

Effects of Postharvest Chemical Treatments and Modified Atmosphere Packaging on Litchi Quality and Shelf Life Under CoolBot Storage

Prativa Chhetri¹, Suvash Tiwari², Mira Dhakal³, C.P. Shriwastav⁴, Prachanda Chaudhary⁵, Kiran Chaulagain⁶

¹Agricultural and Forestry University, CNRM, Rolpa, Madichaur, Nepal.

²Institute of Agriculture and Animal science, Tribhuvan University, Khairahani, Chitwan, Nepal.

³National Horticulture Research Center, Khumaltar, Lalitpur, Nepal.

⁴Agricultural and Forestry University, Faculty of Agriculture, Rampur, Nepal.

⁵SRM Institute of Science and Technology, Chennai, India.

⁶G.P. Koirala Collage of Agriculture and Research Center, PU, Morang, Nepal.

*Corresponding Author: Prativa Chhetri

DOI: <https://doi.org/10.5281/zenodo.23086337>

Article History	Abstract
Original Research Article	<i>The litchi (Litchi chinensis Sonn.), which has a concise postharvest existence, may suffer from significant moisture loss, pericarp browning and microbial rot. This study targeted to evaluate the outcomes of combining chemical treatments with modified atmosphere packaging (MAP) and low-cost CoolBot containers on stretching the postharvest life of litchi. Potassium metabisulfite at 100 ppm was applied to the fruits, which were packaged in a perforated 50 µm LDPE MAP and held under low-humidity conditions (7.4–12°C and 85 ± 10% relative humidity). Physiological weight loss, firmness, titrable acidity, total soluble solids content, spoilage incidence, and shelf life were evaluated over 16 days. The treatment of potassium metabisulfite and MAP showed a notable decline in physiological weight loss (7.28%) and spoilage incidence (55.80%), a maintenance of firmness and TSS content, and an extension of shelf life to 16.41 days compared to control fruit, 12.21 days. Extension of shelf life was attributed to reduced respiration rates, increased humidity retention, and the antifungal activity of sulfite in a modified atmosphere. This combined potassium metabisulfite and MAP system offers a low-cost and practical alternative for managing the post-harvest handling of litchi by smallholder producers.</i> Keywords: Post-harvest, Potassium metabisulfite, Oxalic acid, TA.
Received: 02-08-2026	
Accepted: 07-09-2026	
Published: 01-10-2026	
Copyright © 2025 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited. Citation: Prativa Chhetri, Suvash Tiwari, Mira Dhakal, C.P. Shriwastav, Prachanda Chaudhary, & Kiran Chaulagain. (2026). Effect of postharvest chemical treatments and modified atmospheric packaging on postharvest quality and shelf life of litchi (Litchi chinensis) in CoolBot storage. UKR Journal of Agriculture and Veterinary Sciences, 2(4), 12-22.	

1. Introduction

Postharvest deterioration of fresh horticultural commodities is an important challenge for food security, farm income, and supply-chain efficiency. Losses occur through both quantitative and qualitative changes that reduce the edibility, nutritional value, visual quality, and marketability of produce. Previous reports have indicated substantial postharvest decline of fruits and vegetables in evolving countries, including Nepal (Bhattarai, 2018; Hailu & Derbew, 2015).

Litchi (*Litchi chinensis* Sonn.) is particularly susceptible to postharvest deterioration. Although the fruit is valued for its attractive red pericarp, nutritional properties, and commercial importance, its storage life is reduced by pericarp browning, water loss, and microbial rot (S. Ali et

al., 2016; Sivakumar & Korsten, 2006). Even relatively small losses of water can adversely affect browning and firmness, thereby reducing consumer acceptance (Pandit, 2007).

Cold storage is widely used to slow respiration and senescence and consequently delay postharvest deterioration. However, conventional cold-storage systems may be difficult for smallholder producers to access because of their cost and infrastructure requirements. CoolBot-assisted systems, which can operate with conventional air-conditioning units, have therefore been considered as a lower-cost alternative for small-scale cold storage (S. Kumar et al., 2019).

Modified atmosphere packaging (MAP) is another approach applied to delay deterioration during storage. By altering the gaseous environment surrounding the fruit, MAP can reduce oxygen availability, increase carbon dioxide concentration, retain moisture, and influence respiration and ripening processes (Cantín et al., 2008; Guilbert et al., 1996). The capability of MAP can be improved when it is combined with postharvest treatments that limit oxidative damage, browning, and microbial development.

Organic acids and sulfite-based compounds have been investigated as postharvest treatments for maintaining fruit quality. Oxalic acid has been associated with improved antioxidant activity, maintenance of membrane integrity, reduced enzymatic browning, and delayed ripening (Hazarika & Marak, 2022; Huang et al., 2013). Potassium metabisulfite is also used for its antimicrobial and anti-browning properties and may help suppress oxidative reactions and microbial development (Kasnazany et al., 2017).

Although the individual effects of MAP, chemical treatments, and cold storage have been studied, comparatively limited information is available on their

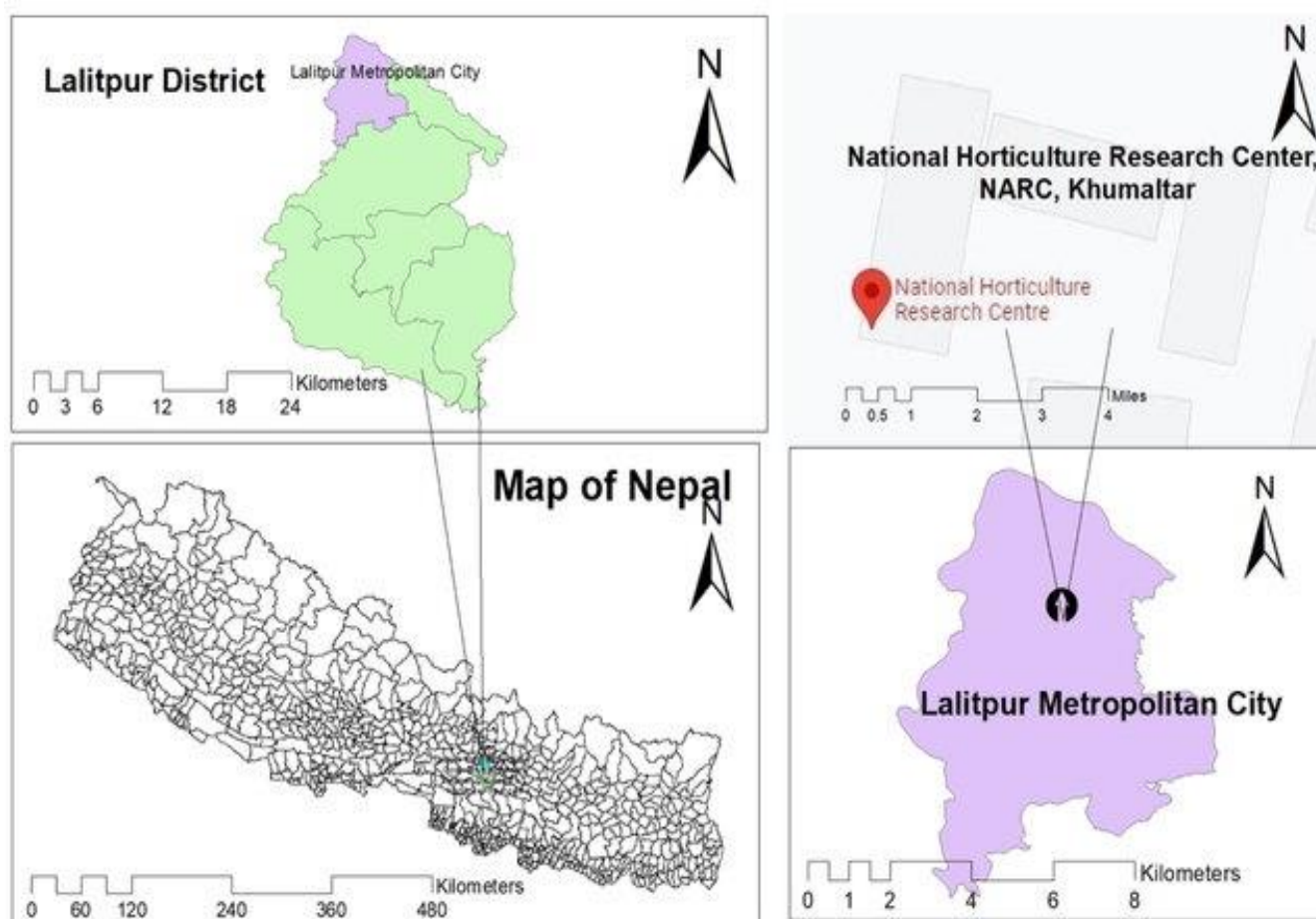
combined application under low-cost CoolBot-assisted storage, particularly for smallholder production systems. The interaction of oxalic acid or potassium metabisulfite with LDPE-based MAP may influence physiological, biochemical, and quality attributes of litchi during storage. Therefore, this research evaluated the effects of postharvest chemical treatments and MAP, individually and in combination, on the postharvest value and storage life of litchi fruit stored under CoolBot-assisted conditions. The study was intended to identify a practical and relatively low-cost approach for improving postharvest management of litchi.

2. Materials And Methods

Site selection

This experiment was demonstrated in 2024 at the laboratory of the National Horticulture Research Center (NHRC), Khumaltar, Lalitpur, Nepal. The site is situated in the mid-hill region of Bagmati Province at 27.6588° N latitude and 85.3247° E longitude, at an elevation of 1,350 masl. The area has a subtropical climate, with reported winter temperatures of approximately 6–7°C and summer temperatures of 28–30°C.

Study Area



Source: Subedi et al. (2024).

Selection of litchi

Litchi cv. Muzaffarpur was selected for the experiment. The fruit was obtained from Pachkhal, Kavre, where the cultivar is widely grown in subtropical conditions. Fruits were obtained at physiological ripeness during the cooler

part of the day, retained on their bunches, placed in cardboard boxes, and transported to NHRC, Khumaltar, on the day of harvest. The harvested fruit was refrigerated overnight and subsequently allowed to equilibrate under room conditions for approximately 4–5 h before treatment.



Storage conditions and experimental design

The experiment was conducted under CoolBot-assisted storage. Temperature and relative humidity were monitored daily using an electronic hygrometer. The study followed a completely randomized design (CRD) containing of seven treatment, with three replications per treatment. Data were observed at 3-day intervals.

2.4 Postharvest treatments

The treatments consisted of a water-dipped control, potassium metabisulfite, oxalic acid, two MAP systems, and combinations of chemical treatments with MAP. The treatment structure was as follows:

Table 1: Description of treatments used in the study at Khumaltar, Lalitpur, 2024.

Treatment	Description
T1	Control (water dip)
T2	100 ppm potassium metabisulfite
T3	5% oxalic acid
T4	50 µm LDPE MAP
T5	Ready-made MAP box
T6	5% oxalic acid + ready-made MAP box
T7	100 ppm potassium metabisulfite + 50 µm LDPE MAP

2.4.1 Control treatment

For the control treatment, the fruit was immersed in water for 20 min and then air-dried to remove excess water. The fruit was subsequently distributed evenly among three baskets, with 30 healthy fruits assigned to each tray, and stored under the specified CoolBot conditions.

2.4.2 Potassium metabisulfite treatment

For the 100 ppm potassium metabisulfite treatment, 1 g of potassium metabisulfite was dissolved in 10 L of water. The selected fruits were dipped in the solution for

20 min and then air-dried before placement in CoolBot storage.

2.4.3 Oxalic acid treatment

For the 5% oxalic acid treatment, 500 g of oxalic acid was added to 10 L of water. The selected fruits were immersed in the solution for 20 min, air-dried to remove excess solution, and transferred to CoolBot storage.

2.4.4 50 µm LDPE MAP

For the LDPE MAP treatment, 50 µm LDPE film was cut to an appropriate size for packaging the fruit. Each package

contained 16 evenly distributed perforations, each approximately 5 mm in diameter. The fruit was placed inside the film package, which was then sealed to limit air exchange before storage under CoolBot conditions.

2.4.5 Ready-made MAP box

A ready-made box intended for MAP applications was used for the fifth treatment. Fruits were arranged carefully inside the box to provide adequate space and reduce bruising. The box was sealed to establish the intended modified atmosphere and then stored under CoolBot conditions.

2.4.6 Oxalic acid + ready-made MAP box

For the combined treatment, 500 g of oxalic acid was dissolved in 10 L of water, and the selected fruit was

immersed for 20 min. The fruit was then air-dried and transferred to the ready-made MAP box. The box was sealed and maintained under CoolBot storage.

2.4.7 Potassium metabisulfite + 50 µm LDPE MAP

For the combined potassium metabisulfite–MAP treatment, 1 g of potassium metabisulfite was dissolved in 10 L of water and the fruit was immersed for 20 min. After air-drying, the treated fruit was placed in 50 µm LDPE packages containing 16 perforations of approximately 5 mm diameter. The packages were sealed and stored under CoolBot conditions.

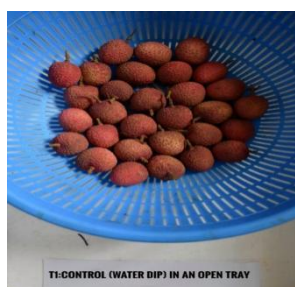


Fig: T1

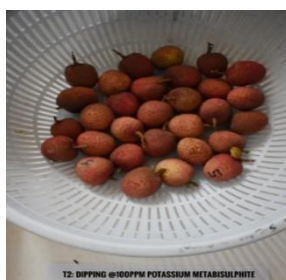


Fig: T2

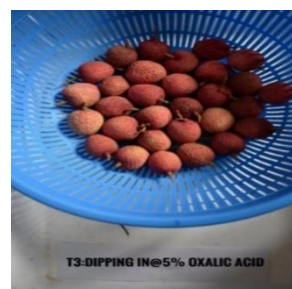


Fig: T3



Fig: T4



Fig: T5



Fig: T6



Fig: T7

3. Observations

Physiological loss in weight (%)

A digital weighing scale was used to calculate the sample weight loss. Every four days, weight measurements were taken. Every sample replication was weighed. The usual approach described in AOAC (1994) was used to compute the weight reduction in %.

$$\text{Weight loss \%} = \frac{\text{wt of the sample at first interval} - \text{wt of the sample at second interval}}{\text{wt of sample at first interval}} \times 100$$

Firmness (kg/cm²)

Firmness was measured in all fruits from each treatment and replication at 4-day intervals. A device known as a penetrometer, which measures a substance's consistency by piercing a rod with a specified force, was used to evaluate

firmness. The hardness was determined using three litchis from each replication. The unit of measurement was kg/cm².

Titrateable acidity (TA)

Titrateable acidity was determined with the Pocket Brix-Acidity meter. For TA, 1 ml of juice from a sample was placed on it every 4 days, and it displayed the results using the angle of refraction.

Spoilage (%)

Fruits were visually examined for evidence of deterioration following each storage period. Samples that displayed symptoms of illness were counted.

$$\text{Spoilage \%} = \frac{\text{wt of decayed sample of a treatment}}{\text{total wt of a sample stored in the treatment}} \times 100$$

Shelf life (days)

Based on appearance and spoiling, the number of days that fruits were suitable for selling was recorded in order to assess their shelf life. It was calculated as the number of days from the beginning of storage and the point at which more than 50 samples per replication began to degrade. At the conclusion of the shelf life, the quality parameters were assessed using the remaining sample. Until the litchis had less than 50% damage, the shelf life was measured.

4. Results and Discussion

Physiological weight loss

All treatments showed a gradual rise in physiological loss in weight (PLW) with storage time, with significant differences between treatments at each observation period ($P < 0.001$). At Day 4, PLW ranged from 0.45% in 50 μ m LDPE MAP to 6.90% in 5% oxalic acid. The control and 100 ppm potassium metabisulfite treatments recorded 2.73% and 6.28%, respectively, while the two combined MAP treatments showed relatively low losses. At Day 8, the lowest PLW was recorded in 50 μ m LDPE MAP (0.91%), whereas the highest was observed in the ready-made MAP box (8.32%). By Day 16, 100 ppm potassium metabisulfite (KMS) + 50 μ m LDPE MAP recorded the lowest PLW (7.28%), while the ready-made MAP box recorded the highest PLW (20.60%). Thus, the combination of 100 ppm KMS with 50 μ m LDPE MAP was the more effective treatment for minimizing weight decline during storage.

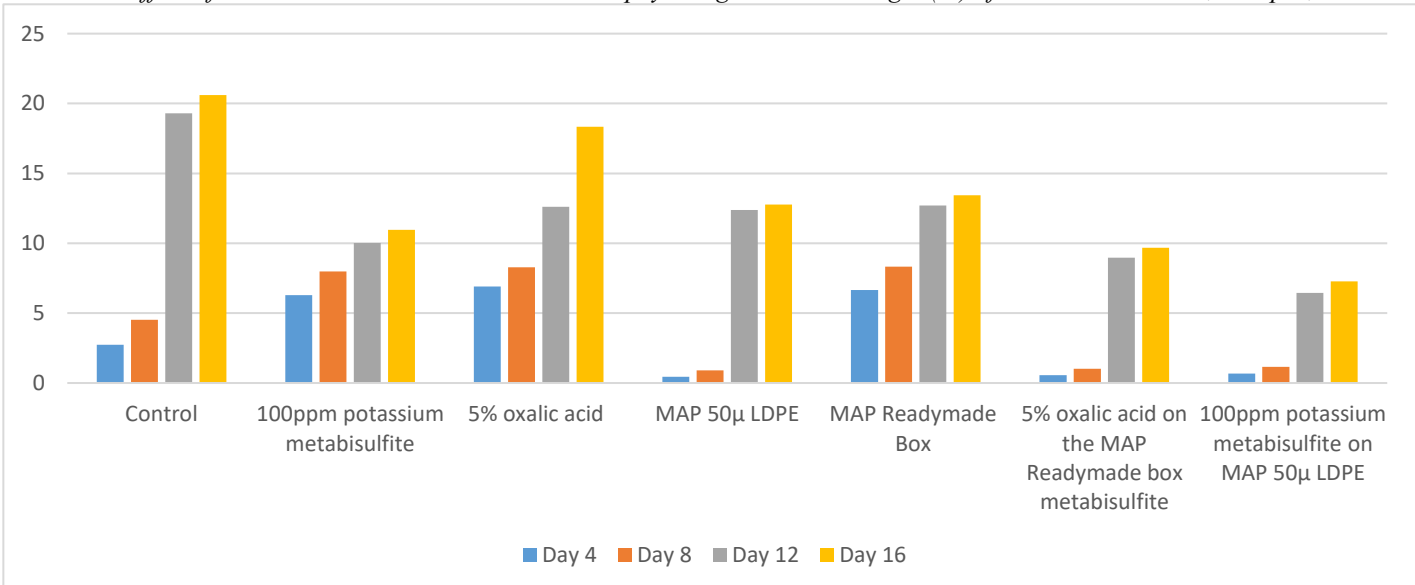
The progressive increase in PLW during storage can be attributed mainly to moisture loss through transpiration and

continued respiratory activity after harvest. The substantially lower PLW observed in LDPE-based MAP treatments indicates that the packaging helped retain moisture around the fruit and consequently reduced water loss. Similar reductions in weight loss have been reported in litchi stored under MAP, where increased humidity within the package reduced transpiration (Ali et al., 2019; Sivakumar & Korsten, 2006).

The lowest PLW at Day 16 was recorded with 100 ppm KMS + 50 μ m LDPE MAP (7.28%), indicating the mixed treatment was particularly effective in maintaining fruit mass. (Khanal et al., 2023) also reported lower PLW in KMS-treated litchi than in untreated fruit. In addition, (Neog & Saikia, 2010) demonstrated improved postharvest preservation of litchi using metabisulfite treatment in combination with perforated LDPE packaging. Therefore, the lower PLW showed in the present study might be attributed primarily to the moisture-retaining effect of LDPE packaging, with KMS providing an additional preservative effect that helped maintain fruit quality during storage.

The high PLW observed in the ready-made MAP box (20.60%) suggests that this packaging system was less effective in conserving moisture than the 50 μ m LDPE system. Differences in packaging characteristics, permeability, and moisture retention may have contributed to this variation. Overall, the present findings support the effectiveness of KMS combined with LDPE-based MAP for declining physiological weight loss and maintaining litchi quality during CoolBot storage.

Table 2: Effect of chemical treatments and MAP on the physiological loss in weight (%) of litchi at Khumaltar, Lalitpur, 2024.



Titrate acidity (TA) showed variation among treatments during storage; however, the effect of treatment was statistically non-significant on all storage dates. The mean TA decreased from 0.60% on Day 4 to 0.48% on Day 8, followed by slight increases to 0.53% on Day 12 and 0.51% on Day 16.

in 100 ppm potassium metabisulfite, while 5% oxalic acid recorded 0.75%. On Day 8, the highest TA was observed in 50 μ m LDPE MAP (0.57%), followed by 5% oxalic acid (0.56%), whereas 100 ppm potassium metabisulfite recorded 0.41%. On Day 12, 5% oxalic acid recorded the highest numerical TA (0.65%), while 5% oxalic acid + MAP ready-made box recorded the lowest value (0.46%).

On Day 16, 100 ppm potassium metabisulfite + 50 μ m LDPE recorded the highest numerical TA (0.65%), whereas 5% oxalic acid + MAP ready-made box recorded 0.39%. Despite these numerical differences, none of the treatment effects was significant ($P > 0.05$).

The non-significant effect of treatments on TA indicates that potassium metabisulfite, oxalic acid and MAP did not consistently alter the acidity of litchi during the 16-day storage period. The decrease in mean TA from 0.60% on Day 4 to 0.48% on Day 8, followed by relatively small fluctuations, is consistent with the normal postharvest utilization of organic acids during respiration and ripening. Previous research has reported a progressive decline in TA of litchi during cold storage and attributed the change to degradation or utilization of organic acids during postharvest metabolism (Mahajan et al., 2013).

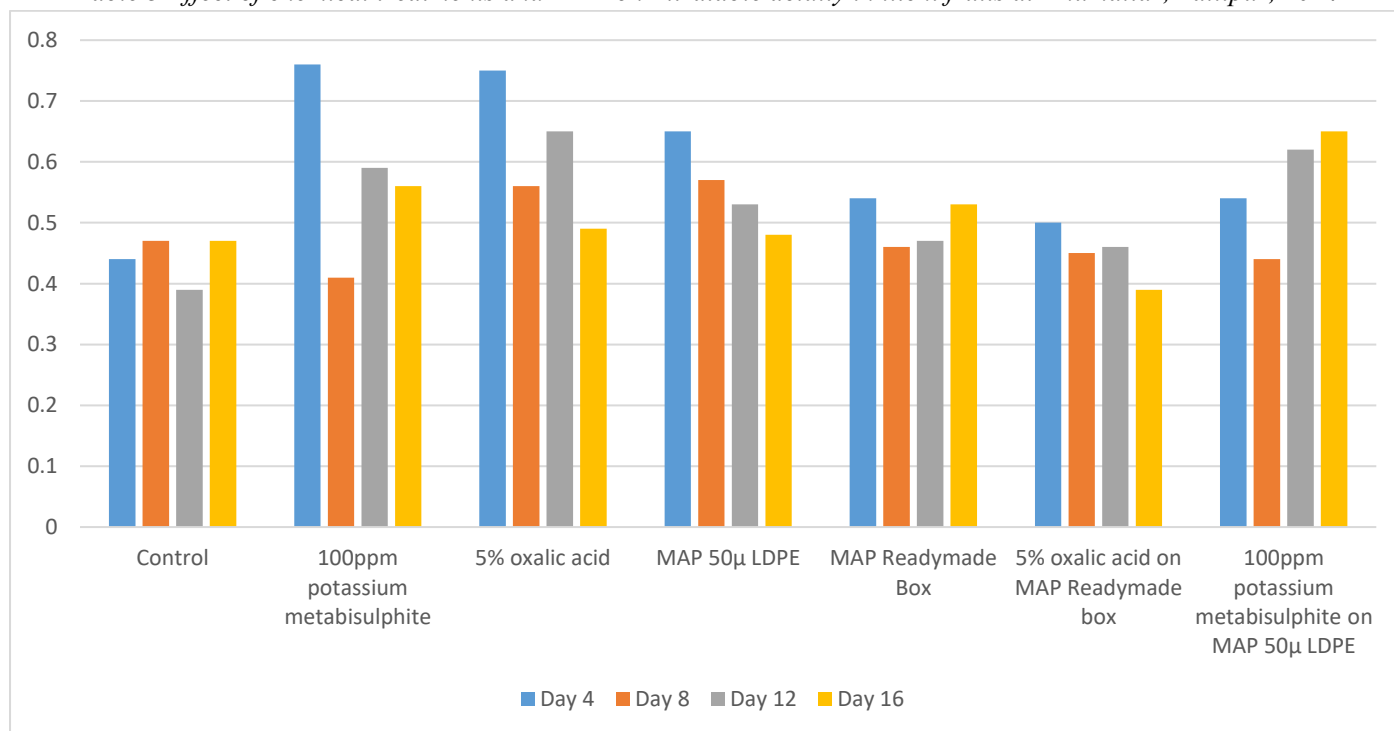
The present results are also comparable with previous MAP studies. (Ali et al., 2019) reported that MAP-maintained litchi had higher TA than unpackaged fruit during low-temperature storage, indicating that MAP can slow biochemical deterioration and organic-acid depletion. Similarly, (Sivakumar & Korsten, 2006) demonstrated that MAP combined with postharvest treatments maintained the biochemical and sensory quality of litchi during

refrigerated storage. However, the present experiment did not show a statistically significant MAP effect, suggesting that the relatively stable storage environment may have limited treatment differences.

The numerical retention of TA in some oxalic-acid treatments is physiologically plausible. (Marboh et al., 2012) reported that oxalic-acid treatment, particularly when combined with hot-water treatment, helped retain TA and other quality attributes of litchi during cold storage. Potassium metabisulfite has also been investigated as a postharvest treatment for litchi; (Khanal & Timilsina, 2023) reported effects of KMS treatments on several biochemical quality parameters, including TA. Nevertheless, because the present TA treatment effects were nonsignificant at every storage interval, the higher values observed for individual treatments should be regarded as numerical variation rather than evidence of superior acidity retention.

Overall, TA showed a general tendency to decline during storage, with minor fluctuations thereafter. The results suggest that organic-acid metabolism continued under CoolBot storage, while the tested chemical treatments and MAP systems did not produce a statistically significant effect on TA.

Table 3 Effect of chemical treatments and MAP on Titratable acidity in litchi fruits at Khumaltar, Lalitpur, 2024



Firmness

Firmness of litchi fruit was significantly affected by treatment on Day 4 ($P < 0.001$), whereas no significant treatment effect was observed on Days 8, 12, and 16. In the present study, the highest firmness on Day 4 was recorded in the control (0.30 kg cm^{-2}), followed by 5% oxalic acid +

MAP ready-made box (0.28 kg cm^{-2}), whereas 100 ppm potassium metabisulfite recorded the lowest firmness (0.05 kg cm^{-2}). Thus, the treatments produced significantly different responses during the initial storage period. However, treatment differences were not significant from Day 8 onward. At Day 16, 50 μ m LDPE MAP and 100 ppm potassium metabisulfite + 50 μ m LDPE showed relatively

higher firmness (0.10 kg cm^{-2}) than the control (0.07 kg cm^{-2}), although these differences were statistically nonsignificant. The reduction in firmness during storage can be attributed to progressive postharvest senescence, moisture loss, and degradation or solubilization of cell-wall pectic substances, which contribute to softening of litchi fruit (Passafiume et al., 2023).

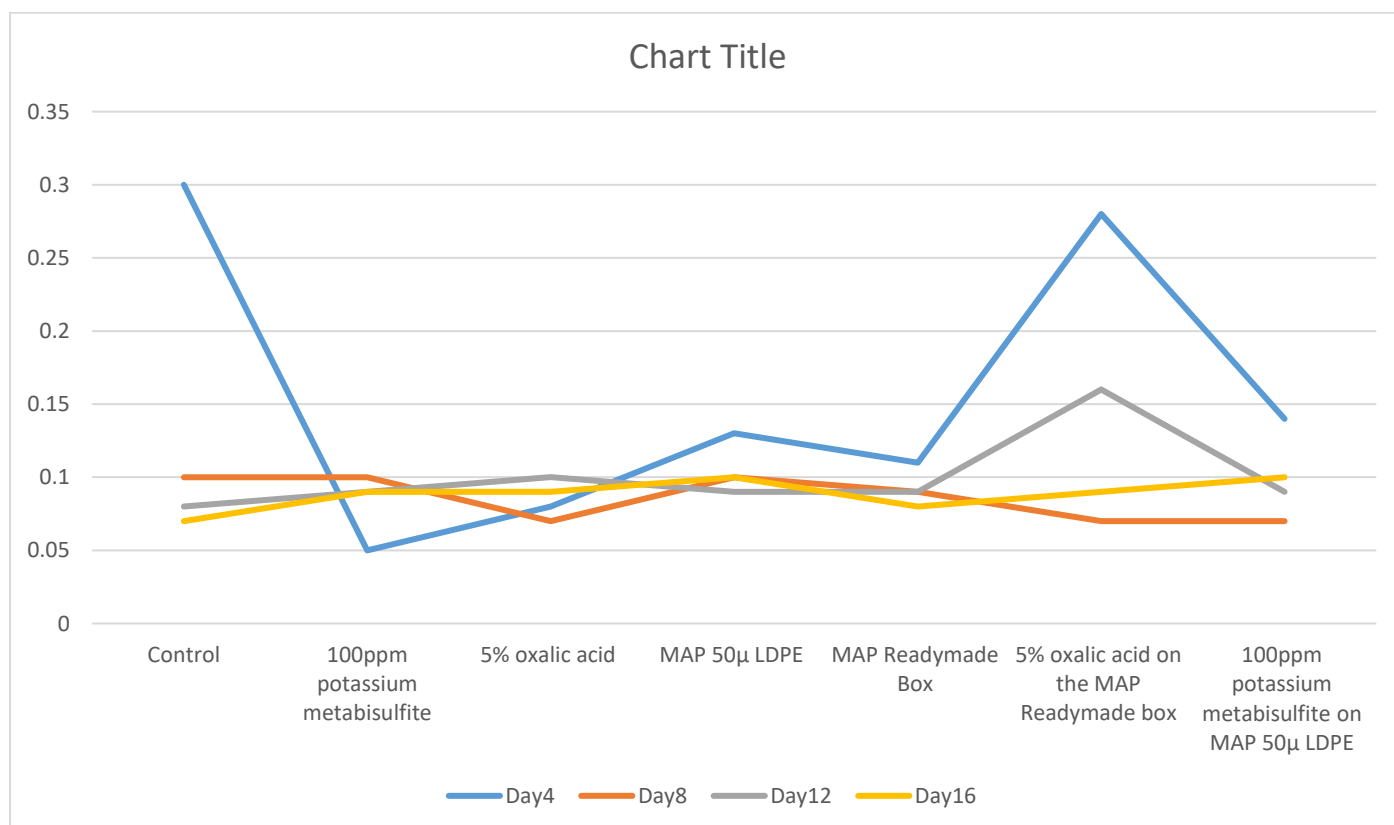
The storage conditions of $7.4\text{--}12^{\circ}\text{C}$ and $85 \pm 10\%$ RH may have slowed the rate of deterioration by reducing metabolic activity and excessive moisture loss. Modified atmosphere packaging (MAP) can further reduce transpiration and maintain a humid microenvironment around the fruit, thereby helping to preserve tissue firmness. (Sivakumar & Korsten, 2006) reported that MAP reduced transpiration and helped retain postharvest quality of litchi, while recent research also demonstrated better firmness retention under suitable MAP conditions during cold storage.

The relatively higher firmness observed in some MAP treatments may be related to reduced water loss and delayed tissue deterioration. Similarly, oxalic acid has been reported to delay postharvest deterioration and maintain membrane

integrity in litchi by reducing oxidative damage (Zheng & Tian, 2006). (Hossain et al., 2021) also reported beneficial effects of 5% oxalic acid combined with polyethylene packaging on the postharvest quality of litchi under refrigerated storage. However, the higher firmness observed in the present oxalic-acid-plus-MAP treatment represents a numerical trend rather than a statistically confirmed treatment effect.

Potassium metabisulfite may contribute to postharvest quality preservation through its antimicrobial and preservative properties. Nevertheless, the present study did not show a consistent significant effect of KMS on firmness throughout storage. Overall, the results indicate that litchi firmness declined mainly during the early storage period, while treatment differences became statistically nonsignificant after Day 4 under CoolBot storage conditions. The maintenance of relatively high humidity and the use of MAP may have contributed to limiting moisture loss, but no individual treatment can be considered statistically superior for firmness retention over the entire 16-day storage period.

Table 4: Effect of chemical treatments and MAP on firmness of litchi fruits at Khumaltar, Lalitpur, 2024



Total soluble solids

The total soluble solids (TSS) content of litchi varied during storage, but the effect of postharvest chemical treatments and modified atmosphere packaging was non-significant ($P > 0.05$) at all storage intervals. The mean TSS decreased

from 17.92°Brix on Day 4 to 17.38°Brix on Day 8 and subsequently to 16.84°Brix on Days 12 and 16.

On Day 4, TSS ranged from 17.13°Brix in 100 ppm potassium metabisulfite to 18.60°Brix in the control. On Day 8, the highest TSS was recorded in the MAP ready-made box (18.70°Brix), while the lowest was observed in

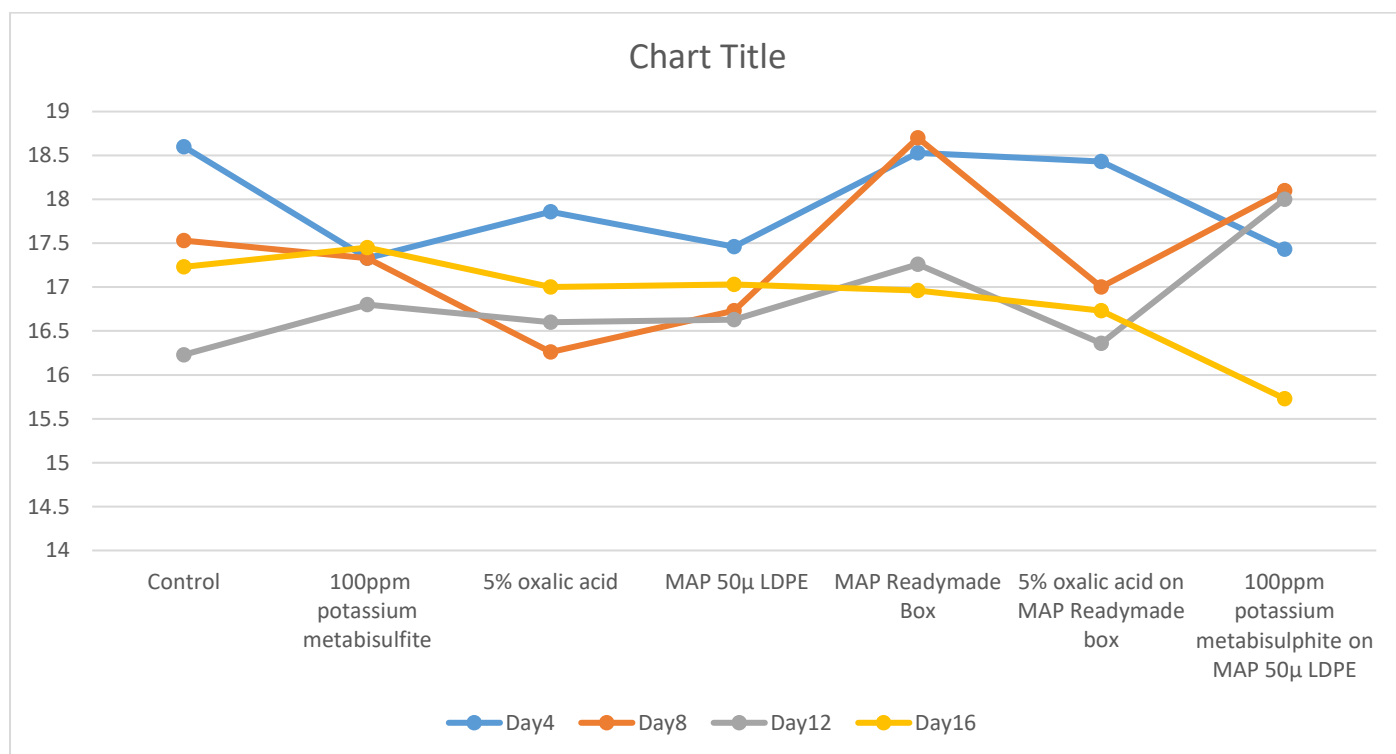
5% oxalic acid (16.26 °Brix). On Day 12, 100 ppm potassium metabisulfite combined with 50 µm LDPE recorded the highest TSS (18.00 °Brix), whereas the control recorded the lowest value (16.23 °Brix). On Day 16, 100 ppm potassium metabisulfite recorded the highest TSS (17.46 °Brix), while 100 ppm potassium metabisulfite combined with 50 µm LDPE recorded the lowest value (15.73 °Brix). Despite these numerical variations, treatment differences were not statistically significant on any storage date.

The nonsignificant treatment effect on TSS indicates that potassium metabisulfite, oxalic acid and MAP did not significantly alter soluble-solids content of litchi during the 16-day storage period. The overall mean TSS declined from 17.92 °Brix on Day 4 to 16.84 °Brix on Day 16. A similar decline in TSS during litchi storage has been reported by (Paull & Chen, 1987) , who attributed the reduction to changes in soluble sugars, particularly sucrose, during postharvest metabolism. Likewise, cold-storage research

showed that TSS gradually decreased during storage, while low temperature slowed the rate of decline (Yun et al., 2016).

The relatively small reduction in TSS observed in the present study may therefore be associated with the reduced metabolic activity under CoolBot storage conditions. MAP can further help maintain fruit quality by reducing transpiration and modifying the gaseous environment around the fruit (Sivakumar & Korsten, 2006). (Semeerbabu et al., 2007) also reported good retention of TSS in LDPE-packed litchi under low-temperature and high-relative-humidity storage. However, because treatment effects were nonsignificant in the present study, the numerical differences among KMS, oxalic acid and MAP treatments should be considered variations rather than evidence of treatment superiority. Overall, TSS was relatively well maintained during storage, with a modest decline over time and no significant effect of the tested treatments.

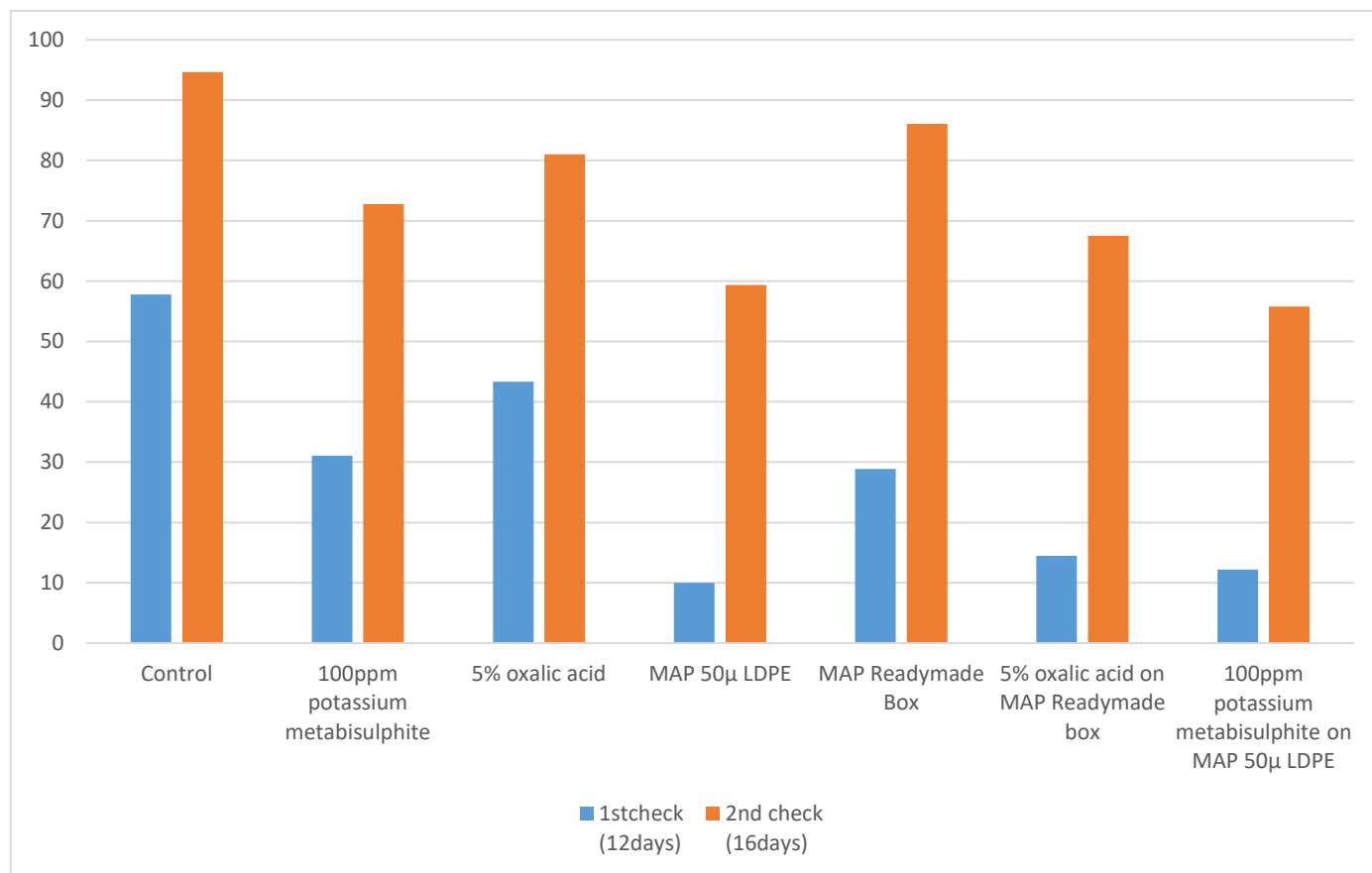
Table 5: Effects of chemical treatments and MAP on total soluble solids(TSS) in litchi fruits at Khumaltar,Lalitpur,2024.



Spoilage

Table 6 provides detailed data on the spoilage percentage of litchi fruit, from Day 4 to Day 16. On Day 12, the highest spoilage was found in the control, with 57.78%, while MAP 50µ LDPE had the lowest spoilage at 9.99%. By Day 16, spoilage increased significantly in all treatments, with the control showing the highest spoilage at 94.66% and 100 ppm potassium on MAP 50µ LDPE exhibiting the lowest spoilage at 55.80%.

Table 6: Effect of chemical treatments and MAP on Spoilage in litchi fruits at Khumaltar, Lalitpur, 2024



At last day of the current study, the control fruits' spoilage incidence had significantly increased due to microbial activity and a gradual loss of natural defense barriers, while Modified atmosphere packing (MAP) treatments significantly decreased spoilage, especially when paired with potassium metabisulfite. Potassium metabisulfite possesses antifungal properties that reduce spore germination and inhibit enzymes that break down cell walls. Because of its sulphite content, using it in higher doses reduces fungal infection and decay loss in many fruits (Kumar et al., 2020). Low oxygen, high CO₂ environments produced by MAP inhibit aerobic spoilage organisms and decrease the metabolism of pathogens (Passafiume et al., 2023).

(Hazarika & Marak, 2022). However, because oxalic acid has a weaker direct antibacterial activity than sulphite compounds, spoilage rates in oxalic acid treatments were intermediate when compared to control and KMS+MAP treatments.

Shelf life (days)

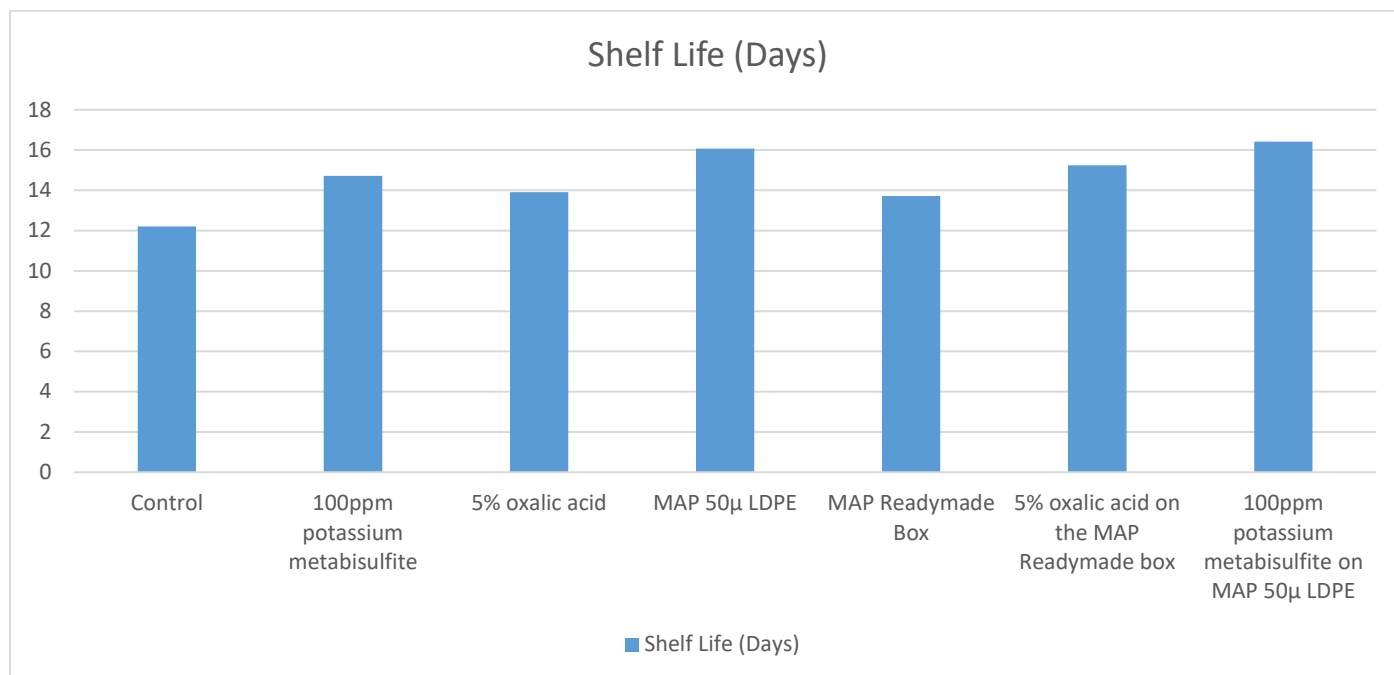
Table 7 provides data on the shelf life of litchi fruits. The shelf life of litchi fruits varied across different treatments. A 100-ppm potassium metabisulfite solution on MAP 50µ LDPE achieved the longest shelf life of 16.41 days. This

was closely followed by MAP 50µ LDPE, with a shelf life of 16.06 days. In comparison, Control had the shortest shelf life of 12.21 days.

Because post-harvest treatment enables the mitigation of both physiological and microbiological deterioration of litchi through a variety of methods, litchi shelf-life extension as a result of treatment differs dramatically from untreated samples. The application of MAP alone to prolong the shelf life of litchi in comparison to untreated samples confirms the findings that higher carbon dioxide and lower oxygen levels lower the rates of respiration and senescence in tropical fruit (Parry, 2012) (Mahajan et al., 2013). As demonstrated in mangos and other perishable fruits, the use of oxalic acid also enhances quality during storage by stabilizing membranes and lowering oxidative damage (Huang et al., 2013).

Potassium metabisulfite with MAP produced the longest storage period, indicating a synergistic effect. It is well known that sulphite chemicals prevent fungal growth and enzymatic browning, while MAP reduces aerobic pathogen activity and enhances fruit quality over time (Ha et al., 2017). Furthermore, it has been demonstrated that comparable combined methods can successfully postpone deterioration and increase the shelf life of litchi and other fruits (Passafiume et al., 2023).

Table 7 Effect of chemical treatments and MAP on Shelf life in litchi fruits at Khumaltar, Lalitpur, 2024



5. Conclusion

An experiment was conducted to enhance the shelf life of Litchi fruit through various post-harvest treatments and Modified atmospheric packaging material in CoolBot storage conditions. After 20 days of observation, fruits treated with the treatment of potassium metabisulfite and MAP showed a significant reduction in physiological weight loss and spoilage incidence, maintenance of firmness and vitamin C content, and an extension of shelf life to 16.41 days compared to control fruit, 12.21 days. Extension of shelf life was attributed to reduced respiration rates, increased humidity retention, and the antifungal activity of sulfite in a modified atmosphere. Therefore, this study concludes that application of potassium metabisulfite 100 ppm and MAP is appropriate for postharvest treatment of litchi fruit to prolong its shelf life and preserve its quality parameters. Hence, combined potassium metabisulfite and MAP system offers a low-cost and practical alternative for managing the post-harvest handling of litchi by smallholder producers.

References

1. Ali, S., Khan, A. S., Malik, A. U., & Shahid, M. (2016). Effect of controlled atmosphere storage on pericarp browning, bioactive compounds and antioxidant enzymes of litchi fruits. *Food Chemistry*, 206, 18–29. <https://doi.org/10.1016/j.foodchem.2016.03.021>
2. Ali, S., Sattar Khan, A., Ullah Malik, A., Anjum, M. A., Nawaz, A., & Shoaib Shah, H. M. (2019). Modified atmosphere packaging delays enzymatic browning and maintains quality of harvested litchi fruit during low temperature storage. *Scientia Horticulturae*, 254, 14–20. <https://doi.org/10.1016/j.scienta.2019.04.065>
3. Bhattarai, D. R. (2018). Postharvest horticulture in Nepal. *Horticulture International Journal*, 2(6). <https://doi.org/10.15406/hij.2018.02.00096>
4. Cantin, C. M., Crisosto, C. H., & Day, K. R. (2008). Evaluation of the Effect of Different Modified Atmosphere Packaging Box Liners on the Quality and Shelf Life of 'Friar' Plums. <https://doi.org/10.21273/HORTTECH.18.2.261>
5. Guilbert, S., Gontard, N., & Gorris, L. G. M. (1996). Prolongation of the Shelf-life of Perishable Food Products using Biodegradable Films and Coatings. *LWT - Food Science and Technology*, 29(1), 10–17. <https://doi.org/10.1006/fstl.1996.0002>
6. Ha, P. T. T., Mien, N. T., Hien, D. T., Tung, N. T., Trang, N. T., & Huong, N. T. (2017). Effect of modified atmosphere packaging (MAP) and postharvest treatments on quality of litchi fruits during storage. *Vietnam Journal of Science and Technology*, 55(4), 411–419. <https://doi.org/10.15625/2525-2518/55/4/8630>
7. Hailu, G., & Derbew, B. (2015). Extent, Causes and Reduction Strategies of Postharvest Losses of Fresh Fruits and Vegetables – A Review. *Journal of Biology*.
8. Hazarika, T., & Marak, T. (2022). Salicylic acid and oxalic acid in enhancing the quality and extending the shelf life of grape cv. Thompson seedless. *Food Science and Technology International*, 28(6), 463–475. <https://doi.org/10.1177/10820132211020612>

9. Hossain, Md. S., Ramachandraiah, K., Hasan, R., Chowdhury, R. I., Kanan, K. A., Ahmed, S., Ali, Md. A., Islam, Md. T., & Ahmed, M. (2021). Application of Oxalic Acid and 1-Methylcyclopropane (1-Mcp) with Low and High-Density Polyethylene on Post-Harvest Storage of Litchi Fruit. *Sustainability*, 13(7), 3703. <https://doi.org/10.3390/su13073703>
10. Huang, H., Jing, G., Guo, L., Zhang, D., Yang, B., Duan, X., Ashraf, M., & Jiang, Y. (2013). Effect of oxalic acid on ripening attributes of banana fruit during storage. *Postharvest Biology and Technology*, 84, 22–27. <https://doi.org/10.1016/j.postharvbio.2013.04.002>
11. Kasnazany, S., Salieh, F., & Omar, A. (2017). *Effect of salicylic acid and potassium metabisulfite on postharvest quality of plum cv. Qadri*. 9, 79–91.
12. Khanal, A., Baral, A., Timilsina, S., & Khanal, S. (2023). Effect of Different Concentrations of Potassium Metabisulphite and Bavistin on Postharvest Life of Litchi (*Litchi chinensis* Sonn var. Muzaffarpur). *Agro Environmental Sustainability*, 1(3), 257–264. <https://doi.org/10.59983/s2023010307>
13. Kumar, N., Neeraj, Pratibha, & Singla, M. (2020). Enhancement of Storage Life and Quality Maintenance of Litchi (*Litchi Chinensis* Sonn.) Fruit Using Chitosan:pullulan Blend Antimicrobial Edible Coating. *International Journal of Fruit Science*, 20(sup3), S1662–S1680. <https://doi.org/10.1080/15538362.2020.1828224>
14. Kumar, S., Kumar, A., & Kumar, S. (2019). Development of a cold storage facility for agricultural produce using air conditioner. *Journal of Postharvest Technology*, 7(1), 93–100.
15. Mahajan, P., Caleb, O., Al Said, F., & Opara, U. (2013). Modified Atmosphere Packaging Technology of Fresh and Fresh-cut Produce and the Microbial Consequences-A Review. *Food and Bioprocess Technology*, 6, 303–329. <https://doi.org/10.1007/s11947-012-0932-4>
16. Marboh, E. S., Lal, R. L., Mishra, D. S., & Goswami, A. K. (2012). Effect of hot water treatment and oxalic acid on colour retention and storage quality of litchi fruit cv. Rose Scented. *Indian Journal of Horticulture*, 69(04), 484–488.
17. Neog, M., & Saikia, L. (2010). Control of post-harvest pericarp browning of litchi (*Litchi chinensis* Sonn). *Journal of Food Science and Technology*, 47(1), 100–104. <https://doi.org/10.1007/s13197-010-0001-9>
18. Parry, R. T. (2012). *Principles and Applications of Modified Atmosphere Packaging of Foods*. Springer Science & Business Media.
19. Passafiume, R., Roppolo, P., Tinebra, I., Pirrone, A., Gaglio, R., Palazzolo, E., & Farina, V. (2023). Reduction of Pericarp Browning and Microbial Spoilage on Litchi Fruits in Modified Atmosphere Packaging. *Horticulturae*, 9(6), 651. <https://doi.org/10.3390/horticulturae9060651>
20. Paull, R. E., & Chen, N. J. (1987). Effect of storage temperature and wrapping on quality characteristics of litchi fruit. *Scientia Horticulturae*, 33(3), 223–236. [https://doi.org/10.1016/0304-4238\(87\)90070-7](https://doi.org/10.1016/0304-4238(87)90070-7)
21. Semeerbabu, M. T., Kudachikar, V. B., Revathy, B., & Usha Devi, A. (2007). Effect of post-harvest treatments on shelf-life and quality of litchi fruit stored under modified atmosphere at low temperature. *Journal of Food Science and Technology (India)*, 44(1), 107–109.
22. Sivakumar, D., & Korsten, L. (2006). Influence of modified atmosphere packaging and postharvest treatments on quality retention of litchi cv. Mauritius. *Postharvest Biology and Technology*, 41(2), 135–142. <https://doi.org/10.1016/j.postharvbio.2006.03.007>
23. Subedi, S., Bhandari, N., Basnet, M., Pradhan, N. G., & Gautam, I. P. (2024). Evaluation of cucumber genotypes under plastic house and open field conditions in Lalitpur, Nepal. *Cogent Food & Agriculture*, 10(1), 2298531. <https://doi.org/10.1080/23311932.2023.2298531>
24. Yun, Z., Qu, H., Wang, H., Zhu, F., Zhang, Z., Duan, X., Yang, B., Cheng, Y., & Jiang, Y. (2016). Comparative transcriptome and metabolome provides new insights into the regulatory mechanisms of accelerated senescence in litchi fruit after cold storage. *Scientific Reports*, 6(1), 19356. <https://doi.org/10.1038/srep19356>
25. Zheng, X., & Tian, S. (2006). Effect of oxalic acid on control of postharvest browning of litchi fruit. *Food Chemistry*, 96(4), 519–523.
26. Zheng, X., Tian, S., Meng, X., & Li, B. (2007). Physiological and biochemical responses in peach fruit to oxalic acid treatment during storage at room temperature. *Food Chemistry*, 104(1), 156–162. <https://doi.org/10.1016/j.foodchem.2006.11.015>