (AA) per 100 g of FW (16). Titratable acidity (TA) (%) was determined according to the method described by AOAC (10) and Gindi et al. (17). Total flavonoid (mg per 100 g pulp) is obtained according to Kumar et al. (16), in which 10 g of fruit sample was ground with a pestle and mortar with

20 mL of 80 % ethanol. The homogenate was centrifuged at 10000 rpm for 20 min. Supernatant was taken for further analysis. For total flavonoid content (TFC), 1 mL of an aliquot was taken into a test tube. About 1.4 mL of distilled water was added to the test tube, to which 0.3 mL of sodium nitrite was added. After 5 min, 0.3 mL of aluminium chloride was added, after 1 min, 2 mL of sodium hydroxide was added and the volume was made up to 5 mL. Absorbance was recorded at 510 nm against a blank, then against the sample. Total antioxidant activity (%) was determined according to Singh et al. (18). Antioxidant activity was measured using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging method. An ultraviolet spectrophotometer (Cary 100 UV-Vis, Varian, MD) was used to measure absorbance at 517 nm. Total antioxidant activity was calculated as the percentage inhibition of the DPPH radical using the equation. The pH measurements were made by taking 20 g of homogenised pulp and mixing it with 80 mL of water. A pH meter was calibrated with a variable standard solution (19). Anthocyanin content (mg/L) was determined according to the method described by Swain and Hills (20). The experimental data were statistically analysed by a completely randomised design (CRD) (21). Analysis of variance (ANOVA) was conducted to assess significant differences among treatments at 5 % levels. The results were statistically analysed using the OPSTAT statistical software tool (Chaudhary Charan Singh Haryana Agricultural University website) (22, 23).

Results and Discussions

Physiological parameter

Table 1 presents the effects of different packaging materials on the physiological loss in weight of strawberry fruits. The data indicate that physiological loss in weight (PLW) increases with advancing days across all treatments. On the 2nd and 4th days after packaging, T4 shows the lowest PLW, followed by T2, whereas T7 shows the highest PLW. Similar results were observed by previous researchers in strawberry (16, 24), in robusta banana (14) and in litchi (25). Strawberries are a perishable crop due to their high respiration rate. So, packaging material changes the external environmental conditions optimal for strawberry fruits by lowering O₂ and increasing CO₂ (15), which, in turn, decreases the rates of respiration and transpiration. This helps to reduce PLW in the strawberry fruit. In unpackaged fruits, catabolic activity is high due to increased transpiration and respiration, leading to greater loss of physiological weight (24).

Table 1 shows the effect of different packaging materials on strawberry fruit length. The data indicate the significant differences among treatments. On the 2nd and 4th days after packaging, treatment T4 recorded the highest fruit length, followed by T3, whereas the lowest fruit length was observed in treatment T7 (unpacked fruits). A similar pattern has been reported previously in strawberry (26). The reduction in fruit length is due to shrinkage. Fruit kept in the punnet boxes (perforated) shows minimal shrinkage because of adequate ventilation and moisture control, which in return control the respiration rate of perishable fruit (27).

Table 1 presents the effects of different packaging materials on the breadth of strawberry fruits at room temperature. The data shows significant variation among the treatments. On the 2nd and 4th days after packaging, T4 shows minimum loss in breadth, followed by T3, as compared to the unpackaged fruits (T7), which shows

Table 1. Effect of post-harvest treatment on physiological loss in weight, fruit length, fruit breadth and firmness of strawberry at different storage days intervals

Treatments	PLW (%)			Fruit length (cm)			Fruit breadth (cm)			Firmness (N)		
	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th
T ₁ : Paper bags	0.00	24.20	61.33	4.82	4.40	3.92	3.82	3.67	3.30	4.8	4.6	4.4
T ₂ : Polyethylene	0.00	22.60	59.07	4.84	4.44	4.02	3.64	3.57	3.45	5.0	4.8	4.6
T ₃ : BOPP	0.00	25.10	61.47	4.83	4.46	4.10	3.51	3.43	3.25	3.8	3.7	3.5
T ₄ : PET punnet	0.00	16.50	47.13	4.88	4.68	4.37	2.84	2.72	2.67	4.2	4.1	4.0
T ₅ : Aluminium foil	0.00	24.80	62.60	4.81	4.42	4.04	3.73	3.57	2.37	2.3	2.0	1.8
T ₆ : Cardboard	0.00	23.30	61.80	4.87	4.38	3.74	3.75	3.58	3.38	2.0	1.7	1.5
T ₇ : Control	0.00	29.20	72.77	4.81	4.34	3.68	3.17	2.88	2.54	3.8	3.4	3.1
C.D.($p \leq 0.05$)	N/A	1.228	2.113	N/A	0.186	0.179	0.177	0.124	0.134	0.168	0.128	0.154
SE(m)	0	0.401	0.690	0.063	0.061	0.058	0.058	0.041	0.044	0.055	0.042	0.071

PLW: physiological loss in weight; BOPP: biaxially oriented polypropylene; PET: polyethylene terephthalate; N: newton; CD: critical difference at the 5 % level of significance; SE(m): standard error of the mean; N/A: not applicable.

maximum loss in breadth of the strawberry fruits. Similar results were reported by previous researchers in strawberry (26) and in orange (12). The respiration rate of fruits present in the perforated punnet boxes is less compared to the unpacked fruits, because the shrinkage is also less in the punnet. As a result, the breadth of the fruits present in the boxes is less reduced (27).

Firmness of strawberry fruits was significantly influenced by the packaging materials during ambient storage (Table 1). At the time of packaging, T₂ shows the highest firmness, followed by T₁, T₄, T₃ and T₇, while T₅ and T₆ show the lowest firmness. The 2nd and 4th days after packaging, T₄ maintains highest firmness followed by T₃ whereas the lowest firmness was observed in T₇ (unpacked fruits). Similar results were observed previously in kiwi fruit (12) and in okra (14). The biochemical processes in the cell wall involve the hydrolysis of starch and pectin. During fruit ripening after fruit harvest, an increase in pectin esterase and polygalacturonate occurs due to depolymerisation. As a result, fruit softening occurs, which can be somewhat prevented by packaging strawberries in perforated punnet boxes (17).

Biochemical parameter

The effect of different packaging materials on the TSS (°Brix) of the fruits is presented in Table 2. Significant differences among treatments are evident under ambient storage conditions. On the day of packaging, T₆ shows the highest TSS, followed by T₁, T₇ and T₂, whereas T₃, T₄ and T₅ show the lowest TSS. On the 2nd and 4th days after packaging, T₄ shows the highest TSS content, followed by T₂, whereas T₇ shows the lowest TSS content. Total soluble solids

increases up to the 2nd day after packaging and reduces on the 4th day after packaging. Similar results were reported in strawberry (24) and in banana (14). After harvesting, as ripening progresses the respiration rate also increases with moisture loss. There is a direct correlation between moisture loss and TSS content of the fruit as complex carbohydrates break down into soluble solids. Amylases, starch phosphorylase and 1,6-β-glucosidase enzymes together produce sucrose, fructose and glucose by breaking starch. When fruits are packed in perforated punnet boxes, respiration rate and TSS content are maintained (28).

Table 2 shows the effect of different packaging materials on the TA (%) of strawberry fruits, with significant variation among treatments. As the day progresses, TA decreases. On the day of packaging, T₄ shows the maximum TA, while T₁ shows the minimum TA. On the 2nd and 4th days after packaging, T₄ shows the highest TA, followed by T₂, whereas unpacked fruits have the lowest TA. Similar results were observed in litchi (25). During ripening, the organic acids present in the strawberry fruits were absorbed by the higher respiration rate. The TA in the strawberry fruits is influenced by the organic acids present in the fruit. There is less reduction in organic acids in fruits packed in punnet boxes (24, 29, 30).

The effect of different packaging materials on the vitamin C content is presented in Table 2, which shows significant differences among the treatments. With increasing days, the vitamin C content of the strawberry fruits also decreases. On the day of packaging, T₄ shows the highest vitamin C content, followed by T₆, whereas T₇ shows the lowest. On the 2nd and 4th days after packaging, T₄ shows

Table 2. Effect of post-harvest treatment on total soluble solids, titratable acidity, Vitamin C content and total phenols of strawberry at different storage days intervals

Treatments	TSS (°Brix)			Titratable acidity (%)			Vitamin C (mg/100 g)			Total phenols (mg/100 g)		
	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th
T ₁ : Paper bags	5.95	6.74	6.36	1.43	0.95	0.53	34.53	30.30	22.23	181.37	96.84	64.28
T ₂ : Polyethylene	5.94	7.11	6.71	1.43	0.98	0.57	34.17	30.47	22.40	183.00	100.23	78.30
T ₃ : BOPP	5.93	6.85	6.43	1.43	0.90	0.54	34.23	29.80	22.60	184.90	98.61	69.42
T ₄ : PET punnet	5.95	7.26	6.76	1.45	1.00	0.59	34.97	32.97	25.90	182.87	105.44	86.31
T ₅ : Aluminium foil	5.93	6.91	6.49	1.43	0.90	0.54	33.20	29.07	21.50	183.60	97.23	63.25
T ₆ : Cardboard	5.96	6.86	6.24	1.43	0.90	0.55	34.60	29.37	21.27	182.40	95.12	62.17
T ₇ : Control	5.95	6.67	5.90	1.43	0.79	0.50	34.10	28.67	18.37	184.03	95.32	60.22
C.D.($p \leq 0.05$)	N/A	0.336	0.331	N/A	0.037	0.027	N/A	1.501	0.899	N/A	4.513	3.558
SE(m)	0.118	0.110	0.108	0.020	0.012	0.009	0.491	0.490	0.293	2.989	1.474	1.162

TSS: total soluble solids; BOPP: biaxially oriented polypropylene; PET: polyethylene terephthalate; CD: critical difference at the 5 % level of significance; SE(m): standard error of the mean; N/A: not applicable.

less loss in vitamin C content than T3, whereas T7 (unpacked fruits) shows greater loss. A similar result was observed in strawberry (16). In the storage of strawberry fruits, as the day progresses, enzymatic oxidation of ascorbic acid occurs due to the presence of more O₂ around the fruit surface and a higher rate of respiration. This is an irreversible process. In packaging materials, the respiration rate is lower, resulting in less ascorbic acid reduction (25, 22).

Significant differences in the total sugar, reducing sugar and non-reducing sugar contents of strawberry fruits were observed among the different packaging treatments (Table 3). As the day progresses, the sugar content increases up to the 2nd day after packaging but again reduces on the 4th day after packaging. On the day of packaging, T7 and T6 show the highest total sugar content, followed by T1, whereas T2, T3, T4 and T5 show the lowest total sugar content. Similar results were observed in tomatoes (31) and in custard apple (32). On the day of packaging, T4 shows the highest reducing sugar content, while T7 shows the lowest reducing sugar content among the strawberry fruits. On the 2nd and 4th days after packaging, T4 shows maximum reducing sugar content, followed by T2 as compared to the T7 which shows minimum reducing sugar content. Previous researchers reported similar results in Indian gooseberry (33). On the day of packaging, T6 and T7 show the highest non-reducing sugar content, while T3 shows the lowest. On the 2nd and 4th days after packaging, T4 shows the highest non-reducing sugar content, followed by T2, whereas T7 shows the lowest non-reducing sugar content in strawberry fruits. Similar results were also observed by previous researchers in Indian gooseberry (33). As the day progresses, the total sugar, reducing sugar and non-reducing sugar content of strawberry fruits also increase due to enzymatic conversion of starch to non-reducing sugar and of non-reducing sugar to reducing sugar. So, strawberry fruits packaged in perforated punnet boxes show higher total sugar, reducing sugar and non-reducing sugar content than unpacked fruits (33–36).

The effect of the different packaging materials on the total phenols, total flavonoids, total anthocyanins and total antioxidant activity of strawberry fruits is presented in Tables 2, 3 and 4. The table shows significant variations in the treatments of all the parameters. On the day of packaging, T1 shows the minimum total phenols content, followed by T6, as compared to T3, which shows the maximum total phenols content. On the 2nd and 4th days after packaging, T4 shows maximum total phenols content, followed by T2, as compared to T7 (unpacked fruits), which shows minimum total phenols content. Similar results were observed in strawberry, loquat and cherry (18, 37–39). On the day of packaging, T4 shows the

highest TFC, followed by T2, as compared to T6, which shows the lowest TFC of the fruits. On the 2nd and 4th days after packaging, T4 shows the highest TFC, followed by T2, whereas unpacked fruits show the lowest TFC. Similar results were observed by previous researchers in blueberries (40). On the day of packaging, T3 shows the highest total anthocyanin content, followed by T4, whereas T7 shows the lowest. On the 2nd and 4th days after packing, T4 shows the highest total anthocyanin content, followed by T2, whereas T7 shows the lowest. Similar results were reported in strawberry (41). On the day of packaging, T5 and T2 show the highest total antioxidant levels, followed by T1, whereas T4 and T6 show the lowest. On the 2nd and 4th days after packaging, T4 shows the highest total antioxidants, followed by T2, whereas T7 shows the lowest. Similar results were also observed by previous researchers in strawberry (18, 42).

During ripening, phenolic compounds are synthesised as secondary metabolites (34). Packaging materials reduce O₂ and increase CO₂ levels surrounding strawberry fruits, thereby restricting respiration and reducing polyphenol oxidase activity (37–39). The controlled-atmospheric conditions within the packaging material directly influenced the fruit's flavonoid content (40). Flavonoid aglycon attached with glycosides (flavanol or anthocyanin) decreases the oxidation activities of flavonoids. There is a direct correlation between antioxidant activity and total phenol and total anthocyanin content (43). The rate of respiration in packed strawberry fruits is lower due to less O₂ and more CO₂ presence in the perforated punnet, which causes less antioxidant and less anthocyanin and phenol reduction (18).

Data presented in Table 4 show the effect of different packaging materials on strawberry fruit pH, with significant differences among treatments. On the day of packaging, T3 shows the highest pH, while T2 and T7 have the lowest pH among the fruits. On the 2nd and 4th days after packaging, T4 shows the highest pH, followed by T2, whereas T7 shows the lowest pH. Similar results were reported in murtilla fruit (19). With respiration rate, CO₂ increases and the pH content of fruits also increases (19).

Across all measured parameters, polyethylene terephthalate (PET) punnets consistently outperformed other packaging materials by reducing physiological degradation and preserving biochemical quality. This can be attributed to the creation of a favourable microenvironment that limits moisture loss, regulates gas exchange and reduces metabolic activity. In contrast, unpacked fruits deteriorated rapidly due to uncontrolled respiration, moisture loss and oxidative stress.

Table 3. Effect of post-harvest treatment on total sugar, reducing sugar, non-reducing sugar and flavonoids of strawberry at different storage days intervals

Treatments	Total sugar (%)			Reducing sugar (%)			Non-reducing sugar (%)			Flavonoids (mg/100 g)		
	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th
T ₁ : Paper bags	4.52	5.64	5.29	2.25	2.90	2.63	2.12	2.53	2.36	147.31	81.25	70.22
T ₂ : Polyethylene	4.51	5.73	5.39	2.26	2.80	2.58	2.09	2.75	2.63	153.61	96.12	82.22
T ₃ : BOPP	4.51	5.67	5.21	2.26	2.78	2.54	2.08	2.67	2.37	145.75	88.22	74.11
T ₄ : PET punnet	4.51	5.86	5.44	2.27	2.66	2.48	2.10	2.98	2.73	161.25	102.44	88.78
T ₅ : Aluminium foil	4.51	5.63	5.10	2.26	2.81	2.60	2.12	2.65	2.21	144.83	85.45	72.14
T ₆ : Cardboard	4.53	5.66	5.20	2.23	2.80	2.58	2.13	2.67	2.32	144.57	78.22	66.54
T ₇ : Control	4.53	5.48	5.08	2.23	3.09	2.65	2.13	2.22	2.27	147.77	75.13	62.17
CD ($p \leq 0.05$)	N/A	0.141	0.204	N/A	0.158	0.100	N/A	0.116	0.096	5.490	4.534	4.016
SE(m)	0.061	0.046	0.067	0.040	0.052	0.033	0.028	0.038	0.031	1.792	1.481	1.311

BOPP: biaxially oriented polypropylene; CD: critical difference at the 5 % level of significance; SE(m): standard error of the mean; N/A: not applicable.

Table 4. Effect of post-harvest treatment on total antioxidant activity, anthocyanin content and pH of strawberry at different storage days intervals

Treatments	Total antioxidant activity (%)			Anthocyanin content (mg/100 g)			pH		
	Storage period (days)								
	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th	Day 0	Day 2 nd	Day 4 th
T ₁ : Paper bags	30.18	25.24	19.28	33.78	29.87	25.45	3.60	3.73	3.74
T ₂ : Polyethylene	30.31	26.89	20.04	33.61	30.89	27.72	3.61	3.80	3.87
T ₃ : BOPP	30.11	26.37	19.77	34.94	30.24	26.44	3.68	3.73	3.78
T ₄ : PET punnet	30.10	28.78	23.45	34.42	31.64	29.27	3.64	3.98	4.14
T ₅ : Aluminium foil	30.31	25.64	19.87	34.34	30.08	26.78	3.63	3.78	3.84
T ₆ : Cardboard	30.10	24.87	18.43	34.27	30.00	26.02	3.64	3.73	3.78
T ₇ : Control	30.13	24.11	18.02	31.50	26.78	21.00	3.61	3.65	3.67
CD (<i>p</i> ≤ 0.05)	N/A	1.319	1.028	1.256	1.688	1.139	N/A	0.150	0.137
SE(m)	0.371	0.431	0.336	0.410	0.551	0.372	0.053	0.049	0.045

BOPP: biaxially oriented polypropylene; PET: polyethylene terephthalate; CD: critical difference at the 5 % level of significance; SE(m): standard error of the mean; N/A: not applicable.

Conclusion

Strawberry fruits exhibited rapid postharvest deterioration under ambient conditions, limiting their marketable shelf life. Packaging materials reduce physiological damage during transportation and storage of fruits by protecting them from the surrounding environment. Among the tested treatments, polyethylene terephthalate (PET) punnets were the most effective packaging system for maintaining fruit quality compared to other materials and the unpackaged control. Storage in PET punnets effectively reduced physiological weight loss and preserved firmness, while maintaining key biochemical attributes, including total soluble solids (TSS), sugars, vitamin C, phenolics, flavonoids, anthocyanins, antioxidant activity, titratable acidity (TA) and pH over a storage period of up to 4 days. These findings support the adoption of PET punnets as a practical and cost-effective packaging solution for short-term storage and local marketing of strawberries under ambient conditions. Further research may explore integration with modified-atmosphere systems or biodegradable alternatives to enhance sustainability.

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Authors' contributions

RM planned the entire experimental design and guided ASV throughout the research. RM, B, NY, MT, SG and MN wrote the article. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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