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Extending vase life and reducing ethylene production in rose cut flowers using Calamondin *(Citrus macrocarpa)* extract

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ABSTRACT

Purpose: Floral preservative vase solutions commonly use citric acid to reduce the pH of water, thereby extending the vase life of cut flowers. This study was conducted to explore the potential of hydrating solutions in extending the vase life of roses and reducing the production of ethylene. **Research Method:** Cut roses were used to evaluate the efficacy of hydrating solutions (calamondin juice, cinnamon and garlic powder extracts and bamboo wood vinegar) and stem cutting every three days to increase the vase life and slow down changes in the visual quality parameters when added in vase solution. **Findings:** Cut roses subjected to calamondin extract (20 ml/L) had a statistically longer vase life of 11.67 days (37.29% higher than the control), followed by bamboo wood vinegar (9.67 days or 13.76%), while untreated samples had 8.50 days (*p value = 0.000*). Roses treated with cinnamon powder and ginger extract attained limit of fitness for decoration at Day 8. During the peak of ripening at day 7, calamondin treatments reduced the ethylene concentration by 10.60% and resulted in the highest carbon dioxide (0.87% vol), which was statistically different from the other treatments. **Research limitations:** No limitations were identified in the study. **Originality/Value:** The study demonstrated that the addition of calamondin extract significantly slows down deteriorative changes in cut flowers. Given the economic feasibility and widespread availability of calamondin fruits in local markets, this postharvest treatment presents a practical and cost-effective option for flower vendors.

INTRODUCTION

Flowers or flower buds cut from the plant are referred to as cut flowers, and each species of cut flower has a unique vase life and freshness longevity, which are significantly influenced by preharvest factors, harvesting activities and postharvest handling conditions. Vase longevity, which is usually determined by a flower's sensitivity to ethylene, is a major factor influencing consumers' decision to purchase and repurchase cut flowers (Rihn et al., 2015). The vase life of cut flowers is limited due to microbial infection, depletion of organic reserve through respiration, withering, poor water quality, storage temperature, ethylene sensitivity and mechanical damage (Vehniwal & Abbey, 2019). Lower storage temperatures can reduce carbon dioxide production, as flowers undergo high respiratory activity that depletes the already limited organic substrates in the petals.

Tinebra et al. (2021) emphasized that the postharvest storage potential is inversely related to respiration, especially in flowers where organic respiratory reserves are minimal. The quality of a cut flower depends on its morphological traits and longevity, which are measured by the duration of these characteristics. Shelf life is a critical factor in determining the market value of cut flowers (Cavalcante et al., 2021).

Among cut flowers, cultivated roses have the highest production area and market share worldwide, and their ornamental and economic value is significantly influenced by flower opening and senescence (Chen et al., 2023). In the Philippines, cut flower production is limited to a small number of growers. There has been increasing demand for cut flowers in recent years, which triggered greater production; however, despite the expansion of cultivation areas, there is still a shortfall in supply.

Rose (*Rosa* spp.), belonging to the Rosaceae family, is one of the most in-demand ornamental plants in the world for its high economic and cultural importance. Cut rose flowers play a significant role in the rose cultivation industry (Mortazavi et al., 2007). Energy transformation and metabolic activity continue in roses after detachment from the parent plant due to their high content of moisture and richness in endogenous enzymes. Cut roses have a comparatively short vase life, which affects flower longevity, petal abscission, functional petal life, neck bending, wilting and overall deterioration and senescence.

Vase life is strongly influenced by temperature, sunlight exposure during vase storage, hydrating solutions, and the stem's ability to absorb and uptake of water. Previous studies (Darandeh & Hadavi, 2012; Kandel et al., 2021) revealed that adding citric acid in the vase solutions improved flower longevity and extended the postharvest life of cut flowers by controlling microbial activity and lowering the solution's pH. This study evaluated the potential of citric acid from calamondin, cinnamon powder, ginger extracts, and bamboo wood vinegar to extend the postharvest life and reduce ethylene production in the cut rose's samples

Floral preservative solutions are among the most widely used strategies of the flower vendors to enhance quality of cut flowers and other ornamentals (Nguyen et al., 2020). Holding solutions may contain a mixture of plant growth regulators, carbohydrates, mineral salts, organic acids and ethylene inhibitors. Among the many citrus fruit sources of citric acid, calamondin (also known as calamansi) was selected as the key ingredients of the vase solution due to its higher citric acid content and other beneficial properties, making it potentially more valuable, accessible, and economically feasible than other citrus commodities.

Essential oil made from ginger rhizome extracts contains linalool and borneol, and also possesses antifungal and antibacterial properties (Ma et al., 2021), which could enhance plant development. In addition, cinnamon essential oil, which is mostly derived from aldehydes, is popular for its potent antioxidant and antimicrobial properties (Shu et al., 2024), and was found to reduce pathogen infections and rate of deterioration in many vegetables and fruits. Moreover, bamboo wood vinegar or pyrolysis oil, produced from natural carbonization (Sudaria et al., 2016) has acetic acid as the main component and has exhibited potential in enhancing the harvest and postharvest qualities of fruits and vegetables.

MATERIALS AND METHODS

Materials

The materials used in this study included 'Hybrid tea' cut roses (purchased from a rose farm in Valencia, Bukidnon, Philippines), vases, sterile distilled water, hydrating solutions prepared from calamondin fruits, cinnamon powder, ginger, bamboo wood vinegar, BH-4S Portable multi-gas detector, and digital weighing scale.

Methods

Experimental design and treatments

Experimental site: The experiment was conducted in the Postharvest Laboratory Room of the College of Agriculture, University of Southern Mindanao, Kabacan, Cotabato, Philippines. The room conditions during the study were maintained at a temperature range of 25–31 °C, relative humidity of approximately 60%, and light intensity between 700 and 750 lux.

The study was carried out a factorial Completely Randomized Design with two factors and three replications per treatment combination. Factor A refers to the stem cutting (without cutting and with cutting), while factor B refers to the hydrating solutions (untreated/water only, calamondin extract (20 ml/L), cinnamon powder (20 g/L), ginger extract (20 g/L) and bamboo wood vinegar (1 ml/L)). There were 10 cut roses per experimental unit as the test materials. Stems (approximately 60 cm in length) of rose cut flowers were put in vase containers (5 cut flowers per vase, 2 vases per experimental unit) with hydrating solution treatments added to 500 ml of water. Rose stem cutting was done above the nodes, with *45°* angle, at 2 cm stem length. For Factor A, cut roses assigned to the stem cutting treatment were trimmed using sharp, clean cutters at 2-day intervals. The vases used to store the roses were sanitized with a dilute bleach solution prior to addition of vase solution.

Preparation of hydrating solutions

Preparation of calamondin extract: Calamondin juice was manually extracted and homogenized using a mixture of methanol and water. The resulting solution was thoroughly mixed and then diluted with distilled water to achieve a concentration of 20 mL per liter for use as a vase solution. The final pH of the prepared vase solution was 2.80.

Preparation of cinnamon powder: A commercially available cinnamon powder was dissolved in distilled water at a concentration of 20 g per liter. The final pH of the prepared vase solution was 5.0.

Preparation of ginger extract: Ginger extract was prepared from fresh ginger rhizomes, which were washed and dried at 40 °C for 48 hours. The dried rhizomes were ground and stored at 15 °C prior to extraction. Soxhlet extraction was performed using 85% ethanol, followed by concentration and drying of the extract. The final product was stored at 5 °C and subsequently mixed with distilled water at a concentration of 20 g/L for use as a vase solution. The final pH of the prepared solution was 3.6.

Preparation of bamboo wood vinegar: A basic wood vinegar extraction system was established, consisting of key components such as a burning chamber, smoke/gas generator, smoke pipe, smoke chamber, and wood vinegar collector. The process began by stacking bamboo materials inside the smoke/gas generator, which were then left to sit for 90 days to undergo essential purification. The resulting bamboo wood vinegar was mixed with distilled water at a concentration of 1 mL/L for use as a vase solution. The final pH of the prepared solution was 3.4.

Postharvest quality parameters

Data parameters include: A) visual quality rating: rating of 9 – excellent, field fresh, no defect; 7 – good condition, minor defects; 5 – fair condition, moderate defects; 3 – limit of marketability; 2 - poor, serious defects, limit of fitness for decoration; 1 – unfit for decoration; B) bending, discoloration and wilting: 0 – No bending/discoloration/wilting; 1-1-25% bending/discoloration/wilting; 2–26-50% bending/discoloration/wilting; 3 – above 50% bending/discoloration/wilting. Data parameters such as visual quality, neck bending, and petal discoloration and wilting were monitored at days 1, 2,4, 6, 8, 10, 11, 12, while weight loss at days 6, 9 and 11.

Vase life in cut roses refers to the duration (in days) during which the flowers maintain their decorative value, specifically until they reach the threshold of fitness for decoration (VQR-2), following treatment with hydrating vase solutions. It is measured from the time the rose is cut and placed in water until it loses its ornamental appeal due to wilting, petal discoloration, or other signs of senescence.

Gases monitoring: The BH-4S Portable Multi-Gas Detector was used to monitor ethylene, carbon dioxide, and oxygen levels through natural diffusion of ambient air into the device. Gas measurements were conducted every other day, beginning from the initial setup of the experiment.

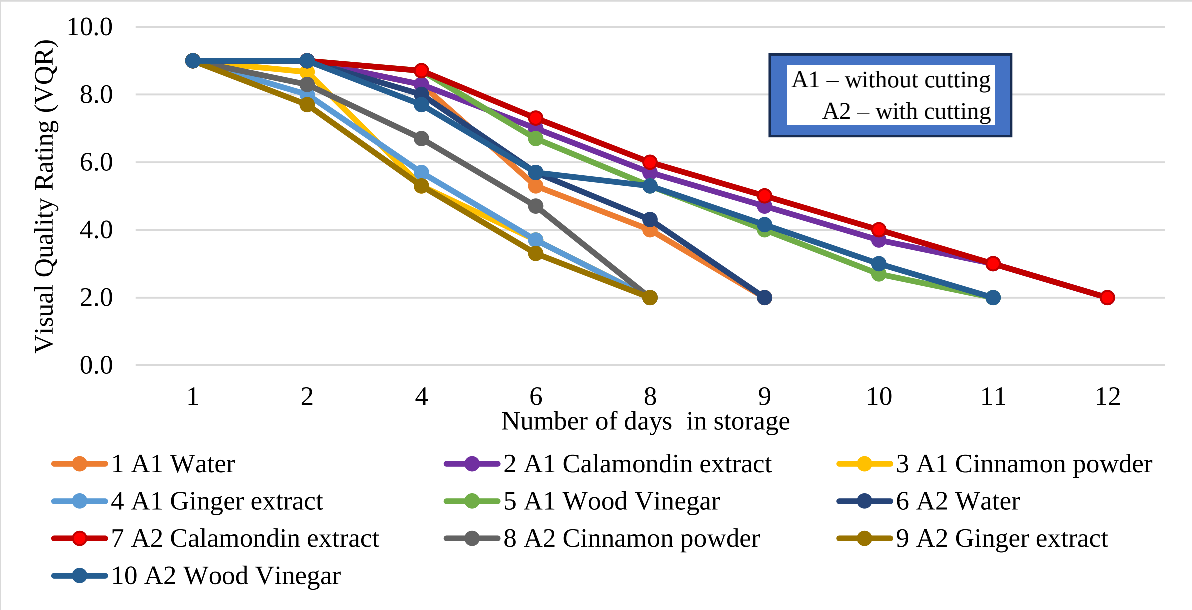
Statistical analysis

All data parameters were subjected to appropriate statistical data analysis using the Statistical Tool for Agricultural Research (STAR), software version 2.0.1. Analysis of Variance (ANOVA) was employed to determine significant differences among treatment means, with the F-test used to assess overall significance. The level of significance was set at 5%, and treatments showing significant differences were further analysed using the Least Significant Difference (LSD) test.

RESULTS

Visual quality rating and vase life

The visual quality rating (VQR) of the treated rose cut flowers is presented in Figure 1. Roses treated with cinnamon powder and ginger extract reached the VQR-2 threshold (the limit of fitness for decoration) earliest, on day 8. In contrast, those treated with calamondin extract and bamboo wood vinegar remained in good condition with minor defects on Day 8, and only reached VQR-2 on days 11 and 9, respectively. For samples subjected to stem recutting every two days, VQR ratings were generally similar to those of samples without stem cutting, provided they received the same hydrating solution treatments. Figures 2 and 3 provide photo documentation of the treated cut flowers at 6 and 11 days after treatment application, showing that the calamondin treatment consistently maintained superior physical appearance compared to the other treatments.



VQR Rating: 9 – excellent, field fresh, no defect; 7 – good, minor defects; 5 – fair, moderate defects; 3 – limit of marketability; 2 - poor, serious defects, limit of fitness for decoration; 1 – unfit for decoration

Fig. 1. Visual quality rating (VQR) of rose cut flowers treated with various hydrating solutions and stem cutting up to 12 days in storage. USM, Kabacan, Cotabato, Philippines, 2025.

Fig. 2. Cut roses treated with various hydrating solutions and stem cutting at day 6. USM, Kabacan, Cotabato, Philippines, 2025.

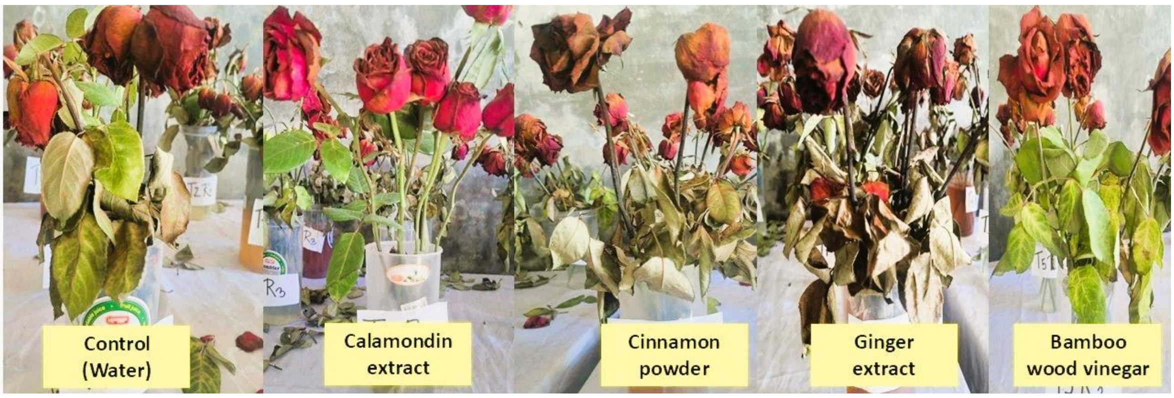


Fig. 3. Cut roses treated with various hydrating solutions and stem cutting at day 11. USM, Kabacan, Cotabato, Philippines, 2025.

Table 1. Vase life or number of days to which the roses attain VQR-2 (limit of fitness for decoration) after treating the cut flowers to four hydrating solutions and to stem recutting for every 2 days. University of Southern Mindanao, Kabacan, Cotabato, Philippines, 2025.

Treatments	Without cutting	With cutting	Factor B**
Water	8.33	8.67	8.50[c]
Calamondin extract	11.67	11.67	11.67[a]
Cinnamon	6.67	7.00	6.83[d]
Ginger	6.67	6.67	6.67[d]
Bamboo wood vinegar	9.00	10.33	9.67[b]
Factor A	8.47	8.87	

	F value	Pr (>F)
Factor A	3.27	0.0855
Factor B	71.14	0.0000
Factor A:Factor B	0.45	0.3308

CV (%) - 6.99; Mean – 8.67 days. **highly significant, Least Significant Difference (LSD) Test. Means followed by different letters are significantly different at $p<0.05$.

Table 2. Neck bending, petal discoloration and wilting of rose cut flowers treated with various hydrating solutions and stem cutting at days 8 and 11 after treatment application. USM, Kabacan, Cotabato, Philippines, 2025.

	Day 8		Day 11	
Treatments	Without Cutting	With Cutting	Without Cutting	With Cutting
	Neck Bending			
Water	3.0	3.0	3.0	3.0
Calamondin extract	1.7	1.7	2.0	2.3
Cinnamon powder	3.0	3.0	3.0	3.0
Ginger extract	3.0	3.0	3.0	3.0
Bamboo wood vinegar	3.0	2.7	3.0	3.0
	Petal Discoloration			
Water	3.0	3.0	3.0	3.0
Calamondin extract	2.0	2.0	2.0	2.0
Cinnamon powder	3.0	3.0	3.0	3.0
Ginger extract	3.0	3.0	3.0	3.0
Bamboo wood vinegar	2.3	2.0	3.0	3.0
	Wilting			
Water	3.0	3.0	3.0	3.0
Calamondin extract	1.3	1.7	2.3	2.3
Cinnamon powder	3.0	3.0	3.0	3.0
Ginger extract	3.0	3.0	3.0	3.0
Bamboo wood vinegar	2.3	2.7	3.0	3.0

Rating Scale: 0 – No bending/discoloration/wilting; 1 - 1-25% bending/discoloration/wilting; 2 – 26-50% bending/discoloration/wilting; 3 – above 50% bending/discoloration/wilting.

Table 1 revealed highly significant differences in the vase life of cut roses based on the type of hydrating solution used (Factor B). However, no significant differences were observed with respect to stem recutting every other two days (Factor A), nor in the interaction between the two factors. Among the treatments, calamondin extract significantly extended the vase life of cut roses to 11.67 days, followed by bamboo wood vinegar at 9.67 days, compared to 8.50 days in the untreated control. No significant interaction was found between hydrating solution type and stem recutting in terms of their effect on vase life.

Additional data parameters reflecting the physical attribute of cut rose flowers on days 8 and 11 after treatment application are presented in Table 2, including neck bending, petal discoloration, and wilting. Among the treatments, calamondin extract demonstrated superior performance. On day 8, cut flowers in all other treatments exhibited notable deterioration in physical appearance, whereas those treated with calamondin showed minimal signs of decline, with neck bending rated at 1.7, petal discoloration at 2.0, and wilting ranging from 1.3 to 1.7—corresponding to a verbal description of 1–25% bending, discoloration, and wilting. Furthermore, no visible differences were observed in the physical characteristics of rose samples regardless of whether stems were recut every other two days.

Table 3. Weight loss percentage (%) of rose cut flowers treated with various hydrating solutions and stem cutting at days 3, 6, 9 and 11 of storage. USM, Kabacan, Cotabato, Philippines. 2025.

Treatments	Without cutting	With cutting	Factor B**
Water	8.33	8.67	8.50^{c}
	Factor A Day6**	Day9*	Day11**
Without cutting	54.72	65.47^{b}	67.47^{b}
With cutting	46.51	79.09^{a}	85.31^{a}
Treatments	Factor B Day6*	Day9^{ns}	Day11 ^{ns}
Water	51.66^{a}	68.71	76.00
Calamondin extract	43.60^{b}	65.13	75.42
Cinnamon powder	52.48^{a}	68.37	76.70
Ginger extract	53.73^{a}	64.93	76.22
Bamboo wood vinegar	51.60^{a}	71.74	77.59
	Factor A × B Day6 ^{ns}	Day9^{ns}	Day11^{ns}
Without Stem Cutting			
Water	55.08^{a}	65.44	68.94
Calamondin extract	52.22^{a}	65.56	66.94
Cinnamon powder	54.62^{a}	63.66	65.33
Ginger extract	55.81^{a}	63.28	66.14
Bamboo wood vinegar	55.86^{a}	69.42	69.98
With Stem Cutting			
Water	48.24^{b}	71.97	83.06
Calamondin extract	34.98^{b}	64.75	83.90
Cinnamon powder	50.33^{a}	73.08	88.07
Ginger extract	51.64^{a}	66.58	86.31
Bamboo wood vinegar	47.35^{b}	74.06	85.20
CV (a) %	11.10	8.60	7.49
CV (b) %	6.41	7.83	4.55
Mean	50.61	67.78	76.39

	Day 6		Day 9		Day 11	
	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)
Factor A	24.01	0.0001	5.14	0.0346	106.66	0.0000
Factor B	4.59	0.0086	1.54	0.2288	0.18	0.9468
FactorA:FactorB	2.05	0.1258	0.70	0.6013	0.85	0.5092

** - highly significant, Least Significant Difference (LSD) Test, * - significant, ns – not significant
Means followed by different letters are significantly different at $p<0.05$.

Weight loss

The percentage weight loss of cut rose flowers as influenced by hydrating solutions and stem recutting, is presented in Table 3. A highly significant interaction was observed between stem recutting and hydrating solution treatents on day 6. Roses with stems recut every two days exhibited significantly lower weight loss when treated with calamondin extract, bamboo wood vinegar, or water, ranging from 34.98 to 48.24% However, on days 9 and 11, roses subjected to stem recutting showed consistently higher weight reduction compared to those without stem cutting. No significant differences were found among the hydrating solution treatments alone, or in the interaction between the two factors, with respect to weight reduction at these later stages.

Table 4. Ethylene (ppm) concentrations of rose cut flowers treated with various hydrating solutions and stem cutting at days 1,3, 5, 7 and 9 of storage. USM, Kabacan, Cotabato, Philippines, 2025.

	Ethylene (ppm)				
	Day1^{ns}	Day3**	Day5**	Day7*	Day9**
Water	20.10	35.50^{ab}	53.33^{b}	88.00^{a}	25.67^{b}
Calamondin extract	20.06	30.50^{c}	49.17^{c}	78.67^{b}	31.33^{a}
Cinnamon powder	20.06	30.33^{c}	49.17^{c}	83.50^{ab}	32.50^{a}
Ginger extract	20.03	37.67^{a}	54.33^{b}	85.50^{a}	25.17^{b}
Bamboo wood vinegar	20.06	34.67^{b}	60.33^{a}	84.83^{a}	25.67^{b}
Ethylene (CV, %)	5.65	6.82	4.14	5.91	5.71
Ethylene (Mean)	20.06	33.73	53.27	84.10	28.07

	Day 3		Day 5		Day 7		Day 9	
	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)
Factor A	0.23	0.6394	1.75	0.2004	0.49	0.4929	0.83	0.3728
Factor B	11.74	0.0000	26.11	0.0000	2.89	0.0485	29.37	0.0000
FactorA:FactorB	0.27	0.8915	1.22	0.3326	0.32	0.8597	0.67	0.6211

**highly significant, LSD Test, * - significant; ns – not significant
Means followed by different letters are significantly different at p<0.05.

Table 5. Carbon dioxide (% vol) concentrations of rose cut flowers treated with various hydrating solutions and stem cutting at Days 1,3, 5, 7 and 9 of storage. USM, Kabacan, Cotabato, Philippines, 2025.

	Carbon dioxide (% Vol)				
	Day 1**	Day3**	Day5^{ns}	Day7*	Day9**
Water	0.75^{a}	3.08^{bc}	3.62	0.73^{bc}	0.44^{a}
Calamondin extract	0.74^{ab}	3.23^{a}	3.69	0.87^{a}	0.31^{c}
Cinnamon powder	0.73^{bc}	3.18^{ab}	3.71	0.79^{b}	0.27^{c}
Ginger extract	0.72^{c}	3.00^{c}	3.55	0.70^{c}	0.41^{b}
Bamboo wood vinegar	0.72^{c}	3.04^{c}	3.55	0.60^{d}	0.39^{b}
Carbon dioxide (CV, %)	2.18	3.06	4.27	8.58	8.80
Carbon dioxide (Mean)	0.73	3.11	3.62	0.74	0.36

	Day 1		Day 3		Day 5		Day 7		Day 9	
	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)
Factor A	0.12	0.7343	4.06	0.0575	1.03	0.3218	0.70	0.4134	0.64	0.4337
Factor B	7.22	0.0009	6.10	0.0022	1.49	0.2422	15.29	0.0000	30.55	0.0000
FactorA:FactorB	0.68	0.6154	0.79	0.5464	0.20	0.9377	2.78	0.0550	0.61	0.6575

**highly significant, LSD Test, * - significant; ns – not significant
Means followed by different letters are significantly different at p<0.05.

Effects on ethylene, carbon dioxide and oxygen

Table 4 presents the ethylene production in cut rose flowers as influenced by four hydrating solutions and stem recutting every two days. Initial ethylene concentrations ranged from 20.03 to 20.10 ppm across all treatments. The peak in ethylene production was observed on day 7 of storage, with the highest concentration recorded in roses treated with water only (88.00 ppm), which was statistically comparable to other treatments except for calamondin extract, which showed a significantly lower concentration of 78.67 ppm. By day 9, ethylene levels in roses treated with calamondin extract and cinnamon powder were statistically comparable.

Tables 5 and 6 present the effects of hydrating solutions and stem recutting on carbon dioxide (CO_2) and oxygen (O_2) concentrations, respectively. During the peak of ethylene production on day 7, roses treated with calamondin extract exhibited the highest CO_2 concentration at 0.87%, which was statistically different from the other treatments. No significant differences were observed in O_2 concentrations among treatment means on day 7, with values ranging from 18.18% to 18.56%. A highly significant interaction between hydrating solution and stem cutting was recorded for oxygen levels on day 3. On this day, roses treated with any hydrating solution but without stem cutting showed statistically comparable oxygen concentrations to those treated with cinnamon powder and stem cutting, with values ranging from 19.95% to 20.50%.

Table 6. Oxygen (% vol) concentration of rose cut flowers treated with various hydrating solutions and stem cutting at days 1,3, 5, 7 and 9 of storage. USM, Kabacan, Cotabato, Philippines, 2025.

	Oxygen (% Vol)			
	Day 1**	Day5**	Day7ns	Day9**
Water	20.70a	19.62a	18.18	15.59b
Calamondin extract	20.28b	19.15c	18.56	16.33a
Cinnamon powder	20.77a	19.50ab	18.48	16.48a
Ginger extract	20.25b	19.28bc	18.28	14.22c
Bamboo wood vinegar	20.82a	19.29bc	18.52	15.65b

	Oxygen at day 3: Factor A×B**	
	Without cutting	With cutting
Water	19.95a	20.03bc
Calamondin extract	20.00a	20.10b
Cinnamon powder	20.07a	20.50a
Ginger extract	20.03a	19.91c
Bamboo wood vinegar	20.10a	20.13b

	Day1	Day3	Day5	Day7	Day9
Oxygen (CV, %)	0.53	0.49	1.11	3.30	2.72
Oxygen (Mean)	20.56	20.08	19.37	18.41	15.65

	Day 1		Day 3		Day 5		Day 7		Day 9	
	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)	F-value	Pr (>F)
Factor A	8.26	0.0094	8.38	0.0090	0.23	0.6339	0.03	0.8727	0.00	0.9763
Factor B	36.67	0.0000	9.52	0.0002	4.59	0.0086	0.45	0.7710	26.35	0.0000
FactorA:FactorB	1.19	0.3473	6.20	0.0021	2.00	0.1335	0.59	0.6769	1.42	0.2631

**highly significant, LSD Test, ns – not significant
Means followed by different letters are significantly different at $p<0.05$.

DISCUSSION

Vase life of cut flowers

Vase life refers to the duration which a cut flower maintains its aesthetic appeal when placed in a vase. This period is assessed through various physical attributes including flower opening, petal coloration, florets, pedicel and stem measurments, fresh weight, senescence patterns, foliage folding and overall longevity (De et al., 2015). Water uptake and water loss of cut flowers are some of the major indicators of the vase life (Frew et al., 2018). The quality and longevity of flowers are influenced by a combination of factors including genetical composition, pre-harvest conditions, techniques used in harvesting, postharvest practices such as handling, packaging, storage and transportation.

The key strategy used by many to extend the postharvest life of cut flowers is through natural products which have anti-microbial properties (lemon juice, fruit extracts and essential oils) which can be used as an alternative to synthetic chemical vase solutions. Postharvest treatments for cut flowers are very crucial in maintaining freshness, quality, and physical attributes, enhancing vase life (Hussen & Yassin, 2013) and reducing waste products of ornamentals by addressing concerns such as respiration, water uptake and microbial growth. Among these postharvest treatments are preservative solutions and stem recutting, in which cut stems are recut under water to prevent air bubbles from blocking water uptake.

Citric acid as postharvest treatments

Citric acid, primarily sourced from citrus fruits such as limes, lemons, oranges and tangerines, can also be found in vegetables and even animal tissues, though it is mostly concentrated in citrus. When citric acid is added to water, it lowers the pH, which is very beneficial for cut flowers. A reduction in pH helps improve water uptake, inhibits bacterial growth in the vase solution, and prevents petal wilting; therefore, extending the flower's vase life (Mehdikhah et al., 2016). Both the peel and the juice of calamondin contain various phytochemicals which can contribute to extending postharvest life of many commodities. They include flavonoids, phenolic compounds and essential oils with D-limonene as key components. These substances have high antioxidant and antimicrobial properties which aid in preventing the growth of microbes and other pathogenic microorganisms, delaying senescence, hence, prolonging the freshness of flowers.

Jadhav and Gurav (2018) reported maximum bud tightness in rose cut flowers, minimum curling of petals and head bending, and reduction of petal drop with the application of sucrose (7%) + citric acid (0.5%) + aluminum sulphate (0.5%). Meperanum et al. (2025) highlighted the potential of sugarcane vinegar and calamondin extract in extending the vase life of chrysanthemum cut flowers by up to 10 days (3 days longer than the untreated samples).

There are various mechanisms involved in the potential of calamondin fruit in delaying senescence and reducing ethylene production, such as the suppression of ethylene's effects, inhibition of ethylene synthesis as well as the influence of other plant hormones. There are reports that 1-methylcyclopropene and benzyladenine reduce ethylene production and delay the degreening in calamondin. There are natural antioxidants like flavonoids and ascorbic acid, and synthetic ethylene inhibitors which can affect development and fruit ripening and senescence, such as influencing ethylene signaling and production (Mwelase et al., 2024).

Ethylene on flower longevity and senescence

Ethylene significantly affects seed germination, root development, flower maturation and senescence, floral organ abscission (Scariot et al., 2014), fruit ripening, and response to biotic and abiotic stresses. Floral longevity, which is significantly influenced by petal wilting, withering and abscission, is controlled by ethylene through changes in endogenous levels (van Doorn & Woltering, 2008).

Ethylene has a significant impact in senescence regulation in ethylene sensitive flowers, but has little or no impact in ethylene insensitive flowers (Dar et al., 2021). For ethylene sensitive flowers, the senescence of the petal is accompanied by rapid ethylene production increase. The signaling pathway and mechanism of ethylene perception are based on the presence of its receptors, which are essential in carrying out the aging process (Ju et al., 2015). The postharvest life of cut flowers can be prolonged by substances that reduce the hormone production and that can block the ethylene action. Ethylene is synthesized as follows: L-methionine → S-adenosyl methionine (SAM) →ACC → ethylene.

Carbon dioxide and oxygen

Reducing respiration rate and effects of ethylene on sprouting, ripening, flower abscission and senescence can be attained by increasing carbon dioxide and decreasing oxygen concentrations. A study by Poonsri (2020) on *Dendrobium* orchid flowers revealed that low O_2 and high CO_2 significantly improved the storage life, helped retain the total content of anthocyanin, lowered fresh weight loss, respiration rate, ethylene production, protein degradation and protease activity. Low O_2 and high CO_2 restrict the exchange of gases; hence, slowing down the deterioration of produce (Singh & Kumar, 2008). CO_2 is known to have anti-microbial properties that are used in postharvest management. Higher concentrations of CO_2 make the surrounding environment not favorable for the majority of the pests, and can control the growth of microbes by limiting deterioration of tissues. Cut flower wilting can be delayed through high CO_2 and low O_2 packaging; while ethylene production can be reduced by altering internal atmosphere of low O_2 and high CO_2.

CONCLUSION

This study validated the potential of citric acid from calamondin fruit extract wherein the treated rose cut flowers had a vase life that was three days longer than the untreated cut roses. The slowing down of the flower deterioration with citric acid-treated cuttings was mainly due to lower ethylene and higher carbon dioxide concentrations which were noted in day 7 during the peak of ethylene production. The application of calamondin fruit extract is very feasible and economically viable due to the abundant supply of these calamondin/calamansi fruits in the local markets which are being sold at lower cost.

In addition, recutting the stems of cut flowers every two days revealed no significant advantage compared to the uncut roses stems. Therefore, with the application of calamondin extract in the vase hydrating solution, it is no longer recommended to do re-cutting because it will just be an additional work to do.

With these findings of the study, it is recommended that ornamental growers, flower vendors and buyers that for postharvest treatments of cut flowers, 20 ml/L calamondin extract may be used for pulsing. For future research trials on cut flowers, optimization of calamondin extract concentration could be explored, shelf life and stability could be assessed, and the addition of sucrose and other substances to calamondin could be evaluated for possible enhancement of postharvest attributes.

Conflict of interest

The author declares that there is no conflict of interest or competing interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Cavalcante, L., de Araujo, F. F., Ribeiro, W. S., Santos, M. N. S., & Finger, F. (2021). Postharvest physiology of cut flowers. *Ornamental Horticulture, 27*(4), 374-387. https://doi.org/0.1590/2447-536x.v27i3.2372

Chen, Y. H., Miller, W. B., & Hay, A. (2023). Postharvest bacterial succession on cut flowers and vase water. *PLoS ONE, 18*(10), e0292537. https://doi.org/10.1371/journal.pone.0292537

Dar, R. A., Nisar, S., & Tahir, I. (2021). Ethylene: A key player in ethylene sensitive flower senescence: A review. *Scientia Horticulturae, 290*(7), *110491*. https://doi.org/10.1016/j.scienta.2021.110491

Darandeh, N., & Hadavi, E. (2012). Effect of pre-harvest foliar application of citric acid and malic acid on chlorophyll content and post-harvest vase life of Lilium cv. Brunello. *Frontiers in Plant Science, 2*, 1-6. https://doi.org/10.3389/fpls.2011.00106

De, L. C., De, P., & Chhetri, G. (2015). Pre- and postharvest physiology of *Cymbidium* orchids. *International Journal of Horticulture, 5*(6), 1-5. https://doi.org/10.5376/ijh.2015.05.0006 https://doi.org/10.1590/2447-536X.v27i4.2372

Frew, A., Weston, L. A., Reynolds, O. L., & Gurr, G. M. (2018). The role of silicon in plant biology: A paradigm shift in research approach. *Annals of Botany 121*(7), 1265-1273. https://doi.org/10.1093/aob/mcy009

Hussen, S., & Yassin, H. (2013). Review on the impact of different vase solutions on the postharvest life of rose flower. *International Journal of Agricultural Research and Review, 1*(2),13-17. https://doi.org/10.13140/RG.2.1.2133.3528

Jadhav, P. B., & Gurav, N. P. (2018). Extending the storage-life and shelf-life of a rose flowers cv. Dutch postharvest using chemical compounds and cold storage (Ecofrost). *International Journal of Research and Review, 5*(6),151-156.

Ju, C., Van de Poel, B., Cooper, E. D., Thierer, J. H., Gibbons, T. R., & Delwiche, C. F. (2015). Conservation of ethylene as a plant hormone over 450 million years of evolution. *Nature Plants, 1*(1), 14004. https://doi.org/10.1038/nplants.2014.4

Kandel, D., Atreya, P. N., & Poudel, S. (2021). Postharvest vase life of gerbera under different chemical treatments. *Nepalese Journal of Agricultural Sciences, 21*(1), 144-151. https://www.researchgate.net/publication/354679742

Ma, R. H., Ni, Z. J., Zhu, Y. Y., Thakur, K., Zhang, F., Zhang, Y. Y., Hu, F., Zhang, J. G., & Wei, Z. G., & Wei, Z. J. (2021). A recent update on the multifaceted health benefits associated with ginger and its bioactive components. *Food & Function, 12*(2), 519-542. https://doi.org/10.1039/d0fo02834g

Mehdikhha, M., Onsinejad, R., Ilkaee, M., & Kaviani, B. (2016). Effect of salicylic acid, citric acid and ascorbic acid on postharvest quality and vase life of Gerbera (*Gerbera jamesonii)* cut flowers. *Journal of Ornamental Plants, 6*(3), 181-191.

Meperanum, R. D., Muttulani, M. A. J. J., & Turnos-Milagrosa, L. J. N. (2025). Plant-based hydrating solutions for extending vase life and postharvest quality of chrysanthemum (*Dendrathema x grandiflorum*). *Current Agricultural Research Journal, 13*(1), 263-270. https://doi.org/10.12944/CARJ.13.1.20

Mortazavi, N., Naderi, R., Khalighi, A., Babalar, M., & Allizadeh, H. (2007). The effect of cytokinin and calcium on cut flowers quality in rose *(Rosa hyrida* L.) cv. Illona. *Journal of Food Agriculture and Environment, 5*(3&4), 311-313. https://agris.fao.org/search/fr/records/647760bb5eb437ddff77b0d8

Mwelase, S., Adeyemi, J. O., & Fawole, O. A. (2024). Recent advances in postharvest application of exogenous phytohormones for quality preservation of fruits and vegetables. *Plants, 13*(22), 1-22. https://doi.org/10.3390/plants13223255

Nguyen, T. K., Jung, Y. O., & Lim, J. H. (2020). Tools for cut flower for export: Is it a genuine challenge from growers to customers? *Flower Research Journal, 28*(4), 241–249. https://doi.org/10.11623/frj.2020.28.4.02

Poonsri W. (2020). Effect of modified and controlled atmosphere storage on enzyme activity and senescence of *Dendrobium* orchids. *Heliyon, 6*(9), 1-6. https://doi.org/ 10.1016/j.heliyon.2020.e05070

Rihn, A. L., Yue, C., Behe, B. K., & Hall, C. (2015). Consumer preferences for cut flower guarantees. *Acta Horticulturae*, 1090(1090), 45-54. https://doi.org/10.17660/ActaHortic.2015.1090.8

Scariot, V., Paradiso, R., Rogers, H., & de Pascale, S. (2014). Ethylene control in cut flowers: Classical and innovative approaches. *Postharvest Biology and Technology, 97*, 83–92. https://doi.org/10.1016/j.postharvbio.2014.06.010

Shu, C., Ge, L., Li, Z., Chen, B., Liao, S., Lu, L., Wu, Q., Jiang, X., An, Y., Wang, Z., & Qu, M. (2024). Antibacterial activity of cinnamon essential oil and its main component of cinnamaldehyde and the underlying mechanism. *Frontiers in Pharmacology, 15*, 1-14. https://doi.org/10.3389/fphar.2024.1378434

Singh, A., & Kumar, P. (2008). Influence of post-harvest treatments on modified atmosphere low temperature stored Gladiolus cut spikes. *International Journal of Postharvest Technology and Innovation, 1*(3), 267-277. https://doi.org/10.1504/IJPTI.2008.021461

Sudaria, M. A. M., Lungsod, E. M., Robles, A. C, Gepte, C. L., & Yabao, R. M. (2016). Post-harvest treatment of pyroligneous acid on solanaceous crops at different storage condition. *Journal of Agriculture and Ecology*, *2*(1), 44-56. https://doi.org/10.53911/JAE.2021.12203

Tinebra, I., Sortino, G., Inglese, P., Fretto, S., & Farina, V. (2021). Effect of different modified atmosphere packaging on the quality of mulberry fruit *(Morus alba). International Journal of Food Science*, 1-10. https://doi.org/10.1155/2021/8844502

van Doorn, W. G., & Woltering, E. J. (2008). Physiology and molecular biology of petal senescence. *Journal of Experimental Botany*, *59*(3), 453-480. https://doi.org/10.1093/jxb/erm356

Vehniwal, S. S., & Abbey, L. (2019). Cut flower vase life – influential factors, metabolism and organic formulation. *Horticulture International Journal*, *3*(6), 275–281. https://doi.org/10.15406/hij.2019.03.00142