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Original Article

Color quality and pedicel abscission of calamansi (x *Citrofortunella microcarpa*) stored in CoolBot-equipped cold room

Emma Ruth V. Bayogan[1*], Maria Victoria O. Pasilan[1], Leizel B. Secretaria[1], Michael Angela J. Urquiola[1] and Jenny H. Ekman[2]

ABSTRACT

Calamansi or calamondin, also known as the Philippine lime (x *Citrofortunella macrocarpa*), is a vitamin C-rich citrus fruit with a growing demand in the food industry. However, calamansi fruit is highly perishable and has limited shelf life. In this study, the quality and shelf life of calamansi fruit was evaluated under two different storage conditions: a CoolBot-equipped cold room (12.78°C±5.04°C; 80.22% ±10.04% RH) and ambient conditions (26.85°C ±0.50°C; 85.8% ± 3.60% RH). At 10 days of storage (DAS) in a CoolBot-equipped cold room, 36% less fruit than those in the ambient showed ≥ 51% yellowing, indicating slower color change. At 10 DAS, the low temperature storage resulted in fruit weight loss reduced by up to 5.8%; slower pedicel abscission by 10% and reduced shriveling by 31%. At 15 DAS, 36% and 78% of the fruit showed ≥ 51% yellowing in CoolBot-equipped cold room and ambient, respectively. Fruit samples kept in the CoolBot-equipped cold store had more negative a* values, indicating greater greenness of the calamansi peel. Compared to ambient-stored fruit, hue was higher while the chroma was lower. Moreover, fruit stored in the CoolBot-equipped cold room exhibited better visual quality and controlled decay incidence for up to 20 days of storage. These findings indicate that the shelf life of calamansi fruit can be effectively extended in a CoolBot-equipped room due to reduced deterioration and senescence.

Keywords: Calamondin, decay reduction, low temperature storage, Philippine lime

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[1]University of the Philippines Mindanao, Mintal, Tugbok District, Davao City, 8000, Philippines
[2]Applied Horticultural Research, Suite 352, Biomedical Bldg, 1 Central Avenue, Australian Technology Park, Eveleigh N.S.W. 2015, Australia

*Corresponding Author. Address: University of the Philippines Mindanao, Mintal, Tugbok District, Davao City, 8000, Philippines; Email: evbayogan@up.edu.ph

INTRODUCTION

The Philippine lime, locally known as calamansi (× *Citrofortunella microcarpa*), calamondin, or *lemonsito*, is recognized by the Department of Agriculture as a highly valued indigenous crop in the country (Lamberte, 2018). In 2019, domestic production of calamansi ranked fourth after banana, mango, and pineapple, reaching nearly 126,000 metric tons (Quijano et al., 2021; PSA, n.d.). The highest export volume of calamansi was also recorded that year, at 99 metric tons, with an average annual growth rate of 43% in exports since 2015 (PSA, n.d.). The major export markets of fresh calamansi were Canada, United Arab Emirates, and Hong Kong (Agravante et al., 2013). This highlights the relatively small share of Philippine calamansi exports compared to its total domestic production. Still, it also indicates strong potential for expanding calamansi export volumes due to increasing international demand.

However, calamansi production is facing setbacks in long distance transportation from farm to markets, high perishability and short shelf-life. Fresh and marketable calamansi fruit is harvested and sold at mature-green stage while full yellow calamansi are already considered overripe and associated with reduced commercial value at the retail level (Agravante et al., 2013). Rapid peel yellowing is hastened under ambient conditions (27.39 ± 0.48°C, 83.72 ± 2.05% RH) with more than 60% of peel yellowing taking place within six days of storage (Bayogan & Secretaria, 2018). Furthermore, ambient storage conditions also promote the growth of microorganisms. At retail, Agravante et al. (2013) reported 86% decay incidence caused by *Penicillium digitatum* in calamansi fruit shipped from Mindanao to Metro Manila.

Nevertheless, cooling treatment, particularly cold storage, extends fruit shelf life as it reduces rates of fruit respiration and biochemical changes, and delays microorganism growth (Singh et al., 2014; Kusumaningrum et al., 2015). In addition, storing citrus at 7–10°C with 85–95% RH suppressed fungal decay and prevented chilling injury for short-term storage (Thompson et al., 1996). Cold storage systems are however expensive and uneconomical for small-scale calamansi producers.

As a low-cost alternative, the CoolBot system enables digital air-conditioning units in insulated rooms to maintain temperatures between 0–18°C (CoolBot, 2017). It can be remotely monitored via a mobile app, making it user-friendly for smallholder farmers (Tolesa & Workneh, 2018). CoolBot-equipped cold rooms have effectively slowed deterioration in fruits such as mangosteen (Tac-an et al., 2021), mango (Karithi, 2016), tomato (Majubwa et al., 2022), and sweet orange (Acharya et al., 2020), by reducing weight loss, delaying ripening, and preserving overall quality.

To date, CoolBot technology has not yet been tested on Philippine limes. This study evaluated the effects of low-temperature storage using CoolBot technology on peel color, pedicel abscission, and overall visual quality in wholesale-purchased calamansi fruit.

MATERIALS AND METHODS

Sample Preparation

Newly-harvested mature-green calamansi fruit of uniform quality and size, with intact pedicels and slight presence of scabs, were selected and procured from

Bankerohan Public Market, Davao City. Samples were then transported to the Postharvest Biology Laboratory of the University of the Philippines, Mintal, Davao City for postharvest quality evaluation. Fruit were initially disinfected with 200mg L^{-1} NaOCl solution for 3min and were air dried. Samples were then divided into three replicates consisting of 550-600g calamansi and were placed in clean plastic trays with two sheets of paper on top of the fruit pile and then stored in designated treatment conditions (Table 1). Evaluation of samples during storage was done every five days until 20 days. Two trials were conducted from November to December 2021.

Table 1. Average temperature and relative humidity of individual treatment conditions of two storage trials in calamansi.

Storage Conditions	Trial 1 (November 2021)		Trial 2 (December 2021)	
	Temperature (°C)	Relative Humidity (%)	Temperature (°C)	Relative Humidity (%)
Ambient	26.78 ± 0.51	85.78 ± 3.96	26.84 ± 0.49	85.63 ± 3.22
CoolBot-equipped cold storage	11.41 ± 3.44	77.06 ± 7.05	13.21 ± 5.31	81.43 ± 10.46

DATA GATHERED

Percentage Weight Loss and Shriveling

Fruit samples were assessed for weight loss, shriveling, yellowing, peel color, decay incidence and visual quality. For weight loss, initial weight and final weight per evaluation day of each replicate were measured. Percentage weight loss was calculated using Equation 1. Meanwhile, shriveling was measured by obtaining the number of calamansi fruit that exhibited ≥ 20% shriveled fruit surface area. Percentage of shriveling was calculated using Equation 2.

$$\%\text{Weight Loss} = \frac{\text{Initial Weight-Final Weight}}{\text{Initial Weight}} x100 \quad (1)$$

$$\%\text{Shriveling} = \frac{\text{Total number of shriveled fruit}}{\text{Total number of fruit per replicate}} x100 \quad (2)$$

Pedicel Abscission

The total number of calamansi fruits without intact pedicels and the total number of fruit per replicate were recorded. The percentage of pedicel abscission was calculated using Equation 3.

$$\%\text{Pedicel Abscission} = \frac{\text{Total number of fruit without pedicel}}{\text{Total number of fruit in a replication}} x100 \quad (3)$$

Peel Color and Yellowing

Peel yellowing in calamansi fruit was measured based on the assessment method of Bayogan and Secretaria (2018). Fruit samples were classified according to the percentage of yellowing on the fruit surface area, specifically into the following categories: ≤25%, 26–50%, and ≥51% yellowing. The percentage of fruit samples in each classification was calculated using Equation 4. Meanwhile, the peel color of calamansi samples in Trial 2 was objectively measured using L, a, b*, chroma, and hue angle (h°) color values, with a Nix Pro Color Sensor™ (Nix Sensor Ltd., Ontario, Canada).

$$\%Yellowing = \frac{\text{Total number of fruit per designated degree of yellowing}}{\text{Total number of fruit in a replication}} x100 \qquad (4)$$

Decay Rating and Incidence

Per sampling period, five earlier identified samples were obtained from each replicate for the decay rating of fruit. A scale of 1–5 was used where 1 = no disease, 2 = 1 5% of surface area decayed, 3 = 6 10% of surface area decayed, 4 = 11–15% of surface area decayed, and 5 = ≥16% of the surface area decayed. Calamansi fruit showing some decay in each replicate was separated and counted. Percent decay incidence was calculated using Equation 5.

$$\text{Decay Incidence}(\%) = \frac{\text{Total number of fruit with decay}}{\text{Total number of fruit in a replication}} x100 \qquad (5)$$

Visual Quality

Five earlier identified calamansi fruit per replicate for each treatment were assessed for visual quality and was evaluated according to Bayogan and Secretaria (2018) scale wherein 9–8 = excellent, field fresh; 7–6 = very good, with slight defects; 5–4 = good, with defects progressing, limit of saleability; 3–2 = fair, with defects, limit of edibility; and 1 as poor and unsaleable.

Experimental Design and Statistical Analysis

The experiment was laid out in a completely randomized design with two treatments and three replications for each treatment. Each replicate consists of 550–600 g calamansi and was used for determination of weight loss and percentage peel yellowing. Five samples per replicate were assessed for decay rating and incidence, peel color and visual quality. Data were analyzed using Independent Sample T-test Analysis at 95% confidence level.

RESULTS AND DISCUSSION

Weight Loss and Shriveling

In both trials, calamansi fruit stored in ambient conditions showed an average weight loss of 7.7% at 5 days after storage (DAS) while there was a 3-8% higher weight loss compared to fruit stored in CoolBot conditions at 10-15 DAS (Figures 1A and 1B). Moreover, ≥ 20% shriveling increased during storage, particularly in fruit stored under ambient conditions, with 100% of samples showing signs of shriveling at 20 and 15 DAS for Trials 1 and 2, respectively (Figures 1C and 1D) as a consequence of greater weight loss. Conversely, the incidence of shriveling was minimized in fruit subjected to low temperature treatment, particularly in Trial 2.

This is consistent with the earlier findings of Bayogan and Secretaria (2018), where a 7.45% weight loss was incurred after six days of storage under ambient conditions. The higher weight loss in ambient-stored calamansi can be attributed to greater water loss induced by elevated temperatures (Sun et al., 2022). Additionally, excessive water loss has been found to cause fruit softening and shriveling in citrus fruits (Rymbai et al., 2024). On the other hand, Bhusal et al. (2025) observed reduced weight loss in mandarin oranges stored in a CoolBot-equipped cool chamber for 28 to 49 days.

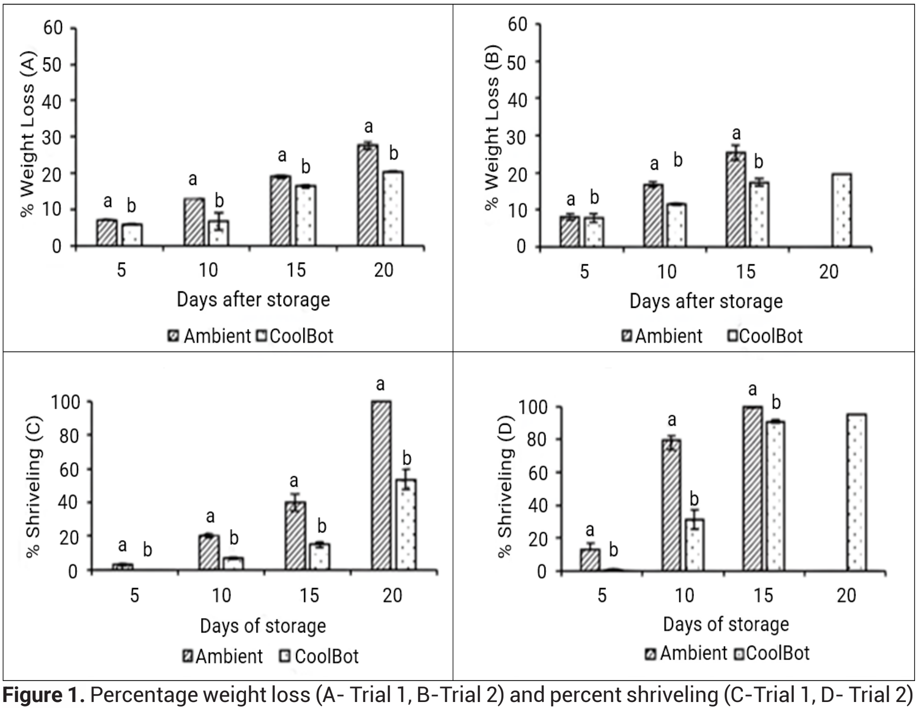

Figure 1. Percentage weight loss (A- Trial 1, B-Trial 2) and percent shriveling (C-Trial 1, D- Trial 2) of calamansi fruit stored under ambient and CoolBot-equipped cold room conditions. Bars represent standard deviation values. Different letters per day of storage indicate a significant difference between treatments at $p \leq 0.05$.

Pedicel Abscission

In both trials, pedicel abscission as indicated by ≥ 20% shriveling progressed significantly in ambient-stored samples, with abscission incidence higher by approximately 9% to 37% at 15 DAS (Figure 2A–2B). Meanwhile, the CoolBot-equipped cold storage effectively retained intact pedicels, limiting abscission incidence to 0–2% among calamansi samples throughout the entire storage period in both trials.

Yuan and Burns (2004) reported that elevated temperatures above 15°C promoted a spike in ethylene production, which reduced fruit detachment force in citrus and consequently increased abscission rates. A similar mechanism may underlie the pedicel abscission in calamansi. Additionally, ethylene has been shown to stimulate cellulase activity in the abscission zones (Kazokas & Burns, 1998), which could further contribute to pedicel detachment. The earlier report of Bayogan and Secretaria (2018) demonstrated that the application of 1-MCP, an ethylene inhibitor, delayed pedicel abscission in calamansi.

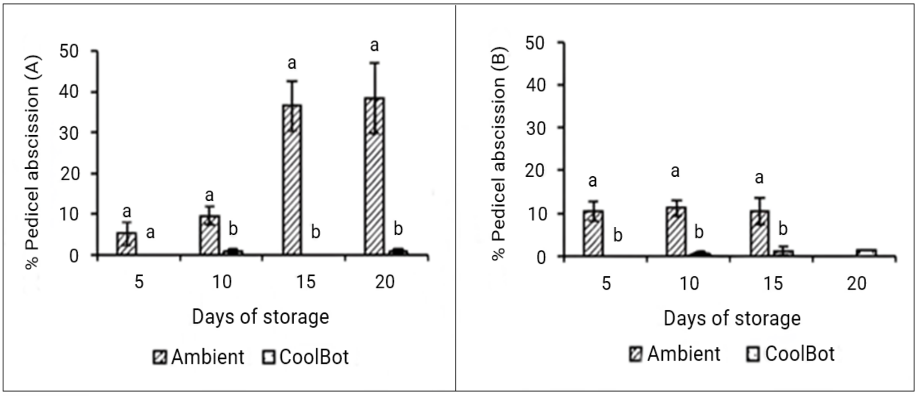

Figure 2. Percentage of pedicel abscission (A-Trial 1, B-Trial 2) in calamansi fruit stored under ambient and low temperature conditions. Bars represent standard deviation values. Different letters per day of storage indicate a significant difference between treatments at $p \leq 0.05$.

On the other hand, ethylene treatment in citrus fruit was found to have no influence on fruit detachment force and abscission when exposed to low air temperatures of 10–15°C (Yuan & Burns, 2004). In other studies, Lado et al. (2015) on grapefruit and Zou et al. (2014) on papaya indicated that ethylene levels in these cold-stored produce remained low, and ethylene production appeared to be suppressed. The low abscission incidence in the present CoolBot-stored calamansi may be due to slower fruit physiological processes due to the lower temperature.

Peel Color and Yellowing

Figures 3A and 3B show that at 10 and 15 DAS in the CoolBot-equipped cold room, there were more fruit (75% and 64%, respectively) that were in the ≤ 50% yellow stage while only 39% and 22%, respectively, remained in this peel color stage in ambient storage. At 15 DAS, 36% and 78% of the fruit showed ≥ 51% yellowing in the CoolBot-equipped cold room and ambient stores, respectively. About 41% of the samples in Trial 1 and 81% in Trial 2, stored under ambient conditions, were developing into the full yellow stage, reaching over 51% yellowing as early as 10 DAS in Trial 2 and 15 DAS in Trial 1. In contrast, 29% and 32% of calamansi fruit stored at low temperature using CoolBot remained more green than yellow, exhibiting 26%-50% yellowing after 20 days in Trials 1 and 2, respectively.

This was further confirmed by the higher b* color values, which indicate yellowness, and higher L* values, which represent the lightness of the peel (Figure 4). Meanwhile, fruit samples kept in the CoolBot-equipped cold store had more negative a* values, indicating greater greenness of the calamansi peel over the entire storage duration. Due to the above b* and a* values, CoolBot-stored fruit had shown higher hue and lower chroma throughout storage compared to ambient-stored fruit.

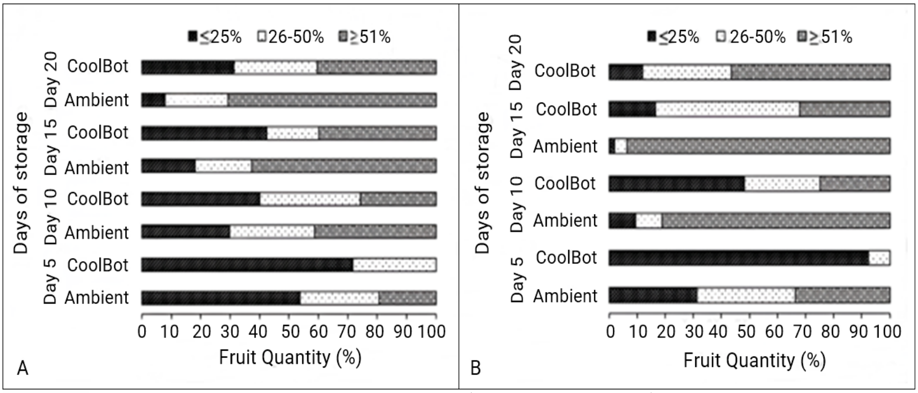

Figure 3. Percentage of yellowing of calamansi (A-Trial 1, B-Trial 2) stored under ambient and CoolBot-equipped cold room conditions.

Porat (2008) reported that high temperatures hasten chlorophyll degradation in citrus fruit. This might be due to evolution of ethylene production at these temperatures (Yuan & Burns, 2004). Yin et al. (2016) found that upon exposure to ethylene, CitERF13 transcript levels increase which triggers expression of pheophorbide hydrolase, the enzyme responsible for chlorophyll breakdown. Moreover, degreening of citrus fruit at low temperatures was seen to progress slowly (Rymbai et al., 2024) and can be associated with reduced ethylene production at cold storage (Saltveit, 1999).

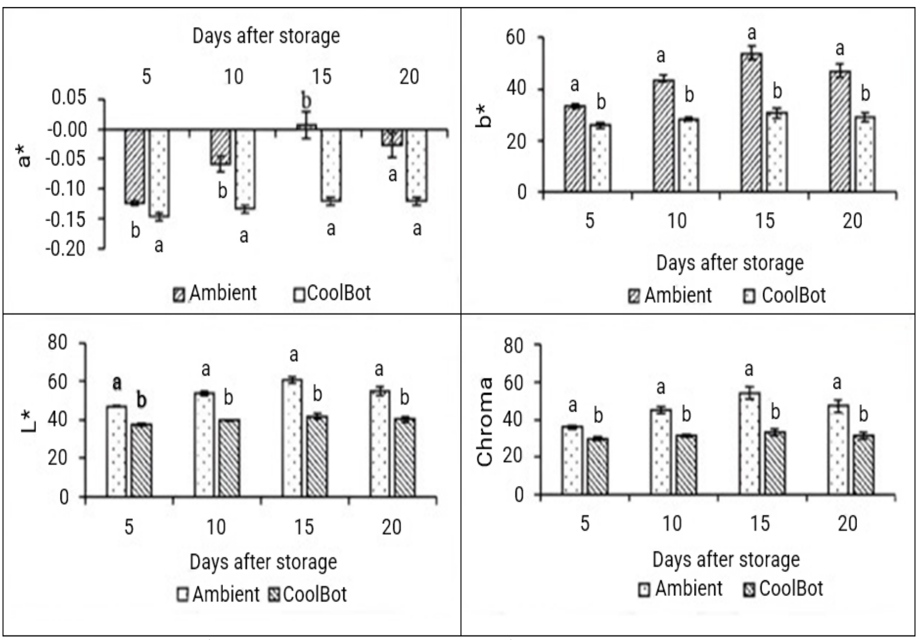

Figure 4. Peel color (L*, a* and b*, chroma and hue) of calamansi stored under ambient and CoolBot conditions (Trial 2). Bars represent standard deviation values. Different small letters per day of storage indicate a significant difference between treatments for Trial 1 at $p \leq 0.05$.

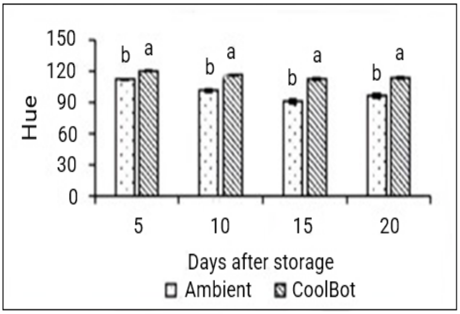

Figure 4. continued

Decay Incidence and Rating

By 15 DAS, decay incidence among ambient-stored samples exceeded 26% in both trials, reaching up to 50% by the end of the storage period. The samples exhibited decay rating scores of 2 to 3, indicating 5–10% decay in the fruit surface area throughout the storage duration (Figures 5A–5D). However, fruit stored in CoolBot cold storage exhibited no signs of decay throughout the entire storage period in Trial 1, and a decay incidence of only 7% by the end of the 20-day storage period in Trial 2.

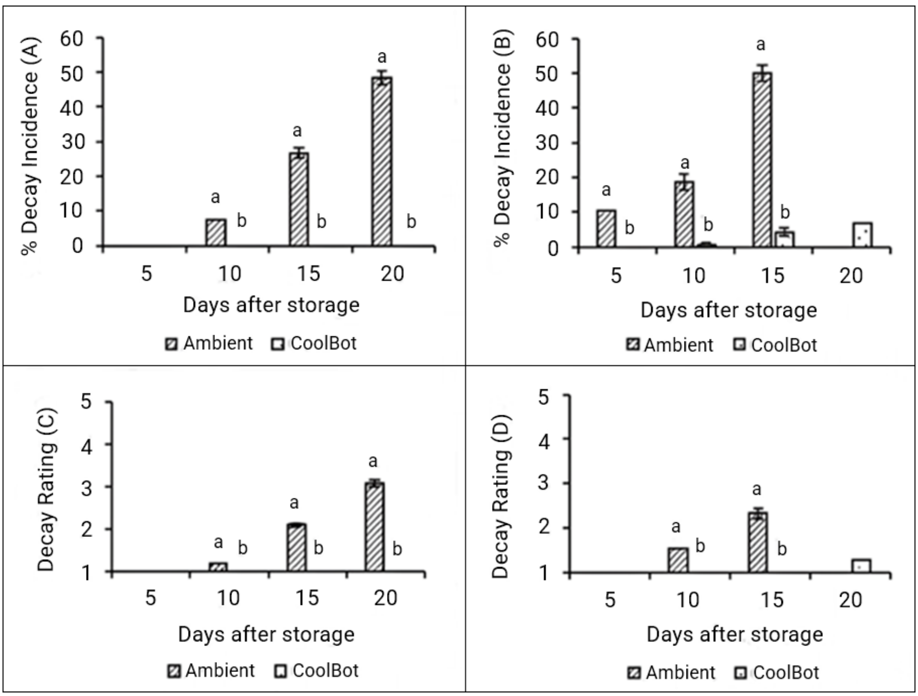

Figure 5. Percentage of decay incidence (A-Trial 1, B-Trial 2) and decay rating (C-Trial 1, D-Trial 2) of calamansi fruit stored under ambient and CoolBot conditions. Bars represent standard deviation values. Different letters per day of storage indicate a significant difference between treatments at $p \leq 0.05$.

Higher disease incidence in fruit samples is due to elevated temperatures and high humidity in ambient conditions, as these favor fungal and bacterial development (Kusumaningrum et al., 2015; Lamberty & Kreyenschmidt, 2022). In addition, these conditions also accelerate fruit ripening, increasing sugars in fruit, making samples more susceptible to microbial growth (Serrano & Bautista, 2007). At retail levels, deterioration by *Penicillium digitatum* is prevalent in Philippine calamondin causing losses of up to 86% (Agravante et al., 2013).

On the other hand, low temperature storage is reported to reduce respiration and decay in blood orange fruit (Habibi et al., 2024). A similar study conducted by Rab et al. (2012) showed that storage of citrus fruit in 10°C effectively prevented decay development. Bhusal et al. (2025) also observed the lowest percentage of decay loss among mandarins stored in CoolBot cold chambers.

Visual Quality

Visual quality was significantly better in calamansi fruit stored in the CoolBot system throughout the entire storage period in both trials (Figures 6A and 6B). At 15 DAS, CoolBot-stored calamansi remained marketable, with a visual quality score of 4–5 in both trials. This can be attributed to a higher percentage of fruit with intact pedicels, lesser shriveling, reduced peel color change, and lower incidence of decay. These effects are due to the low temperature, which inhibits microbial growth and slows down respiration and metabolic activities, thereby delaying ripening and senescence (Habibi et al., 2020).

On the other hand, ambient-stored fruit samples had changed more quickly into poor and non-marketable quality due to higher incidence of decay; faster peel yellowing, pedicel abscission and shriveling as early as 10 days of storage in Trial 2 (Figure 6B, Figure 7).

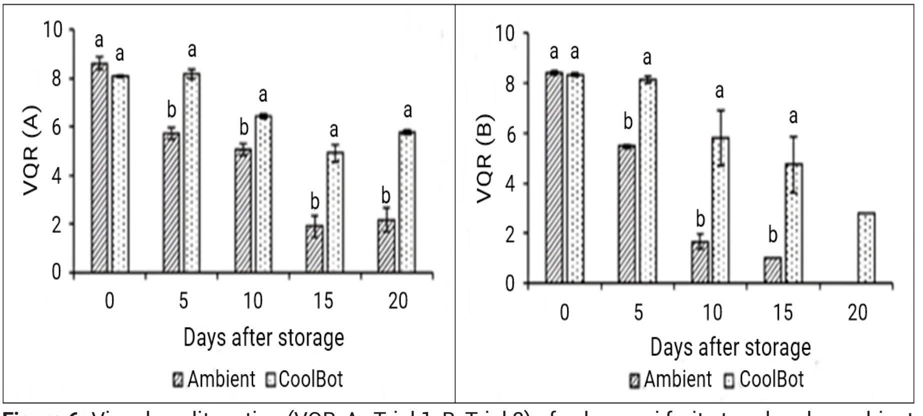

Figure 6. Visual quality rating (VQR, A- Trial 1, B-Trial 2) of calamansi fruit stored under ambient and CoolBot cold room conditions. Bars represent standard deviation values. Different letters per day of storage indicate a significant difference between treatments at $p \leq 0.05$.

CoolBot cold storage has also been shown to extend the shelf life of various fresh produce. Tac-an et al. (2021) reported that storing reddish-purple and dark-purple mangosteen in CoolBot extended shelf life by 21 days. Similarly, the shelf life of 'Apple' mango increased by 23 days when stored at 10 ± 2°C (Ambuko et al., 2018). In addition, shelf life of dragon fruit and tomato was extended by more than 2.5 days and up to 42 days, respectively (Khatun et al., 2022; Majubwa et al., 2022).

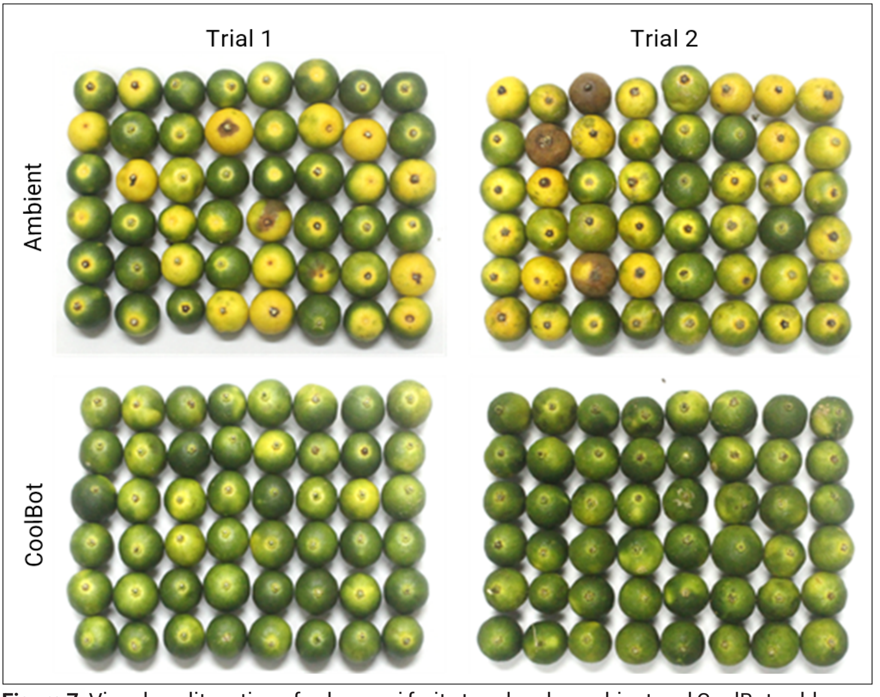

Figure 7. Visual quality rating of calamansi fruit stored under ambient and CoolBot cold room conditions at 10 days of storage.

CONCLUSION

The study evaluated the postharvest physical quality of calamansi fruit stored under two storage conditions (ambient or room temperature and low temperature using the CoolBot technology). Storage of fruit at low temperature conditions using CoolBot technology maintained better quality of calamansi fruit longer compared to storage in ambient room conditions. The CoolBot-equipped cold room reduced weight loss, shriveling and occurrence of disease in calamansi fruit during storage. Storage of fruit in low temperatures retained the pedicel of fruit and slowed down changes in fruit up to 20 days. Better quality of fruit stored in the CoolBot-equipped cold room was maintained until 10 days with a visual quality rating of 4-5 that was still considered marketable. At 10 and 15 days after storage (DAS) in the CoolBot-equipped storage, there were more fruit (75% and 64%, respectively) that were in the ≤ 50% yellow stage while only 39% and 22%, respectively, remained in this peel color stage in ambient storage. At 15 DAS, 36%

and 78% of the fruit showed ≥ 51% yellowing in the CoolBot-equipped cold room and ambient stores, respectively. These results indicate that the use of CoolBot technology in an insulated room store significantly maintained good quality by maintaining intact pedicels and slowing down color change and extended the shelf life of calamansi fruit. Thus, it is an effective technology that can preserve the fresh quality of calamansi and help reduce postharvest losses.

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Author Contributions

ERVB conceptualized the study, checked the protocol and data, and checked the manuscript overall; MVOP gathered and analyzed the data and prepared the initial draft of the manuscript; LBS helped in the procurement of the samples, prepared the figures, and added to the discussion; MAJU assisted with the tests and revisions; and JHE helped secure funding for the study and provided critical suggestions in the implementation of the study and improvement of the paper.

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Availability of Data and Materials

The data underlying these results can be obtained from the corresponding author upon reasonable request.

Ethical Considerations

This study did not involve the use of human or animal subjects.

Competing Interest

The authors declare no competing interests.

References

Acharya, U. K., Pakka, R., & Thapa, B. (2020). Effort to enhance storability of Nepali sweet orange (Citrus sinensis) under different storage conditions. *Journal of the Institute of Agriculture and Animal Science, 36*(1), 207–214. https://doi.org/10.3126/jiaas.v36i1.48420

Agravante, J. U., Serrano, E. P., Masilungan, G. D., Amatorio, E. Q., Castillo, P. C., Domingo, C. L., & Paz, R. R. (2013). Postharvest losses in the supply chain of calamansi (×Citrofortunella microcarpa) and loss reduction with modified atmosphere packaging. *Acta Horticulturae, 1006*, 49–56. https://doi.org/10.17660/ActaHortic.2013.1006.4

Ambuko, J., Karithi, E., Hutchinson, M., Wasilwa, L., Hansen, B., & Owino, W. (2018). Postharvest shelf life of mango fruits stored in a CoolBotcold room. *Acta Horticulturae, 1225*, 193–198. https://doi.org/10.17660./ActaHortic.2018.1225.25

Bayogan, E.V., & Secretaria, L.B. (2018). Yellowing and pedicel abscission are delayed in calamansi (×Citrofortunella microcarpa) fruit treated with 1-methylcyclopropene. *Acta Horticulturae, 1213*, 28. https://doi.org/10.17660/ActaHortic.2018.1213.41 7–292.

Bhusal, S., Acharya, B., Adhikari, S., Giri, H.N., Acharya, K.U., Shrestha, A.K., Adhikari, D., & Shrestha, S. (2025). Effect of storage conditions and plastic packaging on postharvest quality of mandarin (Citrus reticulata Blanco) in Dhankuta, Nepal. *International Journal of Horticulture, Agriculture and Food Science, 9*(2), 20–35. https://doi.org/10.22161/ijhaf.9.2.3

CoolBot™. (2017). *How to build a walk-in cooler for your small farm*. Retrieved from https://agriculture.sc.gov/wp-content/uploads/2017/08/How-to-Build-a-Walk-In-Cooler-for-Your-Small-Farm-3.17.pdf

Habibi, F., Ramezanian, A., Guillén, F., Castillo, S., Serrano, M., & Valero, D. (2020). Changes in bioactive compounds, antioxidant activity, and nutritional quality of blood orange cultivars at different storage temperatures. *Antioxidants, 9*(10), 1016. https://doi.org/10.3390/antiox9101016

Habibi, F., Shahid, M.A., Spicer, R.L., Voiniciuc, C., Kim, J., Gmitter Jr., F.G., Brecht, J.K., & Sarkhosh, A. (2024). Postharvest storage temperature strategies affect anthocyanin levels, total phenolic content, antioxidant activity, chemical attributes of juice, and physical qualities of blood orange fruit. *Food Chemistry Advances, 4*, 100722. https://doi.org/10.1016/j.focha.2024.100722

Karithi, E.M. (2016). *Evaluation of the efficacy of CoolBot™ cold storage technology to preserve quality and extend shelf life of mango fruits* (Doctoral dissertation, University of Nairobi). University of Nairobi Research Archive. https://erepository.uonbi.ac.ke/bitstream/handle/11295/99562/KARITHI%20ESTHER%20THESIS%Final.pdf?sequence=1&isAllowed=y

Kazokas, W.C., & Burns, J.K. (1998). Cellulase activity and gene expression in citrus Fruit Abscission Zones during and after Ethylene Treatment. *Journal of the American Society for Horticultural Science, 123*(5), 781–786. https://doi.org/10.21273/JASHS.123.5.781

Khatun, Z., Dash, P.K., & Mannan, M.A. (2022). Influence of precooling systems on postharvest quality and shelf life of dragon fruits (Hylocereus polyrhizus). *Journal of the Bangladesh Agricultural University, 20*(3), 313–322. https://www.researchgate.net/publication/363602699_Influence_of_precooling_systems_on_postharvest_quality_and_shelf_life_of_dragon_fruits_Hylocereus_polyrhizus

Kusumaningrum, D., Lee, S. H., Lee, W. H., Mo, C., & Cho, B. K. (2015). A review of technologies to prolong the shelf life of fresh tropical fruits in Southeast Asia. *Journal of Biosystems Engineering, 40*(4), 345–358. https://doi.org/10.5307/JBE.2015.40.4.345

Lado, J., Rodrigo, M.J., & Zacarías, L. (2015). Analysis of ethylene biosynthesis and perception during postharvest cold storage of Marsh and Star Ruby grapefruits. *Food Science and Technology International, 21*(7), 537–546. https://doi.org/10.1177/1082013214553810

Lamberte, M. (2018). *Smallholder commodity systems in high-value crops: The case of calamansi and jackfruit in the Philippines.* Southeast Asian Regional Center for Graduate Study and Research in Agriculture. https://serpp.pids.gov.ph/publication/public/view?slug=smallholder-commodity-systems-in-high-value-crops-the-case-of-calamansi-and-jackfruit-in-the-philip

Lamberty, A., & Kreyenschmidt, J. (2022). Ambient parameter monitoring in fresh fruit and vegetable supply chains using Internet of Things-enabled sensor and communication technology. *Foods, 11*(12), 1777. https://doi.org/10.3390/foods11121777

Majubwa, R.O., Msogoya, T.J., Mtui, H.D., & Shango, A.J. (2022). CoolBot cold room technology enhances postharvest quality and shelf-life of tomato (Solanum lycopersicum L.) fruits. *Tanzania Journal of Agricultural Sciences, 21*(1), 11–21. https://www.researchgate.net/publication/352169954_CoolBot_Coldroom_Technology_Enhance_Postharvest_Quality_and_Shelf-life_of_Tomato_Solanum_lycopersicum_Fruits

Philippine Statistics Authority (PSA). (n.d.). *Fruits: Supply utilization accounts by commodity, year and item.* Retrieved June 7, 2025, from https://openstat.psa..gov.ph/PXWeb/pxweb/en/DB/DB__2B__AA__SU/0012B5FSUA4.px/

Porat, R. (2008). Degreening of citrus fruit. *Tree and Forestry Science and Biotechnology, 2*(1), 71–76. http://www.globalsciencebooks.info/Online/GSBOnline/images/0812/TFSB_2(SI1)/TFSB_2(SI1)71-76o.pdf

Quijano, M.F., Quijano, G., & Diaz, R. (2021). Agricultural economic production of Philippine calamansi industry: A basis for production local development plan. *Preprints*. https://doi.org/10.20944/preprints202102.0388.v1

Rab, A., Sajid, M., Khan, N.U., Nawab, K., Arif, M., & Khattak, M.K. (2012). Influence of storage temperature on fungal prevalence and quality of citrus fruit (cv. Blood Red). *Pakistan Journal of Botany, 44*(2), 831–836. https://www.researchgate.net/publication/265939793_Influence_of_storage_temperature_on_fungal_prevalence_and_quality_of_citrus_fruit_cv_Blood_Red

Rymbai, H., Verma, V.K., Talang, H.D., Devi, M.B., Teja, R., Rymbai, D., & Mawlein, J. (2024). Exogenous ethylene induced degreening in colour development of citrus fruits: An overview. *International Journal of Innovative Horticulture, 13*, 40–48. https://indianjournals.com/article/ijih-13-1-004

Saltveit, M. E. (1999). Effect of ethylene on quality of fresh fruits and vegetables. *Postharvest Biology and Technology, 15(3),* 279–292. https://doi.org/10.1016/S0925-5214(98)00091-X

Serrano, E. P., & Bautista, O. K. (2007). Physio chemical basis of postharvest handling. In O. K. Bautista & E. B. Esguerra (Eds.), *Postharvest technology for Southeast Asian perishable crops* (pp. 33–53). Postharvest Horticulture Training and Research Center, University of the Philippines Los Baños and Bureau of Agricultural Research-Department of Agriculture. https://nast.dost.gov.ph/images/pdf%20files/Publications/Outstanding-Awardees%20BOOKS/2008/Postharvest%20Technology%20for%20Southeast%20Asia.pdf

Singh, V., Hedayetullah, Md., Zaman, P., & Meher, J. (2014). Postharvest technology of fruits and vegetables: An overview. *Journal of Postharvest Technology, 2*(2), 124–135. https://journals.acspublisher.com/index.php/jpht/article/view/15769

Sun, Y., Li, Y., Xu, Y., Sang, Y., Mei, S., Xu, C., Yu, X., Pan, T., Cheng, C., Zhang, J., Jiang, Y., & Gao, Z. (2022). The effects of storage temperature, light illumination, and low-temperature plasma on fruit rot and change in quality of postharvest Gannan navel oranges. *Foods, 11*(22), 3707. https://doi.org/10.3390/foods11223707

Tac-an, M.I., Lacap, A.T., Bayogan, E.R., & Lubaton, C.D. (2021). Postharvest quality of two mangosteen (Garcinia mangostana L.) fruit maturities held in ambient and CoolBot-equipped cold storage. *Journal of Science, Engineering and Technology, 9*, 48–60. https://pdfs.semanticscholar.org/3cc6/459f593a5626b87e3b8d62418d7afa077934.pdf

Thompson, J., Kader, A.A., & Sylva, K. (1996). *Compatibility chart for fruits and vegetables in short-term transport and storage* (Agriculture and Natural Resources Publication No. 21560). University of California, Division of Agriculture and Natural Resources, Oakland, California. https://postharvest.ucdavis.edu/compatibility-chart-short-term-transport-or-storage

Tolesa, G.N., & Workneh, T.S. (2018). Effects of evaporative cooling and CoolBot air conditioning on changes in the environmental conditions inside the cooling chamber. *Acta Horticulturae, 1201*, 281–288. https://www.researchgate.net/publication/325714944_Effects_of_evaporative_cooling_and_CoolBot_air_conditioning_on_changes_in_the_environmental_conditions_inside_the_cooling_chamber

Yin, X., Xie, X., Xia, X., Yu, J., Furgeson, I., Giovannoni, J.J., & Chen, K. (2016). Involvement of an ethylene response factor in chlorophyll degradation during citrus fruit degreening. *Plant Journal, 86*, 403–412. https://doi.org/10.1111/tpj.13178

Yuan, R., & Burns, J.K. (2004). Temperature factor affecting the abscission response of mature fruit and leaves to CMN-pyrazole and ethephon in 'Hamlin' oranges. *Journal of the American Society for Horticultural Science, 129*(3), 287–293. https://doi.org/10.21273/JASHS.129.3.0287

Zou, Y., Zhang, L., Rao, S., Zhu, X., Ye, L., Chen, W., & Li, X. (2014). The relationship between the expression of ethylene-related genes and papaya fruit ripening disorder caused by chilling injury. *PLoS One, 9*(12), e116002. https://doi.org/10.1371/journal.pone.0116002