Archives of Agriculture and Environmental Science 10(1): 132-138 (2025)
https://doi.org/10.26832/24566632.2025.1001019

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes

ORIGINAL RESEARCH ARTICLE

Effect of different packaging materials and calcium chloride on post-harvest longevity of banana

Arjun Acharya[1*], Shistachar Joshi[1], and Rasmita Bhatta[2]

[1]Tribhuwan University, Institute of Agriculture and Animal Science, Lamjung Campus, Nepal
[2]Agriculture and Forestry University, Rampur, Chitwan, Nepal
[*]Corresponding author's E-mail: arjun.acharya117@gmail.com

ARTICLE HISTORY

Received: 11 January 2025
Revised received: 07 March 2025
Accepted: 15 March 2025

Keywords

Ripening
Total soluble solid
Titratable acidity
Weight loss

ABSTRACT

Nepal produces large amount of bananas annually but suffers significant losses owing to inappropriate postharvest management. The objective of the study was to determine the influence of polythene and fiber bag packaging, and calcium chloride treatment on bananas quality and shelf life. The two-factor experiment involved treatments that included bananas wrapped in a polythene and fiber bag of size 60 cm × 60 cm, and an open space, combined with calcium chloride concentrations of 1%, 3%, and 5%, along with untreated fruits kept in open space without using any bag as a control. Each treatment was replicated three times in a Completely Randomized Design (CRD). The research was conducted for 16 (sixteen) days and the observation taken were physiological weight loss, ripening percent, titratable acidity (TA), and total soluble solid (TSS). Polythene bag with 5% $CaCl_2$ reduced 89.6% weight loss than that of open space with 0% $CaCl_2$. Similarly, polythene bag with 5% $CaCl_2$ reduced ripening percentage by 10.72% compared to open space with 0 % $CaCl_2$. Polythene bag also reduced ripening percentage by 4.14% compared to fiber bag at 16th Day of study. On the 16th Day, ripening percentage was reduced by 5% by 5% $CaCl_2$ concentration compared to 0% $CaCl_2$. A longer time to reach ripening stage was observed in polythene than those of fiber bags and open space. Thus, the polythene bag with 5% $CaCl_2$ fruits had the highest TSS content (23.2 ^{0}Brix).

Citation of this article: Acharya, A., Joshi, S., & Bhatta, R. (2025). Effect of different packaging materials and calcium chloride on post-harvest longevity of banana *Archives of Agriculture and Environmental Science*, *10*(1), 132-138, https://dx.doi.org/10.26832/24566632.2025.1001019

INTRODUCTION

Banana covers an area of 21,720 hectares with a production of 254,161 Mt and a productivity of 15.22 Mt/ ha in Nepal (MOAD, 2021). Postharvest losses refer to the reduction in quality of food that occurs after harvesting before the food reaches the consumer (Plich & Wójcik, 2001; Turan, 2008). These losses can happen at various stages, such as during handling, storage, transportation, processing, and marketing (Hussain *et al*., 2011). According to FAO (2020), the large quantities of the losses starts right after harvesting and loss increases many fold during storage. In general, postharvest losses have been expected from 20 to 30% for fruits and could go beyond 50% under adverse circumstances. In Nepal, postharvest loss of fruits and vegetables ranges from 30- 50% (Gautam & Bhattrai, 2012). Postharvest loss in banana can be as high as 23- 43.5% and some years even much higher in Nepal (Bhattarai, 2018). Loss was reported to vary between 34- 40 % for banana in Nepal (Bhattarai, 2018), where untreated storage without any packaging accounted 12% (Prasad *et al*., 2015). Therefore, to minimize postharvest losses during storage and maximizing of shelf life, postharvest treatments such as chemicals treatment and packaging are needed for effective marketing of banana in the country (Bhattarai, 2018).

Calcium is used in preserving the textural quality of living produce. Calcium ions form cross-links between free carboxyl groups of the pectin chains, resulting in reinforcing of the cell wall of the fruits. The studies on effect of dipping fruits in calcium chloride solution before storage reported increased post-harvest life of strawberries and pears (Hernández-Muñoz *et al*., 2006; Rosen & Kader, 1989; Wójcik & Lewandowski 2003), shredded carrots (Izumi & Watada, 1994), mango (Singh *et al*., 1998), and banana (Raja *et al*., 2022). Nevertheless, only using ethylene suppressing chemicals is less effective. Similarly, a study by Akter *et al*. (2015) reported that keeping banana within both perforated polythene and fiber cover along with the KMnO4 helps to delay ripening and significantly extend the storage life. When the banana is kept in perforated polythene and fiber bags, it slower down the physio- chemical activity which delay ripening (Sarkar & Chattopadhyay, 1995; 1997). Similarly, storage life of apple was extended by 3% in sealed polythene along with $KMnO_4$ compared to untreated apple kept in an open environment (Bhadra & Sen, 1999). Although, many studies reported packaging materials and calcium chlorides influence on shelf life of bananas separately, there is very limited study on the combined effect of calcium chloride with different packaging materials on extending the storage life of banana in Nepal. The objective of the study was to compare the shelf life of bananas by combined effect of packaging in perforated polythene bag and treated with calcium chloride versus those that were untreated and left unpacked. The study hypothesized that the combined effect of calcium treatment and polythene packaging will increase the shelf life of banana.

MATERIALS AND METHODS

The experiment was carried out in the Horticulture Department laboratory at IAAS, Lamjung, Nepal in March 2020 AD. Randomly selected matured fingers of banana were harvested on 26th march, in the morning after the dew had evaporated from a farm of Lamjung campus. The harvested fingers of the banana were then transported to the laboratory, where they were washed and clean with distilled water. Then fingers were then detached, and treated by immersing in $CaCl_2$ solution of different concentrations (1, 3, and 5%) for 5 min. Then, packaging was done using 9 banana fingers in each replication of each treatment. They were arranged in the laboratory's slab making 12 treatment combinations (detail is given below), with three replications using a Completely Randomized Design. Polythene and fiber bags of size 60 cm × 60 cm with perforation (8 holes/bags), perforated by piercing with a punching machine and each hole having a 3.5 mm diameter were used. Physiological weight loss was recorded on 4th, 8th, and 12th day while ripening was observed till the 16th day since we were aiming for 100% ripening, which was observed on 16th day. Total soluble solid and titratable acidity was noted on the 4th and 16th days after storage. The TA and TSS noted on 4th day is regarded as the initial and on the 16th day is regarded as the final. There were two batches per treatment. One was used to track ripening percentage and physiological weight loss, while the other was for biochemical analysis (TA and TSS).

Treatment details

The study was conducted using 12 different treatments. Bananas were kept in fiber bags without calcium chloride (T1), fiber bags with 1% calcium chloride (T2), fiber bags with 3% calcium chloride (T3), and fiber bags with 5% calcium chloride (T4). Bananas were similarly kept in polythene bags without $CaCl_2$ treatment (T5), polythene bags with 1% $CaCl_2$ (T6), polythene bag with 3% $CaCl_2$ (T7), and polythene bag with 5% $CaCl_2$ (T8). Furthermore, bananas were left in an open space without $CaCl_2$ treatment (T9), while other in open space were treated with 1% $CaCl_2$ (T10), 3% $CaCl_2$ (T11), and 5% $CaCl_2$. Higher concentration of $CaCl_2$ may damage the tissue and reduce the ethylene sensitivity of the fruits which is not desirable (Dhali *et al*., 2024). Similarly, lengthening the storage life for too long also impact the texture and flavor of fruits. Hence, we chose a maximum of 5% $CaCl_2$ concentration treatment.

Weight loss percentage

Initially weight was taken using an electronic digital balance on the day of harvesting and consequently on 4th, 8th, and 12th day. Weight loss percentage was calculated by the formula given below:

Weight loss (%) = (Initial weight – Final weight) × 100 % / Initial weight

Ripening percentage

The ripening percentage of fruits was determined visually based on skin color, sweetness, and softness. It was calculated by using the following formula:

Ripening (%) = Number of riped fruits / Total number of fruits × 100

Total soluble solid

For TSS determination in °Brix, the handheld refractometer (model: Atago, Japan, N-1Brix 0-32%) was used by placing two to three drops of clear juice on the prism surface.

Titrable acidity

The determination of TA was performed using the acid-base titration method given by Tyl & Sadler (2017). Five ml of pulp juice (extracted by squeeze the pulp) was titrated against 0.1 N NaOH (sodium hydroxide). The amount of NaOH consumed to the endpoint was represented by the appearance of pink coloration, and this volume of NaOH was noted. TA was calculated using the following formula:

TA (%) = 0.1 N (NaOH) × V1 (mL) × 0.064 g/mol) × 100 / V2 (mL)

Where V1 is the volume of NaOH consumed during titration of the sample (mL), V2 is the volume of the sample (mL), and 0.064 g/mol is an acid milli-equivalent conversion factor.

Statistical analysis

R-Studio and Microsoft Excel were used for data analysis. Microsoft excel were used for entering and organizing data. Analysis of variance (ANOVA) was done by R studio version 1.4.1717. Duncan's Multiple Range Test (DMRT) was used for separating mean and for comparison between treatments.

RESULTS AND DISCUSSION

Effect on physiological weight loss percentage and ripening percentage

Physiological weight loss

Polythene showed the lowest weight loss in each experimental day compared to fiber bags and open space. On the 12th day, open space showed the highest (20.93%), but polythene showed the lowest (2.91 %) weight loss (Figure 1). Different concentrations of $CaCl_2$ exhibited a significant difference in weight loss in each experimental day (Figure 2). On the 4th day, the highest weight loss was observed in the untreated group (6.52%) which was statistically at par with 1% $CaCl_2$, and the lowest weight loss was observed in 5% $CaCl_2$ (5.19%) which was also statistically at par with 3% $CaCl_2$. 5% treated bananas showed 18.93% and 15.33 % less weight loss on the 8th and 12th day, respectively compared to the untreated one. The combined effect of packaging and calcium chloride treatment in influencing the weight loss of banana during ripening and storage were significantly different only on the 8th and 12th day (Table 1). On the 8th day, the highest weight loss (16.82%) was observed in the control (open space with 0% $CaCl_2$), whereas the lowest weight loss (1.23%) was observed in polythene with 5% $CaCl_2$. On the 12th day of storage, control showed the highest weight loss (22.02%) but polythene with 5% $CaCl_2$ showed the lowest weight loss whereas polythene with 0% $CaCl_2$, polythene with 1% $CaCl_2$ and polythene with 3% $CaCl_2$ weight loss were statistically at par (Table 1).

Ripening percentage

Different packaging materials exerted significant results in terms of ripening. Polythene packaging reduced ripening percentage by 52.08% and 17.08% on the 12th and 16th day, respectively compared to open space. On the 16th day of storage, maximum (100%) ripening was observed in open space, and minimum (94.98%) was found in polythene bag (Figure 3). The remarkable variation in ripening percentage was shown between the different concentrations of calcium chloride. On the 4th day, the minimum ripening percentage (9.03%) was observed in bananas which were treated with 5% $CaCl_2$ and also statistically at par with 3% $CaCl_2$ and maximum ripening was seen in untreated bananas. On the 16th day, the maximum ripening percent (100%) was found in fruit treated with 0% $CaCl_2$ and 1% $CaCl_2$, while the minimum was noted on bananas treated with 5% and 3% $CaCl_2$ (Figure 4). The interaction effects of different packaging materials and calcium chloride on ripening percentage were highly significant. On the 16th day of storage, bananas treated with 5% and 3% and kept in polythene bags were found less ripened compared to other treatments. Bananas in open space whether treated or untreated showed 100% ripening on the 16th day (Table 2).

Effect of different packaging materials in total soluble solids and titratable acidity

Total soluble solids contents increased with the storage period (Table 3). The highest total Soluble solids contents (21.15 ^{0}Brix) were found in polythene bag at the final ripening stage of storage and the lowest total soluble solids content (14.03 ^{0}Brix) was

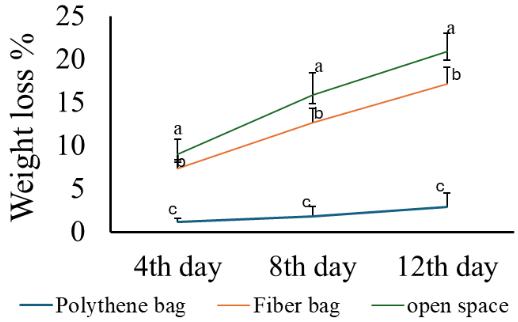

Figure 1. *Effects of packaging materials on weight loss of banana during storage and ripening. Note: Values on the same day with different*

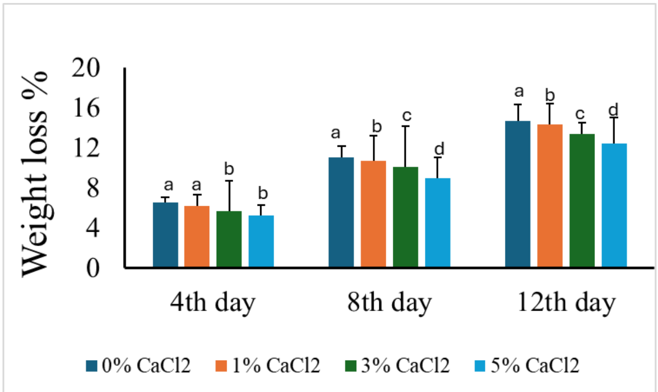

Figure 2. *Effects of different concentrations of Calcium Chloride on weight loss of banana during storage and ripening. Values on the same day with different superscripts are different at 1% level of significance.*

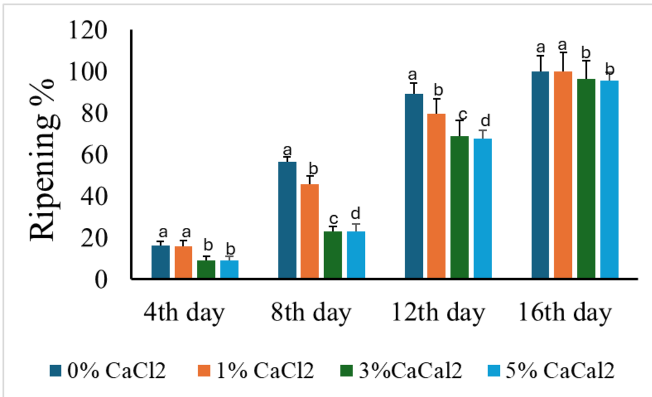

Figure 3. *Main effects of packaging materials on ripening percentage of banana during storage. Values on the same day with different superscripts are different at 1% level of significance.*

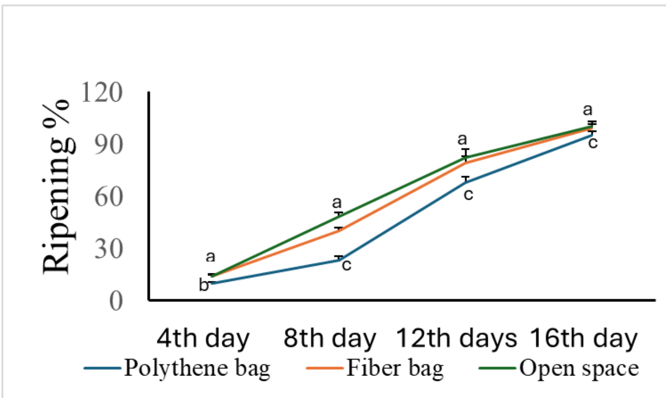

Figure 4. *Main effects of different concentrations of calcium chloride in ripening percentage of banana during storage. Values on the same day with different superscripts are different at 1% level of significance.*

Table 1. Combined effects of different packaging materials and calcium chloride on weight loss of banana during storage.

Packaging materials	Chemical $CaCl_2$	Weight loss % in 4th day	Weight loss % in 8th day	Weight loss % in 12th day
Fiber bags	T1=0%	8.02	13.82^{c}	18.51^{d}
	T2=1%	7.75	13.09^{d}	17.72^{e}
	T3=3%	7.11	12.41^{e}	16.47^{f}
	T4=5%	6.85	11.49^{f}	15.97^{f}
Polythene bags	T5=0%	1.74	2.33^{g}	3.31^{g}
	T6=1%	1.34	2.01^{g}	3.19^{g}
	T7=3%	0.89	1.83^{h}	2.87^{g}
	T8=5%	0.60	1.23^{h}	2.28^{h}
Open space	T9=0%	9.78	16.82^{a}	22.02^{a}
	T10=1%	9.48	16.81^{a}	21.91^{a}
	T11=3%	8.84	15.93^{b}	20.75^{b}
	T12=5 %	8.13	14.02^{c}	19.06^{c}
	F test	NS	**	**
	LSD (0.05)	0.74	0.56	0.50
	CV%	7.54	3.31	2.17

Note: **= Significant at 1% level of probability; Values in a same column with different superscripts are different.

Table 2. Combined effects of different packaging materials and calcium chloride on ripening percentage of banana during storage.

Packaging materials	Treatment $CaCl_2$	4 (DAS)	8 (DAS)	12 (DAS)	16 (DAS)
Fiber bags	T1= 0%	18.23^{b}	61.33^{b}	93.14^{b}	100^{a}
	T2=1%	18.12^{b}	52.33^{d}	85.39^{c}	100^{a}
	T3=3%	10.28^{cd}	23.13^{f}	69.23^{gh}	98.71^{ab}
	T4=5%	10.14^{d}	22.87^{f}	68.47^{h}	97.82^{b}
Polythene bags	T5=0%	11.27^{c}	25.8^{e}	78.64^{e}	100^{a}
	T6=1%	10.65^{cd}	26.24^{e}	70.31^{g}	100^{a}
	T7=3%	8.37^{e}	20.17^{g}	62.36^{i}	90.65^{c}
	T8=5%	8.31^{e}	20.13^{g}	61.15^{i}	89.28^{c}
Open space	T9=0%	19.28^{a}	82.58^{a}	97.75^{a}	100^{a}
	T10=1%	18.46^{ab}	58.43^{c}	83.24^{d}	100^{a}
	T11=3%	8.93^{e}	26.16^{e}	74.45^{f}	100^{a}
	T12=5%	8.64^{e}	25.59^{e}	73.13^{f}	100^{a}
	F test	**	**	**	**
	LSD (0.05)	0.97	1.39	1.59	1.52
	CV%	4.59	2.23	1.24	0.92

Note: **= Significant at 1% level of probability, Values in the same column with different superscripts are different.

observed in open space which was statistically at par with fiber bag (Table 3). Titratable acidity (TA) contents of fruit pulp for different packaging materials were also found to be significantly difference at the initial ripening stage but non-significant at the final ripening stage (Table 3).

Effect of different concentration of calcium chloride in total soluble solids and titratable acidity

The different concentrations of calcium chloride showed significant variation in TSS and TA at all ripening stages. The maximum TSS (20.71 ^{0}brix) was observed in 5% $CaCl_2$ which was statistically at par with 3% $CaCl_2$ while the minimum TSS (17.73 ^{0}brix) was found in 0% $CaCl_2$ at the final ripening stage of storage (Table 4). Similarly, at the final ripening stage, the highest value of TA (0.34) was observed in 0% $CaCl_2$ which was statistically at par with 1% $CaCl_2$ but the lowest value of TA (0.32) was observed in 5% $CaCl_2$ (Table 4).

Combined effects of different packaging materials and calcium chloride on TSS and TA

The combined effect of different packaging materials and calcium chloride showed significant difference in TSS during the storage. At the final ripening stage, the highest value of TSS content (23.2 ^{0}Brix) was observed in a polythene bag with 5% $CaCl_2$ and the lowest value of TSS contents (17 ^{0}Brix) was observed in an open space with 0% $CaCl_2$, which was statistically at par with open space with 1% $CaCl_2$ (Table 5). The combined effect doesn't show any difference in acidity.

Table 3. Main effects of packaging materials on TSS (Total soluble solid) and TA (Titratable acidity) of banana during the initial (4th day) and final stage (16th day) of storage.

Treatment	Initial TSS	Final TSS	Initial TA	Final TA
Polythene bag	15.62[a]	21.15[a]	0.29[b]	0.33
Fiber bag	14.25[b]	18.38[b]	0.29[b]	0.34
Open space	14.03[b]	18.2[b]	0.30[a]	0.34
F test	**	**	*	NS
LSD (0.05)	0.75	0.92	0.01	0.00
CV%	6.11	5.71	4.60	3.41

Note: *= Significant at 5% level of probability, **= Significant at 1% level of probability; NS= Non-significant, Values in the same column with different superscripts are different.

Table 4. Main effects of different concentrations of Calcium chloride on TSS and TA of banana during storage and ripening.

Treatment	Initial TSS	Final TSS	Initial TA	Final TA
0% $CaCl_2$	12.95[c]	17.73[b]	0.30[a]	0.34[a]
1% $CaCl_2$	14.60[b]	18.46[b]	0.29[ab]	0.34[a]
3% $CaCl_2$	15.33[ab]	20.06[a]	0.29[b]	0.33[b]
5% $CaCl_2$	15.64[a]	20.71[a]	0.28[c]	0.32[b]
F Test	**	**	**	*
LSD(0.05)	0.87	1.07	0.01	0.11
CV%	6.12	5.71	4.60	3.41

Note: *= Significant at 5% level of probability, **= Significant at 1% level of probability; NS= Non-significant, Values in the same column with different superscripts are different

Table 5. Combined effects of different packaging materials and calcium chloride on TSS and TA of banana during storage and ripening.

Packaging materials	Treatment $CaCl_2$	Initial TSS	Final TSS	Initial TA	Final TA
Fiber bags	T1= 0%	13.07[de]	17.2[ef]	0.30	0.34
	T2=1%	15.4[bc]	18[def]	0.28	0.35
	T3=3%	14.2[cde]	19[cde]	0.29	0.33
	T4=5%	14.33[cd]	19.33[cd]	0.28	0.33
Polythene bags	T5=0%	13.27[de]	19[cde]	0.30	0.34
	T6=1%	15.4[bc]	20.4[bc]	0.29	0.33
	T7=3%	16.6[ab]	22[ab]	0.28	0.32
	T8=5%	17.2[a]	23.2[a]	0.27	0.32
Open space	T9=0%	12.53[e]	17[f]	0.32	0.35
	T10=1%	13[e]	17[f]	0.30	0.34
	T11=3%	15.2[bc]	19.2[cd]	0.31	0.34
	T12=5%	15.4[bc]	19.6[cd]	0.28	0.33
	F test	*	*	NS	NS
	LSD (0.05)	1.50	1.21	0.08	0.06
	CV%	6.12	5.71	4.6	3.41

Note: **= Significant at 1% level of probability; NS= Non-significant, Values in a same column with different superscripts are different.

The result indicated that packaged and calcium chloride treated bananas had a higher shelf life. This support the research hypothesis. The study found that fruits treated with 5% $CaCl_2$ and packaged in perforated polythene showed positive result by reducing weight loss and delayed ripening compared to untreated and unpacked fruits. This results align with the findings by Yogi *et al.* (2023), Hailu *et al.* (2014), and Kaur & Kaur (2018). The reduction in weight loss in polythene-packed fruits is credited to the bag capacity to maintain higher humidity, increase CO_2 accumulation, and lower temperature, thereby reducing respiration and water loss. Similarly, fruits treated with 5% $CaCl_2$ showed reduced weight loss and ripening percentage along with maintaining the sugar content. This result aligns with the finding of a previous study by Dhali *et al.* (2024). By slowing down metabolic activities, calcium chloride significantly delays ripening and senescence (Elbagoury *et al.*, 2020). Reduced physiological weight loss and ripening % were also noted by Sahay *et al.* (2015) in bananas treated with calcium chloride and wrapped in polythene.

Bananas packaged in polythene bag showed higher soluble solid content compared to control in this study. This result was supported by the study of Mahara & Karki (2024), who concluded that on the sixteenth day of the study, the TSS in bananas packaged in polythene had increased by 16.97% ($p<0.05$) compared to the bananas kept in open space. Similarly, Akter *et al.* (2015), Dovel (2018), Prasad *et al.* (2015), and Yogi *et al.*

(2023) also reported the similar output. The conversion of starch into soluble sugars during ripening is the reason behind rise in soluble solid (Zewter, 2012). Similarly, polythene packaged bananas had higher titratable acidity compared bananas kept in open space in this study, which aligned with the findings of Sahay *et al.* (2015) and Mahara & Karki (2024). However, Yogi *et al.* (2023) found no difference in TA over the course of the 16-day research.

Conclusion

The packaged and treated bananas showed better performance compared to untreated and unpackaged bananas. Among packaging materials, perforated polythene bag packaging resulted maximum reducing in weight loss and delayed ripening. Similarly, among the calcium treatment groups, bananas treated with 5% $CaCl_2$ showed better performance compared to untreated. Combining performance of polythene and calcium treatment showed better performance compared to others. Specifically, polythene bag packing with 5% $CaCl_2$ showed the maximum reduction in weight loss, delay ripening and retaining the sweetness for the longer time compared to other treatments.

ACKNOWLEDGEMENT

We extend our sincere gratitude to our parents, whose unwavering guidance has been a constant source of inspiration. We would like to mention the advisory committee for mentoring. We are also grateful to IAAS, Tribhuvan University, for incorporating the Undergraduate Practicum Assessment (UPA) in the curriculum, providing us with valuable opportunities to engage in research.

DECLARATIONS

Authors contribution

Conceptualization: A.A. and S.J.; Investigation: A.A and S.J.; Data curation: S.J.; Writing -original draft preparation: A.A. and S.J.; Writing-review and editing: A.A, S.J and R.B. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: No supplementary data is available for the paper.

Funding statement: No external funding is available for this study.

Additional information: No additional information is available for this paper.

Publisher's Note: Agro Environ Media (AESA) remains neutral with regard to jurisdictional claims in published maps, figures and institutional affiliations.

REFERENCES

Akter, H., Hassan, M., Rabbani, M., & Mahmud, A. (2015). Effects of Variety and Postharvest Treatments on Shelf Life and Quality of Banana. *Journal of Environmental Science and Natural Resources*, *6*(2). https://doi.org/10.3329/jesnr.v6i2.22113

Bhattarai, D. R. (2018). Postharvest horticulture in Nepal. *Horticulture International Journal*, *2*(6), 458– 460. https://doi.org/10.15406/hij.2018.02.00096

Bhadra, S., & S. K. Sen. (1999). Postharvest storage of custard apple (*Annona squamosa* L.) fruit var. Local green under various chemical and wrapping treatments. *Environment and Ecology*, *1*(4), 322-228.

Dovel, B. E. (2018). Effect of hot water and calcium treatment on the shelf life of “keitt” and “cavendish” bananas from Mozambique. *Egerton University*, *21*, 1–150, http://41.89.96.81:8 080/xmlui/handle/123456789/1751

Dhali, S., Khan, S. a. K. U., Pérez, J. C. D., & Kabir, M. Y. (2024). Effects of Calcium Chloride on Shelf Life and Quality of Banana (*Musa sapientum* cv. Jin). *Journal of the Bangladesh Agricultural University*, *22*(4), 530–538. https://doi.org/10.3329/jbau.v22i4.78872

Elbagoury, M. M., Turoop, L., Runo, S., & Sila, D. N. (2020). Regulatory influences of methyl jasmonate and calcium chloride on chilling injury of banana fruit during cold storage and ripening. *Food Science & Nutrition*, *9*(2), 929–942. https://doi.org/10.1002/fsn3.2058

FAO. (2020). Research on the measurement of post-harvest losses (Issue 21). https://www.fao.org/3/cb6126en/cb6126en.pdf

Gautam, D. M., & Bhattarai, D. R. (2012). Postharvest horticulture. Bhawani Printers. Chabahil Kathmandu, Nepal.

Hailu, M., Seyoum Workneh, T., & Belew, D. (2014). Effect of packaging materials on shelf life and quality of banana cultivars (Musa spp.). *Journal of Food Science and Technology*, *51*(11), 2947– 2963. https://doi.org/10.1007/s13197-012-0826-5

Hernández-Muñoz, P., Almenar, E., Ocio, M. J., & Gavara, R. (2006). Effect of calcium dips and chitosan coatings on postharvest life of strawberries (Fragaria x ananassa). *Postharvest Biology and Technology*, *39*(3), 247–253. https://doi.org/10.1016/j.postharvbio.2005.11.006

Hussain, P. R., Meena, R. S., Dar, M. A., & Wani, A. M. (2011). Effect of post-harvest calcium chloride dip treatment and gamma irradiation on storage quality and shelf-life extension of Red delicious apple. *Journal of Food Science and Technology*, *49*(4), 415–426. https://doi.org/10.1007/s13197-011-0289-0

Izumi, H., & Watada, A. E. (1994). Calcium treatments affect storage quality of shredded carrots. *Journal of Food Science*, *59*(1), 106–109. https://doi.org/10.1111/j.1365-2621.1994.tb06908.x

Kaur, M., & Kaur, A. (2018). Role of Ethrel, Polythene Bags and KMnO4 on Storage Life of Banana cv. Grand Naine. *Journal of Experimental Agriculture International*, 23(3), 1–8. https://doi.org/10.9734/jeai/2018/41600

Mahara, G., & Karki, A. (2024). Packaging Materials and Their Effect on Shelf Life and Quality of Banana in Kailali District of Nepal. *South Asian Research Journal of Agriculture and Fisheries*, *6*(03), 42–52. https://doi.org/10.36346/sarjaf.2024.v06i03.002

MOAD (2021) Statistical Information on Nepalese Agriculture. Agribusiness Promotion and Statistics Division, Statistics Section.

Prasad, R., Ram, R. B., Kumar, V., & Rajvanshi, S. K. (2015). Study on Effect of Different Packaging Materials on Shelf Life of Banana (*Musa paradisiaca* L.) cv. Harichal Under Different Conditions. *International Journal of Pure and Applied Bioscience*, *3*(4), 132–141.

Plich, H., & Wójcik, P. (2001). The effect of calcium and boron foliar application on post-harvest plum fruit quality. *In International Symposium on Foliar Nutrition of Perennial Fruit Plants*, 594, 445-451. https://doi.org/10.17660/ActaHortic.2002.594.57

Rosen, J. C., & Kader, A. A. (1989). Postharvest physiology and quality maintenance of sliced pear and strawberry fruits. *Journal of Food Science*, *54*(3), 656–659.

Raja, V., Saraswathy, S., Premalakshmi, V., Anitha, T., & Venkatesan, K. (2022). Effect of pre-harvest treatments on yield and postharvest quality of banana (*Musa acuminata*) cv. red banana. *The Pharma Innovation Journal*, 11(9), 897-903.

Sahay, S., Mishra, P. K., Rashmi, K., Ahmad, M. F., & Choudhary, A. K. (2015). Effect of post-harvest application of chemicals and different packaging materials on shelf-life of banana (Musa spp) cv Robusta. *The Indian Journal of Agricultural Sciences*, *85*(8), 1042–1045. https://doi.org/10.56093/ijas.v85i8.50826

Sarkar, H. N., Hasan, A. M., & Chattopadhyay, P. K. (1997). Influence of polyethylene packing on the postharvest storage behavior of banana fruit. *Journal of Horticulture*, *10*, 31–39.

Sarkar, H. N., Hasan, M. A., & Chattopadhyay, P. K. (1995). Studies on shelf-life of banana as influenced by chemicals. *Journal of Tropical Agriculture*, *33*(1), 97–100. http://krishikosh.egranth.ac.in/handle/1/5810091201

Singh, S., Brahmachari, V. S., & Jha, K. K. (1998). Effect of calcium and polythene wrapping on storage life of mango. *Indian Journal of Horticulture*, *55*(3), 218–222.

Turan (2008) Post-harvest Practices on Fruits. 12: 3, July- August, (in Turkish).

Tyl, C., & Sadler, G. D. (2017). pH and Titratable Acidity. *Food science text series*, pp. 389–406). https://doi.org/10.1007/978-3-319-45776-5_22

Wójcik, P., & Lewandowski, M. (2003). Effect of calcium and boron sprays on yield and quality of "Elsanta" strawberry. *Journal of Plant Nutrition*, *26*(3), 671–682. https://doi.org/10.1081/pln-120017674

Yogi, L. N., Adhikari, S. P., Bohara, K., & Thapa, D. (2023). Comparative analysis of different packaging materials on the postharvest performance of banana fruits. *International Journal of Horticulture and Food Science*, *5*(2), 01–06. https://doi.org/10.33545/26631067.2023.v5.i2a.169

Zewter, A. (2012). Effect of 1-methylcyclopropene, potassium permanganate and packaging on quality of banana. *African Journal of Agricultural Reseearch*, *7* (16), 2425–2437. https://doi.org/10.5897/ajar11.1203