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Yoganandi YC
Department of Farm Machinery and power Engineering, CAET, AAU, Godhra, Gujarat, India

Gupta P
Department of Farm Machinery and power Engineering, CAET, AAU, Godhra, Gujarat, India

Seth N
Department of Processing and Food Engineering, CAET, AAU, Godhra, Gujarat, India

Salunkhe RC
Department of Farm Machinery and power Engineering, CAET, AAU, Godhra, Gujarat, India

Dabhi KL
Department of Farm Machinery and power Engineering, CAET, AAU, Godhra, Gujarat, India

Rangpara DJ
KVK, AAU, Arnej, Gujarat, India

Godhani RS
Department of Farm Machinery and power Engineering, CAET, AAU, Godhra, Gujarat, India

Kumar N
Education Systems Management Division, ICAR-NAARM, Hyderabad, Telangana, India

Khokhar AN
Department of Statistics, BACA, AAU, Anand, Gujarat, India

Vyas V
Department of Processing and Food Engineering, CAET, AAU, Godhra, Gujarat, India

Corresponding Author:
Yoganandi YC
Department of Farm Machinery and power Engineering, CAET, AAU, Godhra, Gujarat, India

Evaluation of packaging materials for preserving post-harvest quality of spinach under ambient storage in middle Gujarat

Yoganandi YC, Gupta P, Seth N, Salunkhe RC, Dabhi KL, Rangpara DJ, Godhani RS, Kumar N, Khokhar AN and Vyas V

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Abstract
Spinach (*Spinacia oleracea* L.) is a highly perishable leafy vegetable that undergoes rapid post-harvest deterioration due to moisture loss and tissue senescence. This study evaluated the influence of different packaging materials on the storage stability of spinach under ambient conditions. Five treatments were considered: non-perforated low-density polyethylene (LDPE), non-perforated polypropylene (PP), perforated LDPE, perforated PP, and an unpackaged control. Fresh spinach samples (200 g) were stored for three days and analyzed for physiological loss in weight (PLW), dimensional shrinkage (leaf length and width), colour attributes (L*, a*, b*), and sensory quality. Significant differences ($p < 0.05$) were observed among treatments. The control exhibited the highest deterioration with PLW of 65.60%, shrinkage in length (54.12%) and width (64.94%), and lowest sensory scores. Perforated films moderately reduced losses but were less effective due to higher vapor exchange. Non-perforated LDPE was most effective, recording the lowest PLW (1.06%), minimal reductions in leaf length (11.94%) and width (10.11%), and superior sensory acceptability. Colour values declined over time across all treatments, although packaging type had no significant effect. The results demonstrate that non-perforated LDPE provides the most effective barrier properties for extending the short-term preserving post-harvest quality of spinach during ambient storage.

Keywords: Spinach, post-harvest quality, polypropylene, LDPE (low density polyethylene)

1. Introduction

India is the second largest producer of vegetables globally, after China. Spinach (*Spinacia oleracea* L.), belonging to the Chenopodiaceae family, is a commonly grown leafy green vegetable known by various regional names in India such as *palak*, *saag*, *Indian spinach*, and *desi palak*. It is believed to have originated in the Indo-Chinese region. The crops grown in this region fall under different agroclimatic classifications and include a wide variety of plant types such as leafy vegetables, bulbous crops, tubers, flowers, flower buds, and podded species, among others.

India holds the position of the second-largest producer of vegetables globally, following China. Among the diverse vegetable categories, green leafy vegetables play a particularly important role in Indian diets due to their high nutritional value and medicinal properties. Common leafy greens consumed across the country include spinach, mustard greens, coriander, fenugreek, amaranth, *Chenopodium album* (bathua), taro leaves, moringa, and purslane. These vegetables are recognized not only for their dietary benefits but also for their therapeutic potential and anti-aging properties (Gupta and Prakash, 2009) [1].

Spinach is especially notable among these crops for its popularity and nutritional profile. It is rich in essential vitamins such as the B-complex group (including niacin and folic acid), vitamin C (ascorbic acid), and a range of carotenoids such as ß-carotene, lutein, and zeaxanthin. It also offers essential minerals including iron, copper, phosphorus, zinc, and selenium, along with health-promoting phytochemicals like p-coumaric acid, flavonoids, apocynin and omega-3 fatty acids (Roughani and Miri, 2019) [3].

Major spinach producing states in India include Andhra Pradesh, Telangana, Kerala, Tamil Nadu, Uttar Pradesh, Karnataka, Maharashtra, West Bengal, and Gujarat. The primary states in India known for spinach cultivation are Tamil Nadu, Andhra Pradesh, Kerala, Uttar

Pradesh, Maharashtra, Karnataka, West Bengal, Telangana and Gujarat. Given its wide cultivation and high nutritional value, spinach holds significant economic and dietary importance in both rural and urban regions of the country.

Spinach possesses a wide range of medicinal properties that contribute to its reputation as a "superfood." The leafy portions of the plant act as a mild laxative and are known to offer various health benefits. These include aiding in cancer prevention, regulating blood sugar levels, supporting weight management, enhancing vision, reducing hypertension, and exhibiting anti-inflammatory effects. Furthermore, spinach is associated with strengthening the immune system, reducing the risk of cardiovascular diseases such as heart attacks and atherosclerosis, preventing anemia, promoting healthy skin, and combating the signs of aging.

2. Materials and Methods

2.1 Study Area

2.1.1 Location

The experiment was conducted at Department of Processing and Food Engineering Laboratory, College of Agricultural Engineering & Technology, AAU, Godhra, Gujarat, India. Located at 22°46' N latitude and 73°39' E longitude with an altitude of 143 meter above mean sea level.

2.1.2 Climate

The climate of area is subtropical and semi-arid type with an average rainfall of 900 mm and average pan evaporation of area 6.8 mm/day. May-2025 is hottest month with the mean temperature varying between 35 °C to 45 °C and RH % 45.90 to 61.50.

2.2 Materials

2.2.1 Spinach

The fresh spinach (*Spinacia oleracea* L.) procured from the local vegetable market of Godhra, Gujarat, India, and transported to the department of processing and food engineering laboratory of College of Agricultural Engineering and Technology, Anand Agricultural University. The variety was selected based on good quality and its availability of spinach in the commercial market due to higher yields and its preference in farming community.

Fig 1: Fresh spinach

2.2.2 Packaging material

2.2.2.1 Polypropylene (PP)

Polypropylene (PP) bag (38.5 × 25.5 cm) having procured from the local market of Godhra. Weight of one polypropylene material was 4.97 gm.

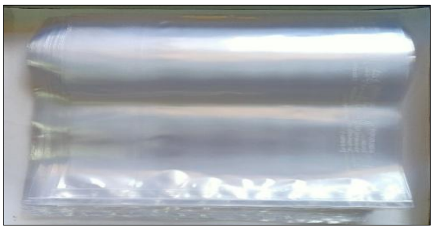

Fig 2: Polypropylene (PP) packaging bag

2.2.2.2 Low Density Polyethylene (LDPE)

Low Density Polyethylene (LDPE) bag (37 × 25.5 cm) size procured from the local market of Godhra.

This is a translucent, transparent materials having low water vapor transmission rate (WTR) Relatively high gas permeability and good chemical resistance. It's soft and flexible and its softening point is below the boiling point of water. Hence it's not possible to sterilize it under steam. It's a good moisture barrier but has sensitivity to oils and poor odor resistance. It's less expensive than most films and is therefore widely used, including applications in shrink or stretch wrapping.

Fig 3: Low Density Polyethylene packaging material

2.2.2.3 Perforated Packaging Material

The perforated (PP) packaging material made by ourselves with the help of punch in the Department of Processing and Food Engineering Laboratory. The perforation in both materials polypropylene (PP) and LDPE was assumed in 5% portion of allover area. The diameter of hole was 4mm for perforation. After the calculation of perforation percentage, we had find the number of hole according to perforation percentage. Number of hole in polypropylene (PP) material was 180, and number of hole in LDPE material was 192.

Fig 4: Perforated polypropylene (PP) material

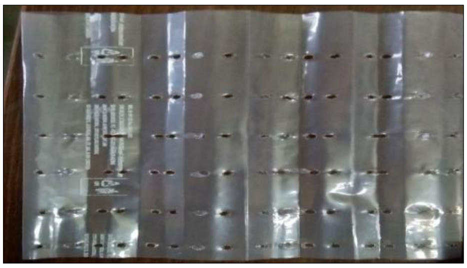

Fig 5: Perforated LDPE material

2.3 Experimental Details for Packaging and Storage of Fresh Spinach

The spinach packed in different packaging materials and kept in department of processing and food engineering laboratory for study post harvest quality. The average temperature and relative humidity were ranged 25 °C to 37 °C and RH 20 % to 72% respectively.

At first discarding the damaged and wilted leaves from fresh spinach and spinach leaves were selected for uniformity of colour and without any defects or mechanical injury and washed properly. For each treatment 200gm of spinach was packed on the basis of treatments and sealed tightly with a rope.For better post harvest quality study of spinach we were taken 3 samples of each treatment. And also marked 5 different leaves of spinach in each packaging sample to study colour change and shrinkage.

The Polypropylene (PP) and Low Density Polyethylene (LDPE) were used for packing of the fresh spinach storage with perforated and non-perforated and also kept at control condition. The weight of all the packaging samples was around 200gm.All samples were kept at ambient condition.

1. Packaging materials: Two different types of packaging material

a. P_1 - Polypropylene bag (PP)
b. P_2-Low Density Polyethylene (LDPE)

2. Packaging condition

a. T_1 - Non perforated packaging
b. T_2 – Perforated packaging
c. C – Control packaging

3. Treatments: 5

4. No. of replications: 3

Fig 6: Packaging treatment of non-perforated polypropylene (PP) packaging

Fig 7: Packaging treatment of non-perforated LDPE packaging

Fig 8: Packaging treatment of perforated LDPE packaging

Fig 9: Packaging treatment of control condition

2.4 Physical Analysis of Spinach

2.4.1 Physiological loss in weight (PLW)

For determining physiological loss in weight, sample was weighed accurately at zero days and subsequently on each 3 hours' interval period with the help of digital Weighing scale. The difference in weight was considered as PLW and percentages calculated using the formula (Koraddi *et al.* 2009).

$$\%\ \text{PLW} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

Fig 10: Weighing scale

2.4.2 Dimensions

The two major perpendicular dimensions of the spinach leaves were measured. The length and width were measured using scale. Length and width of 5 leaves were measured from each sample on each 3 hours' interval period.

Length: Maximum dimensions of the spinach leaf

Width: Maximum dimensions and perpendicular to the length of leaf.

Fig 11: Width measurement of spinach leaf

Fig 12: Length measurement of spinach leaf

2.4.3 Determination of Colour Value

The colour of the fresh spinach was measured in terms of l*, a* and b* values. All the colour measurements were done using a digital photoelectric colorimeter (M/S 3nh, China, and model-NH310) as shown in fig. 13. Instrument was calibrated using standard white tile as per procedure given in the reference manual. The fresh spinach was placed inside the sample cup. Following diagram is representing the CIELAB colour scale. The maximum value for l* is 100 which denotes towards whiteness and the minimum value is 0 which shows that product is dark in colour. Positive a* value denotes redness and negative value represents greenness. Positive b* value denotes yellowness and negative b* value represents blueness. Colour of fresh spinach was determined in three replications. Colour of 5 leaves were measured from each sample on each 24 hours' interval period.

Fig 13: Determination of colour value of spinach leaves

Results and Discussion

3.1Effect of Different Packaging Materials on Spinach

3.1.1 Effect of spinach on physical characteristics

3.1.1.1 Weight

Table 1 and Fig. 14 present the influence of different packaging materials on the weight loss of spinach stored at room temperature. The results revealed significant differences in weight loss percentages among the tested packaging types. The control (unpackaged) spinach exhibited the highest weight loss of 65.60%indicating rapid moisture loss due to direct exposure to ambient conditions. This substantial dehydration is typical for leafy vegetables stored without protective packaging, leading to wilting and quality deterioration. Perforated LDPE and Perforated PP resulted in weight losses of 42.98 and 39.64%**,** respectively. These high values suggest that while the packaging provided some physical protection, the presence of perforations allowed moisture to escape, reducing their effectiveness in preserving water content. In contrast, non-perforated LDPE significantly reduced weight loss to 1.06%**.** Those materials offered a moisture barrier, reducing dehydration and extending the post-harvest life of spinach. The slight difference between LDPE and PP may be attributed to their varying gas and vapor permeability, with LDPE generally having better sealing properties.

Table 1: Effect of packaging material on the total weight loss (%) of spinach

Material	Initial weight (g)	Final weight (g)	Total weight loss (%)
Perforated PP	200.62	121.09	39.64
PP	200.67	197.70	1.48
Perforated LDPE	200.50	114.33	42.98
LDPE	200.47	198.35	1.06
Control	200.77	69.07	65.60

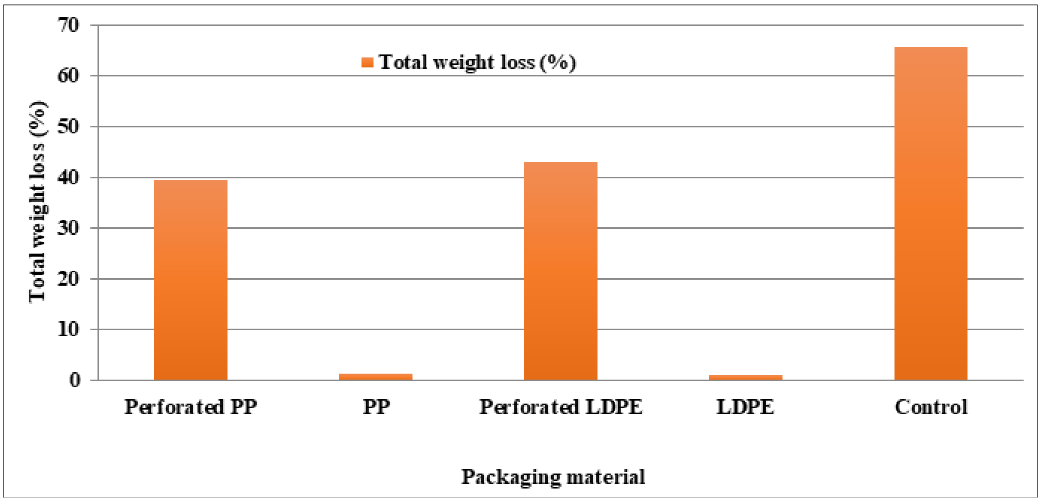

Fig 14: Effect of packaging material on the total weight loss (%) of spinach

It was observed from the ANOVA Table presented that decrease in weight over time is statistically significant at 5% level of significant. This indicates that storage duration has a pronounced effect on the weight loss of spinach. Furthermore, the analysis reveals that the type of packaging material used also has a significant impact on weight loss. The results confirm that different packaging materials influence the rate and extent of moisture loss and structural changes in the leaves. Additionally, the interaction between packaging material and time was also found to be statistically significant at 5% level of significant, suggesting that the effect of storage duration on weight loss varies depending on the type of packaging material used.

Table 2: Analysis of variance for weight loss

Source of Variation	DF	SS	MS	F-Cal.	SEm	Test
P	2	5660.58	2830.29	270.73	0.835	*
T	4	18598.02	4649.50	444.73	1.070	*
P * T	8	50046.36	6255.79	598.40	1.867	*
Error	30	313.62	10.45			
Total	44			CV %: 8.10		

3.1.1.2 Change in length

The effect of different packaging materials on the dimensional stability of spinach leaves was evaluated by measuring the percentage change in leaf length from initial to final stages under ambient storage conditions (Table 3). The results revealed a notable variation in shrinkage across the treatments. The control treatment (no packaging) exhibited the maximum reduction in leaf length (54.12%), indicating significant loss of moisture and structural integrity due to direct exposure to ambient conditions. Among the packaged treatments, both perforated PP and LDPE showed considerable shrinkage of 29.51 and 27.82%, respectively. This suggests that although perforation allows for better gaseous exchange and helps manage internal humidity, it may also facilitate moisture loss, contributing to higher leaf shrinkage. In contrast, non-perforated packaging materials, specifically PP and LDPE, exhibited significantly lower reductions in leaf length, at 17.19and 11.94%, respectively. This implies better moisture retention and protection from environmental desiccation. Overall, non-perforated LDPE was found to be the most effective in preserving leaf dimensions, minimizing shrinkage and maintaining post-harvest quality.

Table 3: Effect of packaging material on total length change of leaves of spinach

Material	Initial length(cm}	Final length(cm)	Change in length (%)
Perforated PP	14.23	10.03	29.51
PP	13.77	11.4	17.19
Perforated LDPE	15.93	11.5	27.82
LDPE	14.8	13.03	11.94
Control	14.17	6.5	54.12

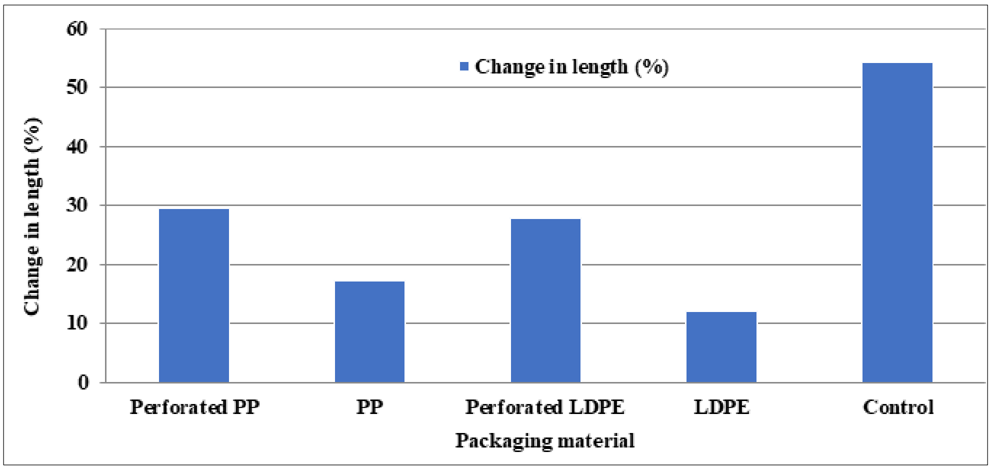

Fig 15: Effect of packaging material on the total length change of leaves of spinach

It can be observed from the ANOVA Table presented in the Appendix-E that the decrease in leaf length over time is statistically significant at ambient storage conditions. This indicates that storage duration has a pronounced effect on the shrinkage of spinach leaves. Furthermore, the analysis reveals that the type of packaging material used also has a significant impact on leaf length. The results confirm that different packaging materials influence the rate and extent of moisture loss and structural changes in the leaves. Additionally, the interaction between packaging material and time was found to be statistically significant, suggesting that the effect of storage duration on leaf length varies depending on the type of packaging material used.

Table 4: Analysis of variance for change in length of spinach leaves

Source of Variation	DF	SS	MS	F-Cal.	SEm	Test
P	2	4.488	2.444	38.546	0.062	*
T	4	10.719	2.680	46.025	0.080	*
P * T	8	53.076	6.635	113.951	0.139	*
Error	30	1.74	0.058			
Total	44		CV %: 9.49			

3.1.1.2 Change in Width

The effect of different packaging materials on the width of spinach leaves under ambient storage conditions is presented in Table 5 and illustrated in Fig. 16. The percentage reduction in leaf width was used as an indicator of the physical degradation and moisture loss occurring during storage. The highest reduction in width was observed in the control treatment, where leaf width decreased from 9.03 cm to 3.17 cm, corresponding to a 64.94% loss. This substantial shrinkage confirms the severe impact of unprotected ambient conditions on the structural integrity of spinach leaves.

Among the packaged treatments, Perforated LDPE and Perforated PP showed high reductions in leaf width, with values of 36.02 and 35.66%, respectively. These findings suggest that while perforated packaging may support internal atmosphere regulation through gas exchange, it also facilitates increased moisture evaporation, resulting in pronounced tissue shrinkage. In contrast, non-perforated PP and LDPE materials demonstrated better performance in preserving leaf width, with reductions of 20.25 and 10.11%, respectively. Notably, non-perforated LDPE was the most effective packaging material in minimizing width loss, indicating its superior ability to maintain internal humidity and reduce moisture stress on the leaves.

Table 5: Effect of packaging material on total widthchange of leaves of spinach

Material	Initial width(cm)	Final width (cm)	Change in width (%)
Perforated PP	9.07	5.83	35.66
PP	8.07	6.43	20.25
Perforated LDPE	8.7	5.57	36.02
LDPE	9.23	8.3	10.11
Control	9.03	3.17	64.94

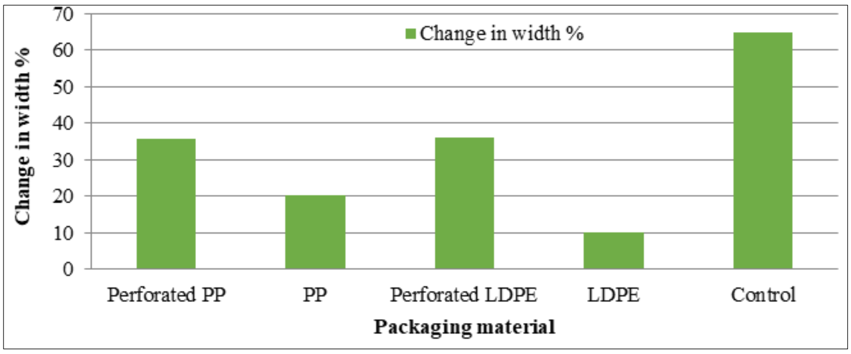

Fig 16: Effect of packaging material on the total width change of leaves of spinach

Table 6: Analysis of variance for change in width of spinach leaves

Source of Variation	DF	SS	MS	F-Cal.	SEm	Test
P	2	1.850	0.925	20.234	0.055	*
T	4	14.987	3.747	81.945	0.071	*
P * T	8	65.099	8.137	177.974	0.123	*
Error	30	1.372	0.046			
Total	44			CV % : 7.43		

It can be observed from the ANOVA Table 6 presented that the decrease in leaf width over time is statistically significant at ambient storage conditions. This indicates that storage duration has a pronounced effect on the shrinkage of spinach leaves. Furthermore, the analysis reveals that the type of packaging material used also has a significant impact on leaf width. The results confirm that different packaging materials influence the rate and extent of moisture loss and structural changes in the leaves.

3.1.1.3 Change in Colour

Colour L*

The variation in leaf colour lightness (L* value) of spinach under ambient storage conditions is presented in Table 7 and illustrated in Fig. 17 The L* value represents the lightness of the leaf surface, with higher values indicating brighter and fresher appearance. A consistent decline in L* values was observed across all treatments over the three-day storage period, indicating progressive leaf darkening and deterioration in visual quality.

Table 7: Total change in colour L* of leaves of spinach with time

Material	Initial colour L*	Final colour L*	Change in colour L* (%)
Perforated PP	41.8	36.77	12.03
PP	41.94	29.63	29.45
Perforated LDPE	41.16	30.58	25.31
LDPE	40.41	31.87	20.43
Control	41.23	29.01	29.23

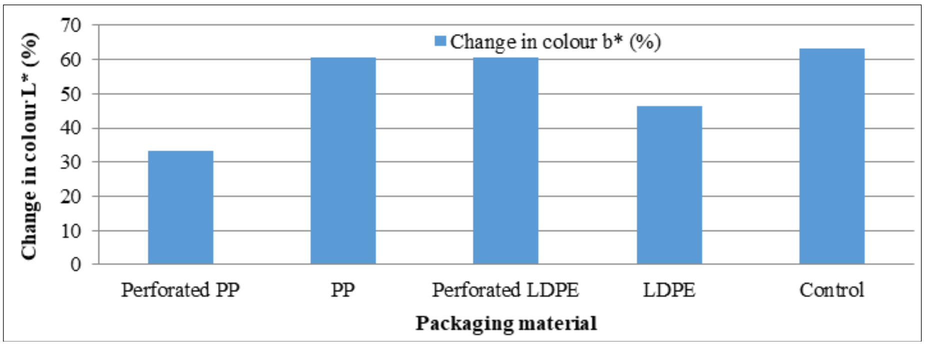

Fig 17: Total change in colour L* of leaves of spinach with time

Table 8: Analysis of variance for change in colour value L* of spinach leaves

Source of Variation	DF	SS	MS	F-Cal.	SEm	Test
P	2	769.892	384.946	3.320	1.207	
T	4	231.013	57.753	2.690	1.558	
P * T	8	129.033	16.129	2.270	2.699	
Error	30	655.389	21.846			
Total	44			CV %: 12.55		

According to the ANOVA Table 8 presented the effect of packaging material on the L* colour value of spinach leaves was found to be statistically non-significant. This indicates that, under ambient storage conditions, the type of packaging material used did not result in a significant difference in the lightness (L*) of the spinach leaves. Additionally, the interaction between packaging material and storage time was also not statistically significant, suggesting that the pattern of change in L* values over time remained relatively consistent across all packaging treatments. Therefore, while L* values decreased over time due to natural senescence and moisture loss, these changes were not strongly influenced by the type of packaging material or its interaction with storage duration.

4.2.4.2 Colour a*

The variation in the colour a* value of spinach leaves stored under ambient conditions is presented in Table 9 and illustrated in Fig. 18. The a* parameter reflects the position on the red-green axis, where negative values indicate greenness a key attribute of fresh leafy vegetables like spinach. A gradual increase in a* values (i.e., becoming less negative) was observed across all treatments over the storage period, signifying a progressive loss of green pigmentation and the onset of yellowing, typically associated with chlorophyll degradation and senescence with time.

Table 9: Total change in colour a*of leaves of spinach with time

Material	Initial colour a*	Final colour a*	Change in colour a* (%)
Perforated PP	-10.24	-6.61	35.45
PP	-9.75	-3.66	59.47
Perforated LDPE	-9.73	-4.12	54.79
LDPE	-9.62	-4.42	50.78
Control	-9.62	-4.42	50.78

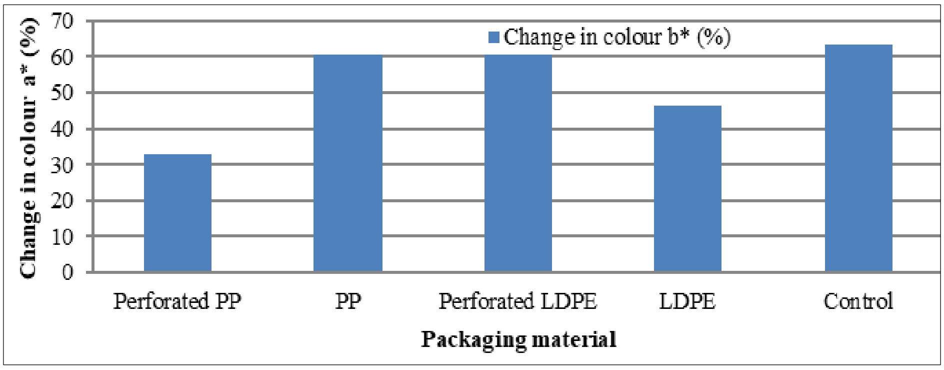

Fig 18: Total change in colour a* of leaves of spinach with time

Table 10: Analysis of variance for change in colour value a* of spinach leaves

Source of Variation	DF	SS	MS	F-Cal.	SEm	Test
P	4	205.737	102.869	47.735	0.379	*
T	2	18.423	4.606	2.137	.4890	NS
P * T	8	10.136	1.267	0.588	0.848	NS
Error	30	64.650	2.155			
Total	44			CV % : 19.56		

According to the ANOVA Table 10 presented in the Appendix-E, the effect of packaging material on the colour a* value of spinach leaves was found to be statistically non-significant. This suggests that, under ambient storage conditions, the type of packaging material did not cause a significant difference in the red-green colour component (a*) of the spinach leaves. Furthermore, the interaction between packaging material and storage time was also not statistically significant, indicating that the pattern of change in a* values over time was similar across all packaging treatments. These findings imply that while the colour a* values showed an increasing trend (less green) over time due to senescence, this change was not significantly influenced by the packaging material used or its interaction with the duration of storage.

4.2.4.3 Colour b*

The change in colour b* values of spinach leaves, which represent the yellow-blue spectrum (with positive values indicating increased yellowness), was monitored over three days of ambient storage and is presented in Table 11 and Fig. 19.

Table 11: Change in Colour b*of leaves of spinach with time

Material	Initial colour b*	Final colour b*	Change in colour b* (%)
Perforated PP	22.66	15.16	33.10
PP	22.91	9.18	60.59
Perforated LDPE	22.91	9.18	60.59
LDPE	22.19	11.67	46.43
Control	21.9	7.56	63.28

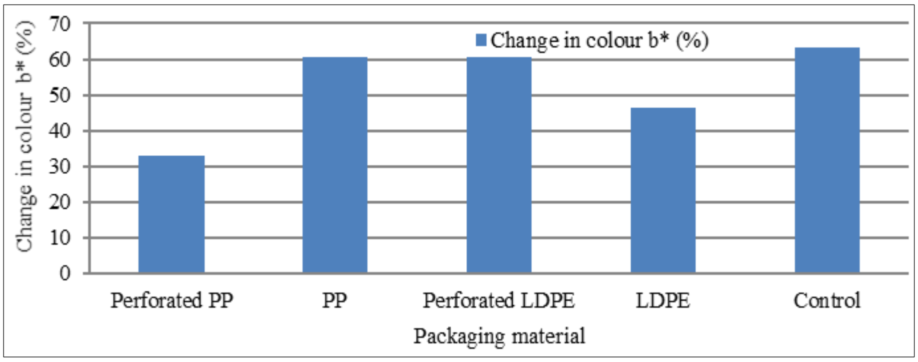

Fig 19: Total change in Colour b* of leaves of spinach with time

A general declining trend in b* values was observed across all treatments, indicating loss of yellowness and progressive colour deterioration over time, which typically reflects senescence and nutrient degradation in leafy vegetables.

Table 12: Analysis of variance for change in colour value b* of spinach leaves

Source of Variation	DF	SS	MS	F-Cal.	SEm	Test
P	4	1130.642	565.321	23.813	1.258	*
T	2	159.306	39.827	1.678	1.624	NS
P * T	8	86.115	10.764	0.453	2.813	NS
Error	30	712.202	23.740			
Total	44			CV % : 28.12		

According to the ANOVA Table 12 presented the effect of packaging material on the colour b* value of spinach leaves was found to be statistically non-significant. This indicates that, under ambient storage conditions, the type of packaging material used did not result in a significant difference in the yellow-blue colour component (b*) of the spinach leaves. Additionally, the interaction between packaging material and storage time was also found to be statistically non-significant, suggesting that the trend of change in b* values over time remained consistent across all packaging treatments. These findings imply that although b* values generally declined over the storage period reflecting a reduction in yellowness due to senescence and pigment loss this change was not significantly affected by the packaging material.

3.1.1.4 Sensory Evaluation of Packaging Study

Table 13 presents the average sensory evaluation scores of spinach leaves stored in different packaging materials on Day 1 (initial) and Day 3 (final). Among all packaging types, LDPE (non-perforated) maintained the highest quality over time, with minimal reduction in texture, colour, leaf quality, and overall acceptability. The control (unpacked) sample showed the lowest scores across all parameters, highlighting rapid deterioration without packaging. These results confirm that non-perforated LDPE is the most effective packaging material for preserving spinach quality during short-term storage.

Table 13: Average value of sensory evaluation of day 1 and day 3

Packaging material	Texture		Colour		Leaf quality		Overall acceptability	
	Initial value	Final value	Initial value	Final value	Initial value	Final value	Initial value	Final value
Perforated PP	7.83	3.67	8.0	3.83	8.0	3.67	7.83	3.67
PP	8.33	5.5	8.33	5.67	8.17	5.5	8.33	5.5
Perforated LDPE	8	4	8	3.67	8.17	3.83	8.17	4.0
LDPE	8.50	6.17	8.33	6.00	8.33	5.67	8.33	6.00
Control	6.33	2.00	6.17	2.00	6.17	2.00	6.17	2.00

Based on the comprehensive evaluation of packaging materials through parameters such as weight loss, change in leaf length and width, colour characteristics (L*, a*, b*), and result of visual sensory quality during ambient storage of spinach, non-perforated LDPE emerged as the best packaging material. It consistently minimized moisture loss, preserved leaf dimensions, and maintained visual quality better than other tested materials. Therefore, non-perforated LDPE was selected as the most suitable packaging material to be used during on field packaging.

4. Conclusions

The laboratory studies were conducted under ambient storage conditions over a three-day period to assess the effectiveness of five packaging treatments: non-perforated LDPE, non-perforated PP, perforated LDPE, perforated PP, and unpackaged control. The performance of these materials was evaluated based on critical post-harvest quality parameters including weight loss, shrinkage in leaf length and width, and changes in colour metrics (L*, a*, b*).

The study revealed significant differences in post-harvest quality parameters of spinach under various packaging treatments. The control group, which was exposed directly to the ambient environment, exhibited the highest weight loss (65.60%), along with the most severe shrinkage in leaf length (54.12%) and leaf width (64.94%). These results clearly indicate that the absence of packaging leads to rapid moisture loss and considerable physical deterioration of spinach leaves due to dehydration and loss of turgidity.

In contrast, the non-perforated LDPE packaging consistently outperformed all other treatments by maintaining the highest level of quality. It recorded the lowest weight loss (1.06%), and minimal reductions in leaf length (11.94%) and width (10.11%). These findings highlight the superior barrier properties of LDPE, which effectively reduced moisture loss and helped preserve the structural integrity of the leaves. Overall, non-perforated LDPE proved to be the most effective packaging material for maintain quality and retaining the post-harvest quality of spinach. These results aligned with those for leaf length, reaffirming that LDPE packaging can significantly delay the physical deterioration of spinach.

Non-perforated LDPE proved most effective in minimizing moisture loss, maintaining structural integrity, and preserving post-harvest quality of spinach during ambient storage.

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