Impact of silver and chlorine impregnated zeolite LDPE Packaging material on biochemical properties of pomegranate under ambient condition

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Received on 07 May 2024; received in revised form 01 October 2024, accepted 25 October 2024.

Abstract

Pomegranate is cultivated worldwide for its promising health benefits. The fruit exhibits non-climacteric characteristics in terms of respiratory behavior. However, the physiological and biochemical transformations pose significant challenges in handling, storing and marketing the fruits. The study was conducted at the Department of Postharvest Management, College of Horticulture, Bagalkot, aimed to identify an effective packaging material for prolonging the shelf life of pomegranate. Significant variations were noted among the different packaging materials concerning physiological and biochemical parameters. Among these, pomegranates packed in chlorine-zeolite-LDPE (CZ-LDPE) composite bags (50-micron thickness) in CFB box exhibited superior qualities in terms of TSS (16.16 °B), titratable acidity (0.33%), juice percentage (77.75%), and optimal color values (L*-39.02, a*-31.14, b*-21.10). Additionally, they experienced the lowest physiological loss in weight (PLW) at 24.06%, and a favorable TSS/acid ratio of 48.47 compared to the control (without any packaging) over a 25-day storage period under ambient conditions (31±1 ºC temperature and 36±1% relative humidity).

Keywords: Organoleptic ratings.

Introduction

The Pomegranate (*Punica granatum*) is a significant and resilient fruit crop that flourishes in tropical and subtropical regions, because of its recognized health benefits. Anthocyanin extracted from pomegranate can neutralize hydroxyl and superoxide radicals (Wang et al., 2010). The fruit's anti-atherosclerotic and anti-inflammatory properties offer potential benefits against various conditions such as arthritis, cancer, cardiovascular disease and HIV-1 (Su et al., 2010; Malik et al., 2005) The edible part is a rich source of polysaccharides, fatty acids, organic acids, total soluble solids, vitamins and essential minerals (Fadavi et al., 2006).

Post-harvest losses in pomegranates often result from inadequate packaging materials, mishandling during transportation and various disorders occurring during storage, whether short or long-term. In addition to external quality issues such as moisture loss, which can lead to husk scald (skin surface browning) and decay development, rapid moisture loss causing surface shriveling significantly impacts the fruit's post-harvest lifespan (Arendse et al., 2014). Therefore, mitigating moisture loss through appropriate packaging and regulation of optimum humidity and temperature

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can address these challenges (Montero-Calderon & Cerdas-Araya, 2012).

Prolonging the shelf life and preserving the quality of pomegranate is a significant challenge. One potential strategy to counteract fruit deterioration and senescence is to remove ethylene hormone or inhibit its effects. Enhancing packaging methods and incorporating anti-ethylene substances, such as zeolite, are becoming increasingly important in extending the shelf life of fruits.

Zeolite, a crystalline alumina silicate with a tri-tetrahedral nanoporous structure, characterized by spacious vacant areas capable of adsorbing large molecules like ethylene, water and ammonia (Khosravi et al., 2015). Utilizing Zeolite LDPE film integrated with chlorine and silver (antimicrobial compounds) offers numerous advantages. Therefore, this study aims to explore the effects of Zeolite LDPE (Z-LDPE) packaging materials infused with chlorine and silver on the physico-chemical properties and other quality parameters of pomegranate fruits.

Material and Methods

Production of Z- LDPE Composite Bags containing silver and chlorine

Z-LDPE bags were manufactured by blending finely powdered natural zeolite with commercial polyethylene. The zeolite and antibacterial substances were introduced into a solvent containing polyethylene beads. The polyethylene beads were dissolved in xylene solvent at the ratio of 1:10 and boiled at 75 °C for one hour with intermittent mixing to get a polyethylene-contained solution. To that solution add combined silver and zeolite powder, chlorine and zeolite powder, and the zeolite powder only, all at the ratio of 1:1 with polyethylene to get three different mixtures. The resulting mixture was poured into petri dishes to form a thin film, which was then dried in a hot air oven at 80°C until all xylene evaporated, leaving a thick, rigid film. The rigid film was cut into small rectangular strips measuring 20 mm x 50 mm. These small strips were kept between heat-stable, non-sticking papers and then hot pressed at 130°C for 5 minutes, resulting in the formation of sheets. These sheets were subsequently utilized in the production of bags by sealing their ends.

Pomegranate fruit

Pomegranate fruits (cultivar: Bhagwa) were harvested from a progressive farmer's field in Kaladagi (16º 12' 14.10" N, 75º 30' 0.00" E), Bagalkot district, Karnataka, India. These fruits were well-developed, exhibited a desirable appearance, were uniform in size and were devoid of any pest or disease infestations.

Packaging materials

In this study, three packaging materials were considered a) Zeolite LDPE covers are impregnated with chlorine and silver b) Corrugated fiberboard boxes and c) Normal polythene covers are used. The fibreboard box has eight circular holes on their sides of the boxes and on LDPE covers maintain one percent ventilation (by using a punching machine to create a hole in the LDPE bag with 1% out of the total area of the bag).

The fruits underwent precooling for approximately thirty minutes in a cool chamber, followed by washing with chlorine water at a concentration of 50 ppm. After air drying, the fruits were packed into various packages as follows: T_1 - Z-LDPE bag, T_2 - Silver + Z-LDPE bag, T_3 - Chlorine + Z-LDPE bag, T_4 - Z-LDPE bag + corrugated fiberboard box, T_5 - Silver + Z-LDPE + corrugated fiberboard box, T_6 - Chlorine + Z-LDPE + corrugated fiberboard box, T_7 - Only corrugated fiberboard box, and T_8 - Control. Subsequently, the packed fruits were stored under ambient conditions (The thickness of each LDPE bag was 50 microns and the dimensions of the CFB box was 30 cm L × 30 cm W× 29 cm D with 4 holes on each side of 2 cm diameter).

Physical, biochemical, and sensory Parameters

Various observations were recorded in pomegranate at every five-day interval and a single fruit was taken randomly for analysis with three replications.

Physiological weight loss (PLW %)

The PLW of pomegranate fruits was calculated by below mentioned formula

$$PLW\ (\%) = \frac{A - B}{A} \times 100$$

Where,

A- Initial weight

B- Final weight

Colour (L a* b*)*

The pomegranate fruit colour was assessed by a Hunter colorimeter (Model: Colour Flex® EZ Standard Box) equipped with an 8 mm diameter aperture. Pomegranate samples were positioned over the aperture of the colorimeter and three measurements were taken for each sample, with the values averaged for accuracy and the colour parameters were expressed in terms of *L*, a*, b** values.

Biochemical parameters

All biochemical parameters (Total soluble solids (ºB), Titratable acidity (%), TSS/Acid ratio and juice percentage) were determined following the standard procedure as described by Ranganna, 1986.

Sensory parameters

Sensory analysis of pomegranates was conducted by panel members comprising of teachers and postgraduate students from the College of Horticulture, Bagalkot. The panelists utilized a hedonic rating scale (9-point) to assess the colour and appearance of the fruit, mouthfeel of the arils, taste and flavour of the arils and the overall acceptability of the fruit.

Results and discussion

Physiological weight loss (PLW)

Table 1 displays information on the weight loss of pomegranate fruits affected by various packaging materials during storage at room temperature. The weight loss of pomegranates increased with the increase in storage period. However, significant differences were noted among treatments when compared to the control (T_8), indicating varying degrees of preservation efficacy. After 25 days lowest percentage of weight loss was observed in treatment T_6 (24.06%) *i.e.*, chlorine-zeolite-LDPE + corrugated fiberboard. Treatment T_5 (27.03%), which involved Silver + Zeolite-LDPE + CFB, demonstrated a comparable PLW. This outcome can be attributed to the polymeric films acting as a mechanical barrier, regulating water vapor movement and maintaining optimal moisture levels within the package. In contrast, the maximum PLW was observed in the control (T_8) *i.e.,* 35.53% because of the adverse effects of elevated temperatures and exposure to open conditions without any packaging barrier, leading to increased moisture loss. Similar findings and outcomes had been reported by previous studies on pomegranates (Mphahlele et al., 2016; Nanda et al., 2001).

Table 1: Effect of Z-LDPE packaging on the percentage of weight loss of pomegranate under ambient storage environment (31±1 ºC and 36±1% RH)

Treatments	Physiological loss in weight (%) Storage period (days)					Mean
	5	10	15	20	25	
T_1	6.24	12.58	20.02	25.78	30.91	19.11
T_2	6.44	11.02	19.14	25.07	29.93	18.32
T_3	5.82	10.15	17.97	24.47	29.01	17.48
T_4	5.21	9.71	15.67	21.84	28.12	16.11
T_5	5.09	9.07	13.06	20.44	27.03	14.94
T_6	4.32	8.37	11.45	19.97	24.06	13.63
T_7	10.42	18.45	25.06	30.00	33.97	23.58
T_8	12.50	24.12	28.96	33.01	35.53	26.82
S.Em±	0.31	0.50	1.05	0.70	0.77	
CD at 1%	1.27	3.58	7.53	5.03	5.49	

Initial value: 0 %

Total Soluble Solids (TSS)

Total soluble solids of the pomegranates exhibited a gradual increase until the 15th day, followed by a slight decline towards the end of the 25th day (Table 2) due to increase in metabolic activities during storage, such as the conversion of soluble sugars into organic acids (Bhatia et al., 2013).

Table 2. Effect of Z- LDPE packaging on total soluble solids (TSS) of pomegranate fruits under ambient storage environment (31±1 ºC and 36±1% RH)

Treatments	Total soluble solids (° Brix) Storage period (days)					Mean
	5	10	15	20	25	
T_1	15.25	15.40	15.52	15.60	15.59	15.43
T_2	15.28	15.37	15.46	15.56	15.54	15.41
T_3	15.25	15.38	15.49	15.63	15.61	15.43
T_4	15.29	15.41	15.51	15.66	15.63	15.46
T_5	15.27	15.40	15.53	15.94	15.80	15.53
T_6	15.37	15.46	15.76	16.17	16.16	15.69
T_7	15.49	15.64	15.71	15.67	15.54	15.56
T_8	15.63	15.71	15.76	15.63	15.52	15.58
S.Em±	0.10	0.09	0.09	0.08	0.11	
CD at 1%	N S	N S	N S	N S	N S	

Initial value:15.23° Brix

At the end of the storage period (25 DAS), the highest TSS was recorded in treatment T_6 (15.63°B), where Chlorine-zeolite-LDPE composite bags were used in conjunction with corrugated fiberboard (CFB). This was followed by treatments T_5 (15.80°B) and T_4 (15.94°B), among others. The rise in TSS during storage could be attributed to the increased concentration of organic solutes resulting from water loss (Ryall and Pentzer, 1974). Additionally, the increase in TSS might be due to various metabolic processes occurring in the fruit as it approaches senescence (Smith et al., 1979). Conversely, the lowest TSS was recorded in T_8, the control group (15.52°B). It is plausible that the control fruits utilized energy for respiration, as suggested by Nanda et al. (2001) and Laribi et al. (2012).

Titratable acidity

Table 3 presents data indicating the titratable acidity of pomegranate fruit, which was initially recorded at 0.43% and decreased over the storage period. A decrease in acidity with the advancement of storage duration. However, maximum titratable acidity after the storage period was observed in treatment T_6 (0.33%), followed by T_5 (0.32%) because of the effective adsorption capabilities of zeolites. Zeolites are recognized for their capacity to adsorb gases like oxygen, carbon dioxide, ethylene, and water vapors owing to their porous structure. This adsorption of gases by zeolites reduces respiration

Table 3. Effect of Z-LDPE packaging on titratable acidity of pomegranate fruits under ambient storage environment (31±1 ºC and 36±1% RH)

Treatments	Titratable acidity (%) Storage period (days)					Mean
	5	10	15	20	25	
T_1	0.42	0.38	0.34	0.30	0.28	0.36
T_2	0.42	0.38	0.34	0.31	0.28	0.36
T_3	0.41	0.39	0.34	0.31	0.29	0.36
T_4	0.41	0.39	0.35	0.33	0.31	0.37
T_5	0.42	0.40	0.36	0.35	0.32	0.38
T_6	0.43	0.42	0.39	0.36	0.33	0.39
T_7	0.41	0.36	0.32	0.29	0.27	0.35
T_8	0.39	0.34	0.30	0.27	0.25	0.33
S.Em±	0.01	0.01	0.01	0.01	0.01	
CD at 1%	N S	0.03	0.04	0.05	0.04	

Initial value: 0.44 %

and metabolic processes in fruits (Khosravi et al., 2015).

On the other hand, the minimum acidity was noticed in T_8 (0.25%), followed by T_7 (0.27%). Fruit acidity content notably decreased during the storage period, a phenomenon consistent with findings by other authors (Selcuk and Erkan, 2014).

TSS/Acid Ratio (%)

The ratio of TSS to acidity (TSS/Acid ratio) of pomegranate fruits was influenced by different packaging materials, as illustrated in Table 4. The ratio exhibited an interesting trend from the 5th to 25th day of storage and on the 25th day of storage, Treatment T_6, showed the lowest ratio (48.47),

Table 4. Effect of Z-LDPE packaging onTSS/ acid ratio of pomegranate fruits under ambient storage environment (31±1 ºC and 36±1% RH)

Treatments	TSS/Acid Ratio (%) Storage period (days)					Mean
	5	10	15	20	25	
T_1	36.32	40.48	46.32	52.87	56.47	44.55
T_2	36.80	40.34	45.33	51.04	54.46	43.69
T_3	37.06	39.89	45.96	50.32	53.79	43.76
T_4	37.13	39.96	44.30	47.80	50.15	42.36
T_5	35.93	38.24	42.74	46.23	49.54	41.26
T_6	35.48	37.18	40.91	45.19	48.47	40.35
T_7	37.70	43.00	48.51	54.17	57.27	45.91
T_8	39.75	45.99	52.90	58.50	60.61	48.77
S.Em±	0.86	0.61	1.32	2.0	1.84	
CD at 1%	NS	2.52	5.44	8.23	7.61	

Initial value: 34.85 %

Table 4. Effect of Z-LDPE packaging onjuice percentage of pomegranate fruits under ambient storage environment (31±1 ºC and 36±1% RH)

Treatments	Juice percentage (%) Storage period (days)					Mean
	5	10	15	20	25	
T_1	80.58	80.58	77.28	75.22	72.70	77.83
T_2	80.58	80.58	77.93	75.67	73.33	78.11
T_3	80.58	80.58	78.33	76.18	74.17	78.41
T_4	80.58	80.58	78.67	76.50	74.53	78.41
T_5	80.58	80.58	79.25	77.33	75.75	79.01
T_6	80.58	80.58	80.42	79.08	77.75	79.83
T_7	80.58	80.33	76.17	74.83	71.87	77.39
T_8	80.58	79.46	75.83	73.33	70.92	76.79
S.Em±	0.57	0.91	0.98	0.44	0.69	
CD at 1%	NS	NS	NS	3.15	2.85	

Initial value: 80.58 %

comparable to T_5 (49.54), T_4 (50.15), T_3 (53.79), and T_2 (54.46), indicating a balanced sweetness and acidity. In contrast, T_8 had the highest ratio (60.61), similar to T_7 (57.27), suggesting a sweeter taste profile. This rise in the TSS/acid ratio may be attributed to starch hydrolysis into sugars, as noted by Wills *et al.* (1989), and is consistent with findings on peach fruits by Ochel et al. (1993).

Juice percentage

Table 5 depicts how different packaging materials affect the fluctuations in juice content (%) of pomegranate fruits during storage. Up to the 15-day storage period, there were no variations in juice content among the treatments. However, at 25 DAS, the highest juice content was observed in treatment T_6 (77.75%), followed by T_5 (75.75%). The minimal moisture loss from the arils observed in these treatments can likely be attributed to the LDPE composite bags and CFB, which act as effective barriers against moisture loss from the fruits, thereby helping to maintain the juice content (Suparlan and Itoh, 2003). The lowest juice percentage was noticed in control *i.e.,* T_8 (70.92 %) followed by T_7 (71.87 %). This may be attributed to the absence of physical barriers in the form of packaging material, leading to higher physiological losses and hastened metabolic and biochemical activities which are the cause for higher losses.

Colour values (L a* b*)*

Fig.1 depicts *L*a*b** values of pomegranate fruit influenced by different packaging materials after 25 days of storage. The external peel colour exhibited a noticeable decrease in *L** values (indicating a shift from lightness to darkness) throughout the storage period. However, the *L** values decline in packaged fruits but are significantly less as compared to the control after 25 days of storage, suggesting better luminosity in

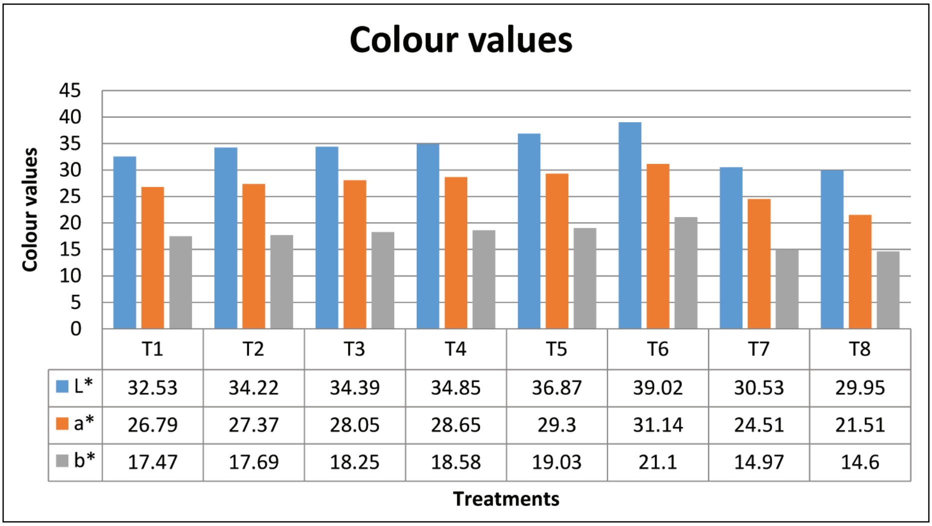


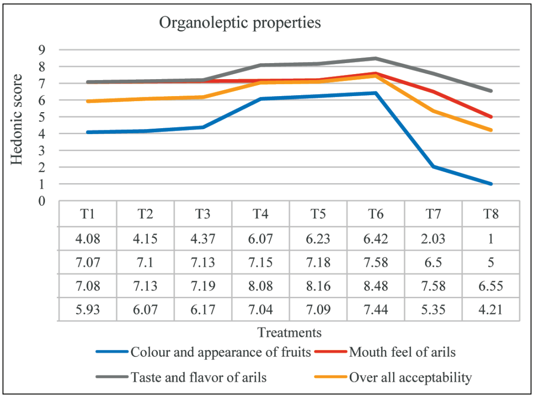
Figure 1. Effect of Z-LDPE packaging on colour values (L*a*b*) of pomegranate fruits at 25 DAS in ambient storage conditions (31±1 ºC and 36±1% RH)

packaged pomegranates. At 25 DAS, T_6 exhibited increased luminosity with L^* values of 39.02, followed by T_5 (36.87), while the minimum L^* value was noticed in the control fruits (T_8 - 29.95). Regarding the b^* value (representing blueness to yellowness), T_6 showed higher values (21.10) were on par with T_5 (19.03) and T_4 (18.58). The minimum was observed in control fruits (14.60) which was on par with T_7 (14.97). These findings align with those of Laribi *et al*. (2012) in pomegranates, who reported that fruits stored under modified atmosphere packaging (MAP) resulted in higher L^* values indicating less dark peel compared to those without any packaged fruits. Additionally, they suggested that the higher loss of peel luminosity in control fruits might be attributed to more fruit dehydration.

The instrumental changes in a^* value (indicating greenness to redness) of the fruit demonstrated a continuous decrease from 0 to 25 days after storage (DAS). At 25 DAS, treatment T_6 exhibited the highest a^* value (31.14), which was comparable to T_5 (29.30), T_4 (28.65), and T_3 (28.05). In contrast, the minimum a^* value was observed in the control fruits (T_8 - 21.51), followed by the fruits packed in only corrugated fiberboard (CFB) boxes (T_7 - 24.51). The higher a^* values in T_6 could be attributed to the Chlorine-zeolite LDPE composite bag maintaining an optimum gas composition of O_2 and CO_2, which prevents the loss of anthocyanin on the skin by creating a modified atmosphere and modified humidity. Conversely, high CO_2 and low O_2 levels may accelerate degradation or delay the biosynthesis of anthocyanin. Similar changes were observed in pomegranates by Miguel *et al*. (2004).

Sensory evaluation (9-point hedonic scale)

Fig. 2 presents the data on sensory evaluation concerning the colour and appearance of fruits, the mouthfeel of arils, the taste and flavour of arils, and the overall acceptability of pomegranate fruits influenced by various packaging materials after 25 days after storage (DAS). The organoleptic assessment was conducted at specified intervals



T1	T2	T3	T4	T5	T6	T7	T8
4.08	4.15	4.37	6.07	6.23	6.42	2.03	1
7.07	7.1	7.13	7.15	7.18	7.58	6.5	5
7.08	7.13	7.19	8.08	8.16	8.48	7.58	6.55
5.93	6.07	6.17	7.04	7.09	7.44	5.35	4.21

Figure 2. Effect of Z-LDPE packaging on sensory parameters of pomegranate fruits after 25 days of storage in ambient storage conditions (31±1 ºC and 36±1% RH)

using a hedonic scale. Results revealed that, during the storage period, the sensory scores for color and appearance were decreased with the storage period. At the 25 DAS, the highest score was given to T_6 (6.42), which was statistically comparable to treatment T_5 (6.23). The lowest score (1.00) was

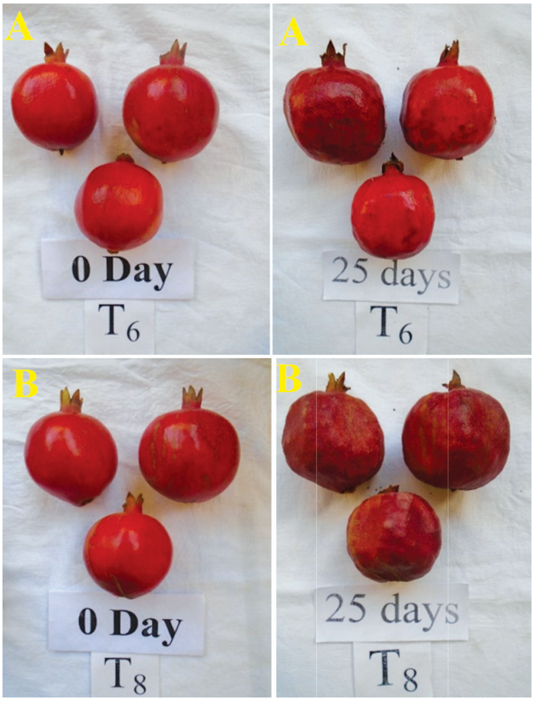


Plate 1: Comparison of pomegranate fruits placed in a chlorine-zeolite-LDPE bag along with CFB box (A) and Control (B) from 0 days to 25 days under ambient conditions (31±1 ºC and 36±1% RH)

recorded for the control (T_8), followed by treatment T_7 with a 2.03 score (Plate 1). The same trend was observed for mouthfeel, where treatment T_6 received the highest score (7.58), and the lowest score was for the control (5.00), followed by treatment T_7 (6.50). The overall acceptability and the taste and flavor of arils followed a similar trend. The highest score for taste and flavor of arils (8.48) and overall acceptability (7.44), was also observed for treatment, T_6, while the lowest score for taste and flavor of arils (6.55) and overall acceptability (4.21) was recorded for treatment, T_8.

The higher sensory scores observed in treatment T_6 was attributed due to the modified atmosphere created around the fruits, which is known to help in retaining TSS, acidity, and increasing the concentration of total volatiles and esters in fruits. Similar results, highlighting the advantage of using Modified Atmosphere Packaging (MAP) in maintaining overall quality and achieving the best visual and quality scores at the end of the storage period in pomegranate fruits, were earlier reported by Porat *et al*., 2009 and Bayram *et al*., 2009.

Conclusion

Based on the results, it is recommended to consider the use of antimicrobial compounds in zeolite-LDPE composite bags (50-micron thickness) along with corrugated fiberboard (CFB) boxes to significantly enhance the postharvest longevity of pomegranate fruits. This innovative packaging technology not only improves key attributes such as total soluble solids, acidity, juice percentage, color values, shelf life, and overall sensory quality but also reduces physiological weight loss, respiration rate, and the TSS/acid ratio. These findings underscore the potential economic viability of using antimicrobial compounds synergized zeolite-LDPE composite bags to extend the shelf life of pomegranates, providing a sustainable solution to enhance fruit quality and marketability in ambient conditions.

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