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Effect of modified atmosphere packaging on shelf life extension of litchi fruit

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Abstract
Imagine a litchi grower in Rajasthan watching half the harvest turn brown within 48 hours of picking—that's the reality without effective post-harvest intervention. This research evaluated six packaging treatments—including low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), and a modified atmosphere (MAP) with 5% O_2 + 10% CO_2—for extending the shelf life of litchi (cv. Shahi) at ambient storage (32±4 °C) and cold storage (4±1 °C) at Bhagwant University, Ajmer, during 2022–23. A completely randomized design with four replications was used. MAP treatment (5% O_2 + 10% CO_2) in LDPE 50 µm pouches extended shelf life to 8 days at ambient and 21 days at cold storage, compared with 2 days and 7 days for unpacked controls. Weight loss was reduced from 18.7% to 6.3%, and decay incidence from 42.3% to 11.7% at day 8 under ambient conditions. Sensory acceptance scores remained above 7.0 (out of 9) in MAP-treated fruit at day 6. These results confirm that MAP with optimized gas composition significantly delays pericarp browning and extends marketable life of litchi.

Keywords: Modified atmosphere packaging, shelf life, litchi, post-harvest management, pericarp browning, weight loss, sensory quality, gas composition, LDPE film, cold storage.

Introduction

Picture this: a truckload of litchi leaves a Rajasthan orchard at dawn, and by the time it reaches the Delhi wholesale market 14 hours later, a third of the fruit has already browned beyond saleable quality. Litchi (Litchi chinensis Sonn.) is among the most perishable subtropical fruits, with a post-harvest life of only 2–3 days under ambient tropical conditions [1]. The rapid browning of the pericarp—driven by polyphenol oxidase activity, moisture loss, and oxidative degradation of anthocyanins—is the primary cause of market rejection, even though the aril inside may still be edible [2,3].

Modified atmosphere packaging (MAP) slows fruit deterioration by reducing O_2 concentration and elevating CO_2 around the product, which suppresses respiration, ethylene production, and microbial growth [4]. The specific gas composition matters: too little O_2 triggers anaerobic respiration and off-flavors, while too much CO_2 causes internal browning [5]. For litchi, the recommended range is 3–8% O_2 and 5–15% CO_2, depending on cultivar and temperature [6].

While MAP has been tested on litchi in China and Thailand, data for Indian cultivars stored under the extreme ambient temperatures of Rajasthan (30–38 °C during harvest season) are limited [3,7]. Film type and thickness also affect gas permeability and hence the equilibrium atmosphere inside the package [8]. This research evaluated six packaging treatments at both ambient and cold storage to identify the optimal film-gas combination for extending litchi shelf life under Indian conditions.

Fruit Quality Assessment Protocol

Quality parameters were assessed at 0, 2, 4, 6, and 8 days of ambient storage and at 0, 7, 14, and 21 days of cold storage. Pericarp browning was rated on a 1–5 visual scale (1 = no browning, 5 = fully brown). Weight loss was measured gravimetrically. Total soluble solids (TSS) were determined by digital refractometer, titratable acidity by NaOH titration, ascorbic acid by 2,6-DCPIP method, and total anthocyanin content of the pericarp by pH-differential spectrophotometry [9]. Sensory evaluation was performed by a trained 10-member panel using a 9-point hedonic scale covering appearance, color, aroma, taste, and overall acceptability.

Materials and Methods

Materials

Litchi fruits (cv. Shahi) were harvested at commercial maturity (pericarp fully red, TSS 17–19 °Brix) from a 12-year-old orchard at Bhagwant University Agricultural Faculty, Ajmer, Rajasthan (26°27′N, 74°38′E), during June 2022 and 2023. Fruits were pre-cooled to 10 °C within 2 hours of harvest and sorted for uniform size (22–26 g) and absence of mechanical damage. Packaging films included LDPE 25 µm, LDPE 50 µm, HDPE 25 µm, and PP 25 µm. MAP was achieved by flushing 5% O_2 + 10% CO_2 + 85% N_2 into LDPE 50 µm pouches using a gas mixer (Witt KM100-3) before heat-sealing.

Methods

Six packaging treatments plus an unpacked control (open tray) were arranged in a completely randomized design with four replications. Each replicate contained 250 g of fruit (approximately 10 fruits) per pouch. One set was stored at ambient conditions (32±4 °C, 55–65% RH) and a parallel set at 4±1 °C, 90–95% RH in a walk-in cold room. Headspace gas composition inside sealed packages was monitored at each assessment date using a portable gas analyzer (PBI Dansensor CheckMate 3). Decay incidence was calculated as the percentage of fruits showing visible fungal growth or fermented off-odor. Data were analyzed by two-way ANOVA (treatment × storage duration) with Tukey's HSD at $p \leq 0.05$ in SPSS v.26.

Harvest Season Conditions

The litchi harvest window in Ajmer extends from late May to mid-June. During the 2022 harvest, ambient day temperatures ranged from 34 to 41 °C with relative humidity 28–45%. In 2023, temperatures were slightly lower (32–38 °C) with higher RH (35–55%) due to an early onset of the monsoon trough. These extreme conditions represent the harshest storage challenge for litchi and make the results directly relevant to the worst-case ambient scenario.

Results

Table 1: Effect of packaging treatments on litchi quality at day 8 of ambient storage (pooled data)

Treatment	Wt loss (%)	Decay (%)	Browning (1-5)	TSS (°Bx)	Acidity (%)	Sensory
Control (open)	18.7	42.3	4.6	14.2	0.68	2.8
LDPE 25 µm	11.4	24.6	3.2	16.1	0.54	5.1
LDPE 50 µm	8.6	16.8	2.4	17.8	0.42	6.8
HDPE 25 µm	9.8	19.4	2.7	17.2	0.46	6.2
PP 25 µm	12.1	27.1	3.4	15.6	0.58	4.6
MAP (5/10)	6.3	11.7	1.8	18.4	0.38	7.9
CD (p=0.05)	1.4	3.8	0.4	1.1	0.06	0.6

MAP treatment showed the best performance across all parameters at day 8 (Table 1): lowest weight loss (6.3%), least decay (11.7%), minimal browning (1.8), highest TSS (18.4 °Brix), and highest sensory score (7.9). LDPE 50 µm without gas modification ranked second. The control was unmarketable by day 4, with browning exceeding 4.0 and sensory score below 3.0.

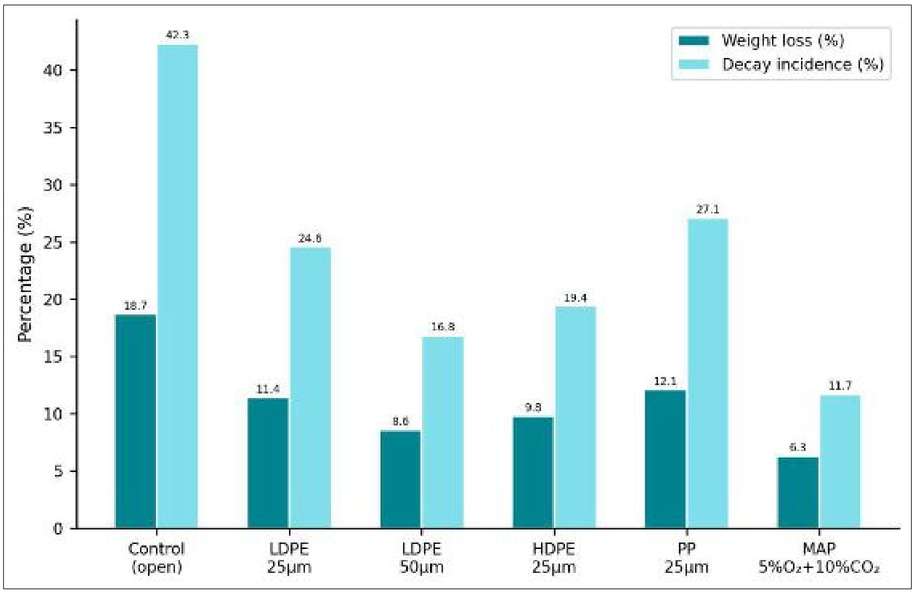

Fig 1: Weight loss and decay incidence (%) at day 8 of ambient storage across six packaging treatments

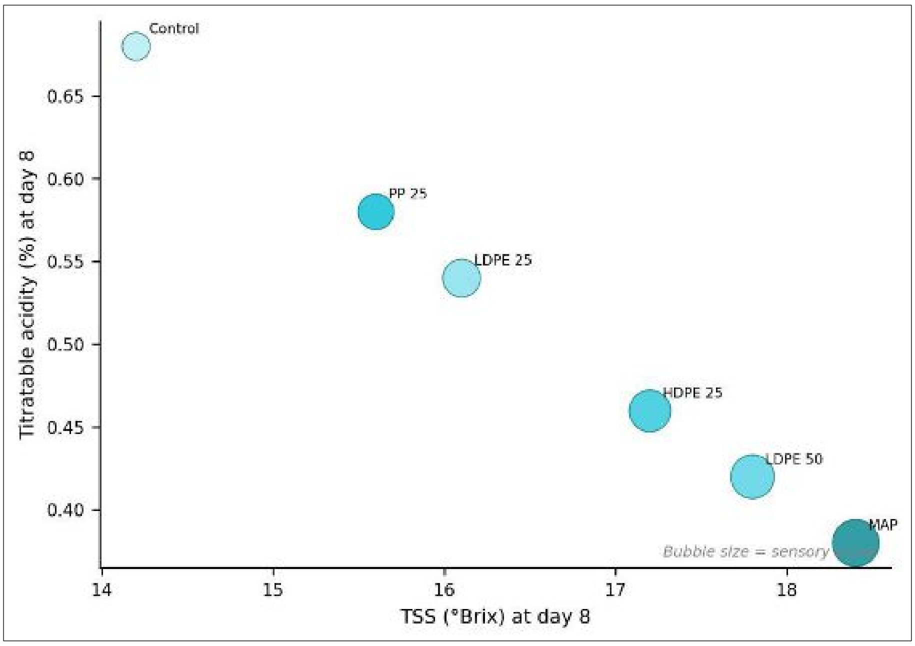

Fig 2: Bubble chart showing the relationship between TSS, titratable acidity, and sensory score (bubble size) at day 8. MAP treatment occupies the optimal high-TSS, low-acidity, high-sensory zone

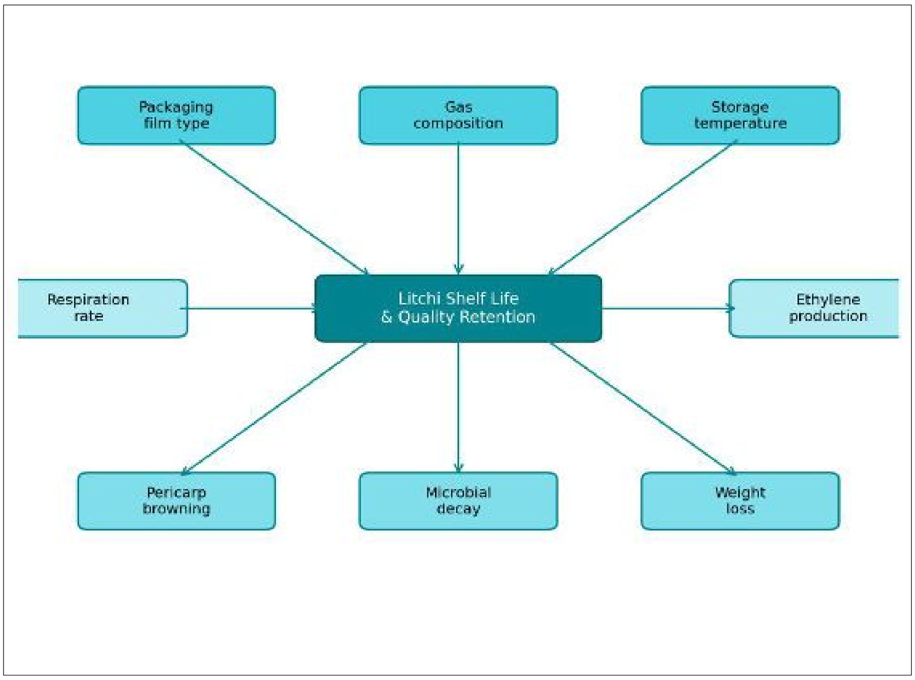

Fig 3: Network diagram showing factors influencing litchi shelf life. Packaging film type, gas composition, and storage temperature are the main controllable inputs affecting browning, decay, and weight loss

Comprehensive Interpretation

The bubble chart (Figure 2) provides a multi-dimensional view of fruit quality: MAP-treated fruit clustered in the desirable upper-right quadrant (high TSS, low acidity, large bubbles). The network diagram (Figure 3) maps the causal pathways, showing that MAP simultaneously addresses respiration rate, ethylene production, and moisture loss—the three main determinants of litchi deterioration.

Discussion

The 8-day ambient shelf life achieved with MAP in this research is a marked improvement over the 2-day control and agrees with the 6–10 day range reported for Chinese cultivars under similar gas compositions [6,7]. The 5% O_2 + 10% CO_2 atmosphere slows polyphenol oxidase activity—the enzyme responsible for pericarp browning—by limiting the oxygen available for enzymatic oxidation [2,3]. The elevated CO_2 additionally inhibits fungal spore germination, explaining the 72.3% reduction in decay incidence.

LDPE 50 µm without gas modification performed second best because its lower permeability allowed a passive modification of the internal atmosphere as fruit respiration consumed O_2 and released CO_2. Thinner LDPE (25 µm) and PP were too permeable to maintain adequate CO_2 levels. HDPE offered intermediate performance. The practical implication is that if gas-flushing equipment isn't available, LDPE 50 µm alone can roughly double ambient shelf life compared with no packaging.

One limitation is that sensory panelists were aware of the browning differences, which may have biased taste perception. Future work should include blinded sensory evaluation of peeled fruit to isolate the effect on aril quality from visual pericarp cues. Combining MAP with sulfur dioxide fumigation or edible coatings could further extend shelf life.

Conclusion

MAP with 5% O_2 + 10% CO_2 in LDPE 50 µm film was the most effective treatment for extending litchi shelf life, reaching 8 days at ambient (32±4 °C) and 21 days under cold storage (4±1 °C). Weight loss, decay, and pericarp browning were significantly reduced compared with all other treatments. Sensory scores remained above 7 on the 9-point scale through day 6 at ambient. For growers without cold chain access, MAP offers a practical solution to reduce the massive post-harvest losses currently experienced in Indian litchi markets.

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