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The role of natural preservatives in extending vase life of cut flowers: a review

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A B S T R A C T

Purpose: Floriculture growers globally encounter ongoing difficulties in keeping cut flowers fresh after harvest. When cut flowers endure longer in the vase, customer satisfaction increases, resulting in higher sales and business viability. While synthetic chemical preservatives have been widely employed to extend the vase life of cut flowers, their adverse environmental and health impacts underscore the urgent need for natural and eco-friendly alternatives. This review critically evaluates the efficacy of some natural preservatives (essential oils, plant extracts, and organic acids) in extending the vase life of cut flowers. **Findings:** The collected data from controlled studies confirm that certain natural substances have significant therapeutic effects. Essential oils, plant extracts, and organic acids can slow senescence across a variety of flower types, extending both their vase life and their marketable period. Their multiple actions include blocking ethylene production, boosting the flower's natural defenses against decay, fighting microbes, preventing stem blockages, and regulating water pH. **Limitations:** Despite promising results, three main issues exist with these natural preservatives. First, the best methods for applying them in practice are not yet fully established or standardized for different flower species. Second, the exact molecular ways they affect and interact inside the plant are not completely clear or fully understood. Finally, current production and processing methods are not ready for reliable, consistent, and cost-effective large-scale commercial use. **Directions for future research:** Future research should focus on three key areas. First, studies should optimize practical application protocols, including precise concentration, timing, and delivery methods. Second, scientists need to clarify the detailed molecular and biochemical mechanisms of action behind these natural compounds. Finally, researchers should develop, standardize, and economically scale up production techniques to make these sustainable solutions commercially viable for the global industry.

Keywords:

Eco-friendly, Essential oils, Organic acids, Plant extracts, Postharvest

INTRODUCTION

The global cut flower trade is undergoing a notable expansion. In 2024, the market is valued at an estimated US\$37.0 billion, and forecasts indicate it will rise to US\$50.1 billion by 2030. According to analysis, this projected growth corresponds to a compound annual growth rate (CAGR) of 5.2% between 2024 and 2030. A detailed look at the market reveals roses as the top-performing segment, with stronger projected growth. Analysts expect roses to achieve a CAGR of 5.8%, reaching a market size of roughly US\$15.8 billion by the end of the decade. Meanwhile, other popular flowers, including chrysanthemums and gerberas, are forecast to grow more moderately, at a CAGR of 5.3% over the same period (Global Industry Analysts, 2025). Cut flowers are universally recognized as symbols of appreciation, affection, and emotional expression. Their global trade has surged in recent years, fueled by growing consumer demand. This demand is supported by the scientifically validated therapeutic benefits these horticultural commodities provide (Yeptho et al., 2025). An important operational factor for both the consumer cohort and producers is the post-procurement vase life longevity of the severed floral species. This variable directly impacts consumer satisfaction indicators and the probability of repeat purchases. To safeguard the continued commercial viability and perceptual integrity of these ornamental commodities, the implementation of rigorous phytosanitary and qualitative governance protocols is imperative. Such standards are fundamentally constitutive for the protraction of their post-excision vitality and the preservation of their pecuniary worth within the mercantile sphere (Vehniwal et al., 2020).

The post-severance ornamental persistence interval is a key challenge in commercial floriculture. This term refers to the time span during which cut flowers retain their aesthetic integrity in a vase. It remains a principal phytotechnical impediment for the industry (Aziz et al., 2020). This parameter is subject to a multifactorial determinacy, encompassing both pre- and post-detachment variables. Within the context of a globalized floral commodity chain, a paramount commercial imperative involves the temporal compression of export logistics, targeting a reduction of diurnal cycles, potentially approximating a hebdomadal scale (Nguyen & Lim, 2021). Following excision, floral organs transition to a state of metabolic heterotrophy, becoming entirely reliant on endogenous reserves. These reserve deposits, comprising carbohydrates, proteins, and lipids, fuel the catabolic and anabolic processes necessary for survival. Their mobilization sustains the physiological functions required to maintain the flower's morpho-visual desirability. Concurrently, a suite of postharvest extrinsic factors, including but not limited to ambient hygrometric conditions, luminous flux, and thermal regimes, exert significant modulatory influences on the duration of vasa viability (Muraleedharan et al., 2020).

Post-detachment quantitative and qualitative depreciations represent a non-trivial challenge for floricultural systems, constituting a transboundary phytocommodity concern (Gupta & Dubey, 2018). The primary etiology of truncated ornamental longevity is the inhibition of hydric assimilation, a phenomenon principally attributable to vascular occlusion. This occlusion manifests through a tripartite etiological framework: (1) the proliferation of microbial consortia and consequent biofilm matrices within xylematic conduits; (2) the introduction and stabilization of gaseous emboli; and (3) the ontogenesis of wound-induced tyloses. These occlusive phenomena collectively impede the axial translocation of hydric solutions and solutes, thereby catalyzing a cascade of degenerative processes. It is noteworthy that the biosynthesis of the phytohormone ethylene, itself potentiated by the wound-response signaling initiated at harvest, functions as a positive feedback mechanism, stimulating the excessive formation of tyloses. This results in a progressive stenosis of xylematic vessels,

thereby exacerbating the trajectory of senescent decline (Dar et al., 2021). Ethylene is a gaseous plant hormone that strongly accelerates senescence. It triggers a series of physiological changes, which include the hydrolytic degradation of cell wall pectins, the catabolism of chlorophyll pigments, and the loss of turgor manifesting as wilting. Furthermore, the physical act of severance induces specific pathophysiological responses, such as gummosis and the exudation of laticiferous substances, which can function as endogenous physical barriers to hydric conductance in particular taxonomic groups (Imsabai et al., 2013).

To address these challenges, preservative solutions are used to extend the vase life and enhance marketability. Flowers are categorized based on vase life: short (less than 5 days) include dahlia (Onozaki & Azuma, 2019), iris (Macnish et al., 2010), daffodil (Doorn, 1998), delphinium (Ahmad et al., 2017), and alstroemeria (Macnish et al., 2008), medium (6–14 days) include protea (Stephens et al., 2002), gladiolus (Murali & Reddy, 1991), ginger (Choresca & Bayogan, 2019), primrose (Asadi-Kavan et al., 2020), heliconia (Sardinha et al., 2019), marigold (Ahmad et al., 2012), snapdragon (Asrar, 2012), orchid (Khunmuang et al., 2018), and rose (Ha et al., 2021); and finally long (2–4 weeks) (Nguyen & Lim, 2021) encompass tulip (Gómez-Merino et al., 2020), anthurium (Elibox & Umaharan, 2008), carnation (Aalifar et al., 2020), and chrysanthemum (Sedaghathoor et al., 2020). Although chemical preservatives demonstrate efficacy in extending vase life, their associated health and environmental risks have spurred growing interest in natural alternatives as sustainable solutions. They can reduce microbial populations in vase solutions, which is crucial for maintaining flower longevity (Edrisi et al., 2012). Concurrently, the deployment of synthetic germicides is increasingly problematized, given their propensity for hydrosphere contamination and potential anthropocentric hazards (Minde, 2019). In counterpoint, eco-friendly formulations are accruing significant scholarly and commercial traction. These alternatives offer analogous biocidal efficacy but ostensibly avoid the deleterious impacts of their synthetic antecedents (Nguyen & Lim, 2021). A comparative schematic of these benefits is presented in Figure 1.

This incipient paradigm shift, galvanized by the recognition of synthetic chemistry's detriments, necessitates a concerted transition to natural compounds. These botanically-derived substances present a compelling alternative by virtue of their innate biocompatibility, reduced environmental persistence, and frequently more favorable economic profiles (Okigbo, 2005) as shown in Table 1. Among the most promising of these agents are standardized herbal extracts and essential oils (EOs), whose broad-spectrum antimicrobial properties demonstrate significant potential for enhancing the postharvest quiescence of horticultural specimens (Monya et al., 2021). Research has thus increasingly focused to such safer modalities, with EOs, complex volatile secondary metabolites, emerging as a particularly salient avenue of inquiry (Lambert et al., 2001; Mihajilov-Krstev et al., 2010). These oils offer a safe and environmentally friendly alternative to traditional preservatives due to their effectiveness against certain pathogens. Organic acids like salicylic acid (SA) and citric acid (CA) also work effectively to inhibit xylem vessel blockage, enhance water uptake, and boost relative fresh weights (Alkaç et al., 2023).

This review aims to provide a comprehensive understanding of postharvest senescence physiology and explore eco-friendly solutions for extending vase life. By fundamentally evaluating natural preservatives and their applications across different flower types, this work seeks to optimize vase life, maximize value for floriculture producers, and minimize environmental impact.

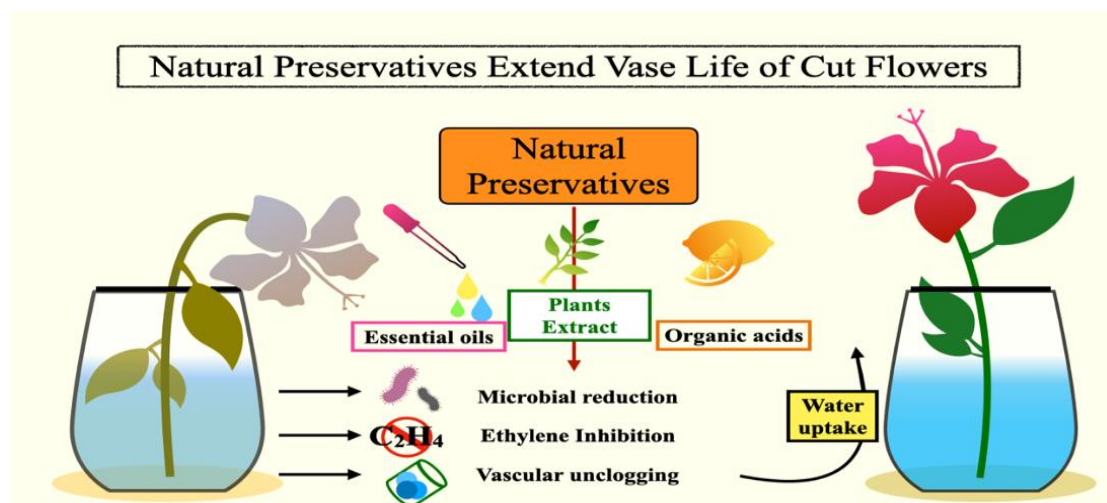


Fig. 1. Schematic overview of the role of natural preservatives (essential oils, plant extracts, and organic acids) on extending vase life of cut flowers.

Table 1. Comparison of natural vs. chemical preservatives for extending vase life of cut flowers.

Feature	Natural preservatives	Chemical preservatives
Source	Plant-based (e.g., essential oils, extracts, acids)	Synthetic compounds (e.g., STS, silver nitrate)
Mode of action	Antimicrobial, antioxidant, pH/osmotic regulation	Antimicrobial, ethylene inhibition
Environmental impact	Biodegradable, eco-friendly	Potentially toxic to environment
Toxicity to humans	Generally safe	Some are hazardous or restricted
Cost and availability	Variable (depends on source)	Often low-cost, widely available
Efficacy	Moderate to high (depends on formulation)	High, especially in short-term outcomes
Consumer preference	Increasing due to sustainability	Declining due to health/environmental concerns

MATERIALS AND METHODS

Effect of natural preservatives on vase life of cut flowers

Essential oils

Essential oils (EOs) are complex mixtures of volatile compounds derived from aromatic plants, obtained from parts such as leaves, flowers, and seeds. These secondary metabolites contain many different natural compounds, with major groups including terpenoids and phenolics. These compounds give the oils useful biological properties, enabling them to fight microbes, reduce inflammation, and act as antioxidants (Agrawal et al., 2024; Durczyńska & Żukowska, 2024; Raghuvanshi et al., 2023). The EOs combat pathogens in several ways, such as breaking down bacterial cell walls and draining the cell's energy, like ATP. Furthermore, EOs create oxidative stress inside the pathogen cells by producing reactive oxygen species (ROS). Together, these attacks make it hard for the microbes to survive. This shows the EOs could be natural replacements for artificial antimicrobials (Falleh, 2025). Overall, EOs are promising natural tools that are compatible with biology, have a low environmental impact, and are effective against harmful pathogens. For these reasons, they are now being considered as natural alternatives to synthetic chemicals. The EOs can preserve cut flowers and make them last longer in a vase.

Many studies show that EOs can help cut flowers last longer. For example, Nesreen et al. (2022) found that clove oil (25 mg L^{-1}) made 'Rosalin' gerbera cut flowers live much longer in a vase than other treatments. Bazaz and Tehranifar, (2011) also reported a longer vase life for *Alstroemeria* cut flowers treated with thyme oil. In another study, Manfredini et al. (2017) tested several EOs on roses and noted that eucalyptus, cinnamon, lemongrass, and peppermint's essential oils (all at 1%), as well as clove oil (0.1%), improved the cut flowers' condition after harvest. Solgi (2018) demonstrated that adding thymol (25 or 50 mg L^{-1}) to the vase solution greatly extended the vase life of cut carnations. These results are further supported by El-sayed and Elziat (2021) Their work confirmed that thyme and clove oils significantly increase the vase life of gerbera cut flowers.

Bayat et al. (2013) studied the use of EOs as preservatives for *lisianthus* cut flowers. They found that these oils greatly extended the flowers' vase life compared to untreated ones. For example, at a concentration of 200 mg L^{-1} , *Echinophora platyloba* oil increased vase life by 71%. *Zataria multiflora* oil at the same concentration increased it by 32%. In an earlier study, Bayat et al. (2011) also tested EOs on carnation cut flowers. They used ajowan oil, summer savory oil, and thyme oil. Summer savory oil at 100 ppm worked best, extending the vase life by 4.4 days. However, not all treatments were helpful. Thyme oil at a higher dose (200 mg L^{-1}) actually had a harmful effect on the flowers.

Saemi et al. (2018) validated that ajowan essential oil increased the longevity of rose cut flowers (*Rosa × hybrida* cv. 'Angelina'), both in the presence and absence of gray mold infection. Eldeeb and Adam (2021) reported that clove, lavender, and thyme oils at concentrations of 100 and 200 mg L^{-1} increased the vase life of carnation cut flowers.

Gururani et al. (2023) evaluated the effectiveness of EOs in extending the vase life and improving solution uptake of cut chrysanthemum flowers (cv. 'Madam Collette'). Thyme oil emerged as the most effective treatment, extending the vase life from 9.25 days (untreated) to 18.50 days at a concentration of 50 mg L^{-1} . Solution uptake also rose significantly, increasing from 25.65 mL for untreated flowers to 66.58 mL for those treated with thyme oil. In another study, Nirmala et al. (2023) tested EOs derived from *Artemisia*, *Ocimum*, *Geranium*, and *Rosemary* on cut chrysanthemum (cv. 'Arctic Queen') to preserve quality and extend vase life. Geranium oil at 2.5% produced the longest vase life of 8.98 days. This was achieved by suppressing microbial growth in the vase solution and stems.

Collectively, these studies highlight the promise of EOs as natural preservatives for cut flowers. They can improve postharvest quality and longevity. Their antimicrobial action, along with their eco-friendly and safe profile, positions them as a viable alternative to synthetic chemicals in floriculture.

Plant extracts

Plant extracts are derived from many parts of a plant. These include flowers, seeds, fruits, peels, leaves, stems, bark, wood, and roots. Many common edible and medicinal plants and spices have shown strong effects. Examples are oregano, rosemary, thyme, sage, basil, turmeric, ginger, garlic, nutmeg, clove, mace, savory, and fennel. These extracts work well when used individually. They are also effective when combined with other preservation methods (Tajkarimi et al., 2010). These natural materials combat specific pathogens effectively. This makes them useful as fragrances, flavorings, and ingredients in medicines. Their antibacterial power mainly comes from high levels of phenolic compounds, such as carvacrol, thymol, and eugenol, which have potent antimicrobial activity (Lambert et al., 2001). Natural flower preservatives are safe for biological systems and the environment, often outperforming synthetic alternatives while meeting both sustainability goals and the practical needs of horticulture (Özcan & Erkmen, 2001; Bayat et al., 2013).

Fruit extracts show promise as natural additives to extend the vase life of cut flowers. They offer a more sustainable alternative to synthetic preservatives. Though research in this particular field remains limited. However, early studies have started to investigate the useful benefits of these extracts (Babarabie et al., 2018). For instance, Tashenehdari (*Scrophularia striata* Boiss.) extract has been shown to effectively prolong the vase life of cut gerberas by inhibiting bacterial growth, a major cause of flower senescence. Concentrations of 1.5% and 2% of the extract were most effective in extending the lifespan of the flowers while maintaining their quality and visual appeal (Mohammadi et al., 2020).

In a study on cut carnation flowers, Basiri et al. (2011) reported that rosemary extract positively influenced the vase life of carnations and improved certain physiological characteristics of the cut flowers. Babarabie et al. (2018) established that the acidic components and carbohydrates present in apple extract contribute to extended vase life. Even though rosemary essential oil helped gerbera cut flowers (*Gerbera jamesonii*) last longer, its combination with apple extract acts best. Using 60 ml/L of apple extract extended the vase life of flowers to 20.33 days, considerably longer than the control group, while among all tested plant extracts, a 20% savory extract proved most effective for Alstroemeria cut flowers, achieving a notable vase life of 18 days. Other plant extracts showed limited success, although 8-hydroxyquinoline sulfate (8-HQS) at a concentration of 200 mg L⁻¹ also demonstrated significant vase life extension, reaching nearly 20 days (Kabari & Soleimandarabi, 2019).

Borage leaf extract shows great potential for keeping gladiolus cut flowers fresh longer. It can extend their vase life from about 6 days to an impressive 13 days. When used at a 3% concentration, the extract improves flower quality in two key ways. Reducing oxidative stress and limiting bacterial growth are two actions that both enable the flowers to last considerably longer (Zulfiqar et al., 2024).

Moringa leaf extract comes from the *Moringa oleifera* tree. Research shows it works well as a natural plant booster (Phiri & Mbewe, 2010). Moringa leaf extract influences a range of biochemical and physiological processes in plants (Nasir et al., 2016; Yasmeen et al., 2013). It does this by increasing antioxidant enzymes and protecting cell membranes (Ashraf et al., 2016; Aslam et al., 2016). A study by Hassan and Fetouh (2019) tested the extract on Gladiolus cut flowers 'White Prosperity' variety. Different concentrations of the extract, including 1%, 2%, 3%, and 4% were used. All tested concentrations prolonged vase life compared to water, with the 3% solution yielding the best results, as increasing the concentration further provided no additional benefit.

Boondouylan and Kunyamee (2022) studied herbal extracts for cut chrysanthemums. These extracts helped keep the flowers fresh while also boosting both their longevity and visual appeal. Vehniwal et al. (2020) tested a special vase solution for cut carnations cv. 'White Sim'. The solution had compost tea, putrescine, and extracts from rosemary and lemon. They found that a combination of 3.5% compost tea and 15 mg L⁻¹ putrescine worked best, it extended vase life and matched the performance of commercial preservatives.

In summary, plant extracts from fruits, herbs, and moringa leaves all have the potential to extend the vase life of cut flowers. They are beneficial because they combat microbes, reduce stress-related damage, and stop bacteria from growing, which makes them a good, eco-friendly alternative to synthetic preservatives. More research is needed so that scientists can identify the best ways to use them and uncover their exact mechanisms.

Organic acids

Ascorbic acid

Ascorbic acid (AsA), also called vitamin C, is an essential antioxidant found throughout plants (Macknight et al., 2017). It has many important actions: it shields plants from oxidative damage and acts as a redox buffer (Pignocchi & Foyer, 2003), works as a helper for certain enzymes (Smirnoff & Wheeler, 2000), and helps control how cells divide and grow (Kerk & Feldman, 1995). Additionally, AsA is integral to plant signaling pathways. This organic acid influences various developmental and stress responses (Noctor et al., 2000; Pignocchi & Foyer, 2003). Although plants can absorb minor variations in endogenous AsA, substantial imbalances have detrimental effects on growth and overall health. This demonstrates the compound's critical importance in plant development (Gallie, 2013). These central physiological functions make AsA valuable for the postharvest management of cut flowers. It is applied to reduce oxidative stress and thereby extend vase longevity. As a key antioxidant, AsA is integral to sustaining vase life through the detoxification and removal of reactive oxygen species (ROS). When used as a preservative, AsA performs two key functions, reducing the number of pathogens in the vase solution and helping flower cells remove ROS more effectively. This happens because AsA triggers several positive changes, namely (1) improving water uptake by causing the plant to develop more and wider xylem vessels; (2) lowering oxidative stress, as indicated by decreased hydrogen peroxide and malondialdehyde levels; (3) boosting natural defenses, through increased activity of the flower's own antioxidant enzymes. Together, these actions slow down senescence, demonstrating that treating cut flowers with AsA is a useful method for maintaining their postharvest freshness and quality (Mahmoudian et al., 2025).

Practical applications confirm AsA's considerable potential for enhancing the postharvest longevity of cut flowers. In a study of two chrysanthemum cultivars, 'Reagent Sunny' and 'Yellow Fiji', treatment with AsA delayed visual deterioration, including petal discoloration, while also preserving the freshness of both leaves and petals. When used at a concentration of 200 mg L⁻¹, AsA kept them fresh for about two extra days and slowed down the loss of chlorophyll compared to untreated samples (Budiarto et al., 2022). A similar effect was seen in lisianthus (*Eustoma grandiflorum*), a flower that typically does not last long in a vase. However, treatment with AsA extended its vase life, with the best results coming from a concentration of 200 mg L⁻¹, at which the flowers absorbed more water and stayed fresh the longest (Azizi et al., 2015). Supporting this evidence, Sheikh et al. (2014) also found that lisianthus cut flowers treated with a 300 mg L⁻¹ AsA solution had a vase life of 16.81 days, which was the longest duration recorded in their experiment. Further confirmation comes from research on gladiolus (*Gladiolus* spp.), in which Ravanbakhsh et al. (2017) reported that AsA significantly extended the vase life of these cut flowers. The best results were achieved with a 6 mM AsA concentration, which produced the maximum longevity, a finding that highlights the versatility of AsA as a natural preservative effective across different flower species.

Research has also explored a combination of AsA with other natural preservatives. In a study on marigolds (*Tagetes erecta*), Sharma et al. (2023) used a dual treatment of AsA and SA. Their specific combination of 200 mg L⁻¹ AsA with 50 mg L⁻¹ SA extended vase life by 40% by increasing the flowers' antioxidant defenses and suppressing microbes in the vase solution, which consequently improved water uptake and delayed senescence. These findings highlight AsA's promise as a viable, sustainable alternative to commercial synthetic preservatives.

Citric acid

Citric acid (CA), a naturally occurring organic acid, plays a diverse role in plant physiology and postharvest management. CA has emerged as a valuable natural preservative for extending the vase life of cut flowers. The primary action of CA improves water quality and restricts microbial growth. A key mechanism is its ability to acidify the vase solution, thereby lowering the pH and effectively inhibiting harmful bacteria and fungi. This is critical, as these microbes can clog the flower's xylem, preventing proper hydration (van Doorn, 2014). The chelating properties of CA facilitate iron mobilization and transport, a mechanism that is essential for plant health maintenance (Darandeh & Hadavi, 2012). Additionally, studies by Eidyan et al. (2014), and Darandeh and Hadavi (2012) suggest that CA can enhance the postharvest longevity of cut flowers, such as lilies and tuberoses, by improving physiological processes.

The effectiveness of CA as a natural preservative has been widely researched in different cut flowers. For example, Vahdati Mashhadian et al. (2012) examined the effects of SA (0, 100, 200, or 300 ppm) or CA (0, 100, or 200 ppm) on Chrysanthemum (*Dendranthema grandiflorum* (Ramat.) Kitamura cv. 'Patriot') cut flowers. They found that different levels of SA or CA greatly increased vase life. The best result was obtained from 300 ppm SA, which resulted in a vase life of 21.77 days. The control group, in contrast, lasted only 6.88 days. In another study, Mehdikhah et al. (2016) tested Gerbera flowers (*Gerbera jamesonii*). Their results showed that among the concentrations tested (50, 100, or 200 mg L⁻¹), 100 mg L⁻¹ CA was the best concentration, achieving a maximum vase life of 11.31 days, and by significantly enhancing water uptake, this treatment suggests a potential mechanism for its effectiveness.

Further studies by Bayat and Aminifard (2018) revealed that CA concentrations of 100, 200, and 300 ppm significantly prolonged the vase life of *Narcissus tazetta* cv. 'Shahla' cut flowers compared to the control. Amin (2017) proposed that CA inhibits bacterial growth in the vase solution and improves water conductance through the flower's vascular system, thereby enhancing water uptake. This hypothesis is supported by Krause et al. (2021), who observed reduced fresh weight loss in *Lilium pumilum* cut flowers treated with a combination of 100 mg L⁻¹ CA and 20 g L⁻¹ sugar solution. Gun (2020) also reported that a 100 mg L⁻¹ CA solution significantly extended the vase life of *Narcissus tazetta* cut flowers compared to untreated controls.

Recent research continues to support the benefits of CA for cut flower preservation (Alkaç et al., 2023). In a study on carnations (*Dianthus caryophyllus* L.), a concentration of 200 mg L⁻¹ CA produced the most favorable outcomes, extending the vase life of treated flowers to 16 days, representing a 17% increase compared to untreated controls. Furthermore, this treatment facilitated the highest water uptake (38.53 g per stem), and adequate water absorption is essential for maintaining floral hydration, thereby preserving freshness and postharvest vitality.

Gibberellic acid

Gibberellic acid (GA) is an important plant hormone that affects many different stages of a plant's growth, for instance helping seeds to germinate and making stems grow longer, which leads to taller plants. Furthermore, GA plays a role in flowering. It can increase the number of flowers, trigger the flowering process, and even control sex expression in some plant species. Moreover, GA has been shown to overcome dormancy, a physiological state that delays germination or growth in academic studies (Davière & Achard, 2013; Plackett & Wilson, 2016). GA is an important plant hormone that affects many different stages of a plant's growth. For instance, GA helps seeds to germinate and also makes stems grow longer, which leads to taller plants. Furthermore, GA plays a role in flowering, as it can increase the number

of flowers, trigger the flowering process, and even control sex expression in some plants, achieving this by sustaining their visual quality and delaying deterioration (Jaber & Mashkoor, 2025).

In a study by Mutui et al. (2006) solution with 10 mg L⁻¹ of GA4+7 was found to be effective in preserving the quality of *Alstroemeria* cut flowers during transport. This treatment extended the vase life, delayed leaf senescence, and overall enhanced the postharvest quality of the flowers. Isapareh et al. (2014) investigated the effect of GA₃ on the longevity of cut *Alstroemeria* 'Bridal' flowers. Their study revealed that GA₃ at 50 or 100 mg L⁻¹ significantly extended vase life by 3.33 or 3 days, respectively, compared to other treatments. These findings suggest that GA₃ application can be an effective method to prolong the freshness and visual appeal of cut 'Bridal' *Alstroemeria* flowers. GA at a concentration of 50 ppm significantly prolonged the vase life of *Tagetes erecta* L. by effectively delaying flower senescence. This effect was attributed to enhanced floral turgidity and reduced petal fading. Consequently, it resulted in a maximum postharvest life of 14.66 days, outperforming both the control and other GA₃ treatments (Sharma et al., 2023). In another research, GA₃ treatment resulted in increased floret opening and extended vase life in cut gladiolus flower in a concentration-dependent manner across concentrations of 0, 25, 50, 100 and 200 mg L⁻¹, with 25 mg L⁻¹ yielding the most favorable outcomes, while higher concentrations did not provide additional benefits (Saeed et al., 2014). The combined treatment of GA₃ and calcium chloride exhibited a pronounced positive impact on vase life, while simultaneously mitigating microbial proliferation (Sardoei, 2014).

Salicylic acid

Salicylic acid (SA) is an inexpensive phenolic substance that is commonly used in the postharvest treatment of crops to extend their storage life (Supapvanich & Promyou, 2013). As a key plant hormone, SA plays a key role in activating plant responses against both biotic and abiotic stresses. It does so through morphological, physiological, and biochemically-related pathways (War et al., 2011). SA has the ability to positively influence plant physiology in many different ways, including regulating ethylene production, enhancing disease resistance, reducing oxidative stress, and decreasing respiration. These factors contribute to delaying senescence (Asghari & Aghdam, 2010). Furthermore, SA has a dual mechanism for inhibiting the growth of bacteria. First, it lowers the water's pH, which creates a less hospitable environment for bacterial growth. Second, it limits the production and activity of ethylene, a gaseous hormone that initiates plant senescence and can work with bacteria to accelerate tissue decay (Monya et al., 2021). The various effects of SA are seen in the beneficial effects of SA on the preservation of cut flowers. Some of the most notable of these effects include extended vase life via SA has been studied extensively, with multiple studies showing the positive benefits of SA on the extended vase life of cut flowers through several synergistic mechanisms. Research indicates that SA provides protection from oxidative stress through two primary routes: by decreasing membrane damage due to oxidative stress and by regulating protein production and subsequent transport of proteins to the flower tissue via the phloem. Additionally, SA has a secondary mechanism of suppressing the production of ethylene. With the suppression of ethylene, cut flowers can remain more aesthetically pleasing and last longer as cut flowers (Khudair et al., 2025).

Numerous studies have demonstrated the efficacy of SA in extending the vase life of cut flowers. For instance, Seman and Rafdi (2019) identified a combination of 200 mg L⁻¹ SA and 2% sucrose as the optimal vase solution for maintaining the quality of cut *Antigonon leptopus* stems. This treatment acidified the vase water (pH < 4), which improved water uptake. This maintained the flowers' freshness, color, and weight while reducing petal drop,

ultimately extending vase life by 1.6 times compared to untreated flowers. The two varieties of *Gladiolus* cut flowers ('Pusa Shanti' and 'Pusa Chandni') evaluated in the study by Sharma et al. (2024) were found to benefit from both Sodium Nitroprusside and SA when they were used as additives in vase solution. According to the results, for cut flowers, 'Pusa Shanti' *Gladiolus*, SA was more effective than Sodium Nitroprusside. Conversely, Sodium Nitroprusside was the best treatment for the 'Pusa Chandni' *Gladiolus* cut flowers. The use of both these agents improved the vase life and overall quality of the flowers significantly. Both were also non-toxic, inexpensive, biodegradable, and environmentally friendly alternatives to currently available chemical preservatives that could potentially harm humans or other living organisms. Additionally, the results of this study indicated the promise of using SA and/or Sodium Nitroprusside to prolong the postharvest life of cut flower species that are prone to vascular blockage caused by bacteria and/or the presence of ethylene.

Ghadimian and Danaei (2020) studied the effects of SA on the vase life of *Rosa hybrida* cv. 'Black Magic'. The study showed that SA-containing treatments significantly enhanced both fresh weight and water uptake relative to the control group, where the most substantial increases in both parameters were observed at the 200 mg L⁻¹ concentration. The most effective concentration of SA was found to be 200 mg L⁻¹, as this concentration reduced ion leakage more than the other concentrations (50, 100 or 150 mg L⁻¹) and increased the chlorophyll index and anthocyanin content compared to the other concentrations. These findings are consistent with the findings of (Çanakçı, 2008), who reported that SA treatments increased vase life and the amount of chlorophyll and anthocyanin present in flower petals.

Bayat and Aminifard (2017) reported a significant enhancement in vase life for five economically important cut flowers (*Alstroemeria peruviana*, *Gerbera jamesonii*, *Lilium asiaticum*, *Rosa hybrida*, and *Polianthes tuberosa*) when treated with SA as a preservative. Increasing SA concentrations correlated with prolonged vase life, with the optimal effect observed at 300 mg L⁻¹ compared to control groups. SA treatment extended vase life by 40 for *Alstroemeria peruviana*, 67% for *Gerbera jamesonii*, 21% for *Lilium asiaticum*, 71% for *Rosa hybrida*, and 56% for *Polianthes tuberosa*. Also, in a recent research noted that application of SA significantly extended the vase life of lisianthus cut flowers (Piri & Jabbarzadeh, 2025).

Together, the research underscores the significant potential of SA as a natural and effective preservative for extending the vase life of cut flowers. It functions through multiple mechanisms, including the suppression of ethylene production, enhancement of water uptake, reduction of oxidative stress, and inhibition of bacterial growth. This makes SA a viable and sustainable alternative to synthetic chemicals in floriculture. To fully realize its potential, further studies are required to optimize SA concentrations for specific flower varieties and to gain a more detailed understanding of its mode of action. Performance of different cut flowers in response to various types of natural preservatives was shown in Table 2.

Table 2. Performance of different cut flowers in response to various types of natural preservatives.

Crop	Natural preservative	Effect	Reference
Alstroemeria (<i>Alstroemeria peruviana</i>)	GA	Extended the vase life, delayed leaf senescence, and enhanced the postharvest quality	(Mutui et al., 2006)
	GA	Extended the vase life	(Isapareh et al., 2014)
	SA	Enhancement in vase life	(Bayat & Aminifard, 2017)
	Savory extract	Extended the vase life, the greatest solution uptake	(Kabari & Soleimandarabi, 2019)
	Thyme Eos	extended shelf life	(Bazaz & Tehranifar, 2011)
<i>Antigonon leptopus</i>	SA	lowered the vase solution pH below 4. Acidic water demonstrably enhanced the uptake of the solution by the stems, consequently extension of vase life	(Seman & Rafdi, 2019)
Carnations (<i>Dianthus caryophyllus</i>)	Ajowan EOs 100-200 ppm, summer savory EOs 100-200 ppm, and thyme EOs 100-150 ppm	Increase in the vase life	(Bayat et al., 2011)
	CA	Prolonged the vase life	(Alkaç et al., 2023)
	EOs (clove, lavender, and thyme)	Extended vase life	(Eldeeb & Adam, 2021)
	Rosemary and lemon extracts	Prolonged flower freshness and longevity	(Vehniwal et al., 2020)
	Thymol (25 or 50 mg L ⁻¹)	Prolonged the vase life	(Solgi, 2018)
Chrysanthemum (<i>Chrysanthemum morifolium</i>)	Thyme, marjoram, anise, and geranium EOs	Doubled the vase life increase in both longevity and solution absorption	(Gururani et al., 2023)
	AsA 200 mg L ⁻¹	longer leaf and petal freshness and a slower degradation of chlorophyll	(Budiarto et al., 2022)
	CA	Extended vase life	(Vahdati Mashhadian et al., 2012)
	SA	Prolonged the vase life	(Vahdati Mashhadian et al., 2012)
Gerbera (<i>Gerbera jamesoni</i>)	Apple extract & rosemary EOs combination with apple extract	Significant improvement on vase life	(Babarabie et al., 2018)
	CA	Extended the vase life	(Mehdikah et al., 2016)
	Clove EOs (25 mg L ⁻¹)	Increase in the longevity	(Nesreen et al., 2022)
	Tashenehdari (<i>Scrophularia striata</i> Boiss.) extract	Prolonged the vase life, reduced microbial contamination	(Mohammadi et al., 2020)
	Thyme and clove Eos	Extended the vase life	(El-sayed & Elziat, 2021)

<i>Gladiolus grandiflorus</i>	AsA 6 mM	Extend the vase life	(Ravanbakhsh et al., 2017)
	Borage leaf extract	Enhanced extending the vase life and flower quality by mitigating oxidative stress, inhibiting bacterial growth	(Zulfiqar et al., 2024)
	GA	Increased floret opening, extended vase life	(Saeed et al., 2014)
	Moringa leaf extract	Extended vase life	(Hassan & Fetouh, 2019)
	SA	Extended the postharvest life of flowers susceptible to vascular blockage from bacteria or ethylene	(Sharma et al., 2024)
<i>Lisianthus (Eustoma grandiflorum L.)</i>	AsA 200 mg L ⁻¹	Extended the postharvest longevity to the highest uptake of the solution	(Azizi et al., 2015)
<i>Marigold (Tagetes erecta)</i>	Combination of 200 mg L ⁻¹ AsA and 50 mg L ⁻¹ SA	Increased the vase life, improved water uptake and delayed senescence	(Sharma et al., 2023)
	GA 50 ppm	Enhanced floral turgidity and a reduction in petal fading, with a maximum postharvest life of 14.66 days	(Sharma et al., 2023)
<i>Narcissus (Narcissus tazetta)</i>	CA	Prolonged the vase life	(Bayat & Aminifard, 2018)
	CA	Extended vase life	(Gun, 2020)
	GA	Pronounced positive impact on vase life in corporation with calcium chloride, simultaneously combating microbial proliferation	(Sardoei, 2014)
<i>Polianthes tuberosa</i>	SA	Enhancement in vase life	(Bayat & Aminifard, 2017)
<i>Raphanus sativus</i>	SA	Extends vase life, elevates both chlorophyll content and anthocyanin levels in flower petals	(Çanakçı, 2008)
<i>Rose (Rosa spp.)</i>	Ajowan EOs	Percentage of gray mold infection significantly decreased	(Saemi et al., 2018)
	Eucalyptus, cinnamon, lemongrass, peppermint (all at 1%), and clove oil (0.1%)	increased the longevity of rose cut flowers Enhanced the condition of floral stems in postharvest	(Manfredini et al., 2017)
	SA	Increased fresh weight and water absorption	(Ghadimian & Danaei, 2020)

AsA: Ascorbic acid; CA: Citric acid; EOs: Essential oils; GA: Gibberellic acid; SA: Salicylic acid

Functional mechanisms of natural preservatives

The foregoing discussion provides an overview of the potential of various types of natural preservatives available to improve flowers' post-harvest quality. These natural compounds will improve either vase life or water absorption by controlling microbial populations during the vase life. EOs, plant extracts, and organic acids were the largest groups used to extend the longevity of flowers among all other natural preservatives investigated. The mechanisms of natural preservatives in relation to vase life include a combination of many different types of means (physical, chemical, and biological). Below are the key functional mechanisms related to the natural preservatives?

Ethylene inhibition

Ethylene is an important phytohormone responsible for causing wilting and decay as part of the process of senescence. Its biosynthesis begins with S-adenosylmethionine (SAM). SAM is sequentially converted by 1-aminocyclopropane-1-carboxylic acid (ACC) synthase (ACS) and ACC oxidase (ACO) (Yoon & Kieber, 2013; Tipu & Sherif, 2024). The signaling pathways involved in ethylene are divided into two systems: System 1 produces low levels of ethylene during early development, while System 2 is auto-amplifying, responding to the ageing process in plants (Fig. 2). Many natural compounds can effectively block ethylene's harmful effects. SA and CA work by reducing the activity of the ACS enzyme. EOs act differently by directly inhibiting the ACO enzyme. This stops the final step in ethylene production (Khan et al., 2024). By blocking these key steps in ethylene production, these natural preservatives effectively lower ethylene levels. This helps delay aging, protect cell structure and improve how water and nutrients move within the plant. Therefore, when used on cut flowers, these natural materials can significantly enhance their quality and extend their lifespan (da Costa et al., 2021; Nguyen & Lim, 2021).

Antioxidant activity

Reactive oxygen species (ROS) are a common cause of oxidative damage in cut flowers. Antioxidants can neutralize ROS and reduce their harmful effects.

These antioxidants also help to boost the activity of key protective enzymes like catalase (CAT) and glutathione reductase (GR). EOs from rosemary and sage has been shown to increase antioxidant enzyme activity in cut gladiolus flowers. This helps stabilize their cell membranes and extends their vase life (Moussa et al., 2024). Plant extracts, such as those from borage (*Borago officinalis* L.) and savory (*Satureja hortensis* L.), also work to decrease oxidative stress. As a result, they improve membrane stability and influence MDA content. These natural treatments are effective ways to reduce damage in cut flowers. In addition to reducing oxidative stress, floral colors remain stable, and senescence is delayed (Fig. 3) (Kabari & Soleimandarabi, 2019; Zulfiqar et al., 2024).

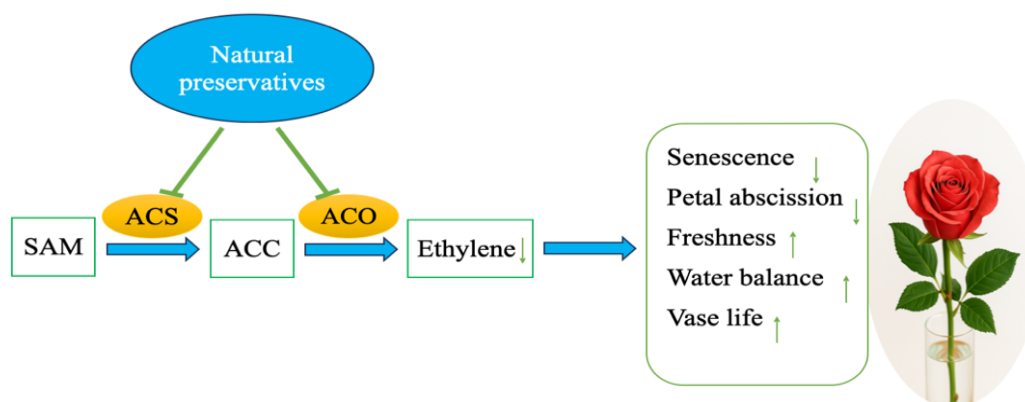


Fig. 2. Ethylene inhibition by natural preservatives in cut flowers. ACC: Aminocyclopropane-1-Carboxylate, ACO: Aminocyclopropane-1-Carboxylate oxidase, ACS: 1-aminocyclopropane-1-carboxylic acid synthase, SAM: S-adenosylmethionine. The figure illustrates the key components involved in ethylene biosynthesis and its inhibition by natural preservatives in cut flowers.

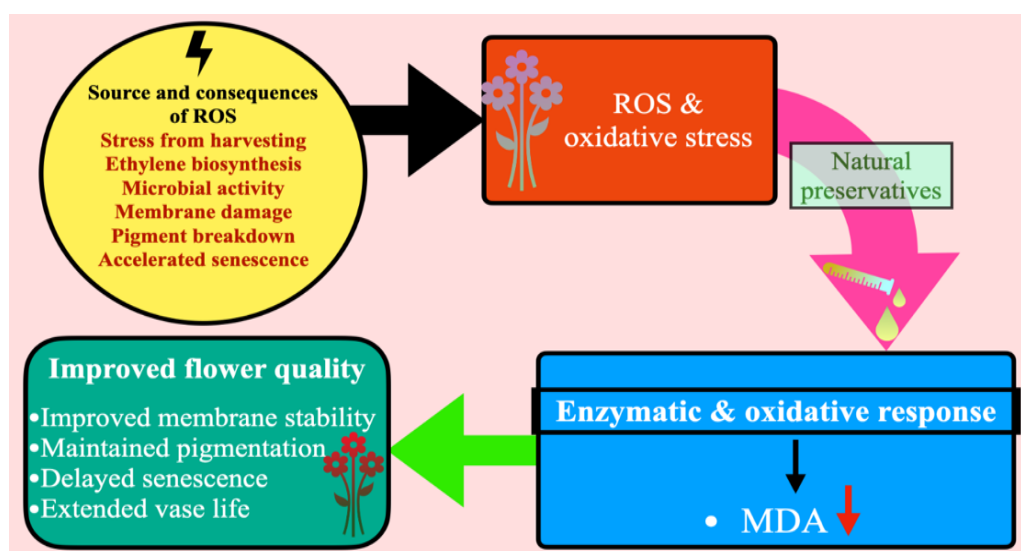


Fig. 3. Antioxidant function of natural preservatives in cut flowers. CAT: catalase, GR: glutathione reductase, MDA: malondialdehyde, ROS: Reactive Oxygen Species. The figure illustrates that natural preservatives scavenge reactive oxygen species (ROS) to mitigate oxidative stress. This reduction in ROS lowers membrane damage, indicated by decreased malondialdehyde (MDA), which in turn improves overall flower quality.

Antimicrobial effects

Microorganisms' rapid growth in the vase water of cut flowers makes them decay and discolor. Microbial growth can be slowed down by the use of different types of natural preservatives that prevent the growth of harmful microorganisms and allow cut flowers to be kept longer (Fig. 4). EOs possess the capacity to suppress microbial populations within cut flower preservative solutions through the disruption of microbial cell membranes (Bhandari et al., 2026). As an example, Thyme oil increased the amount of chlorophyll and the stability of membranes in *Eustoma grandiflorum*, resulting in a longer vase life for this cut flower (Abdossi et al., 2015). Organic acids, for example, CA, have the property to disrupt the membranes of microbial cells. By disrupting the cell membranes, there is an increase in osmolarity, which subsequently prevents the cell from synthesizing the cellular macromolecules necessary for its

growth, thus enhancing the antimicrobial properties of these acids (Zhang et al., 2011; Alkaç et al., 2023).

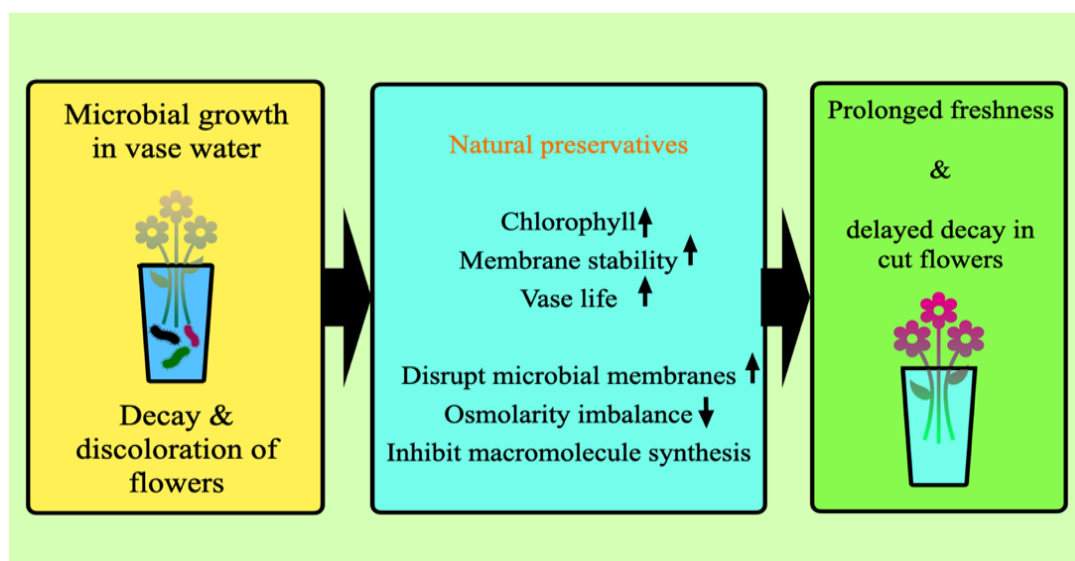


Fig. 4. Antimicrobial properties of natural preservatives in cut flower preservations. This figure demonstrates how natural preservatives inhibit microbial growth in vase water by disrupting cell membranes and impairing macromolecule synthesis, thereby reducing flower decay and extending freshness.

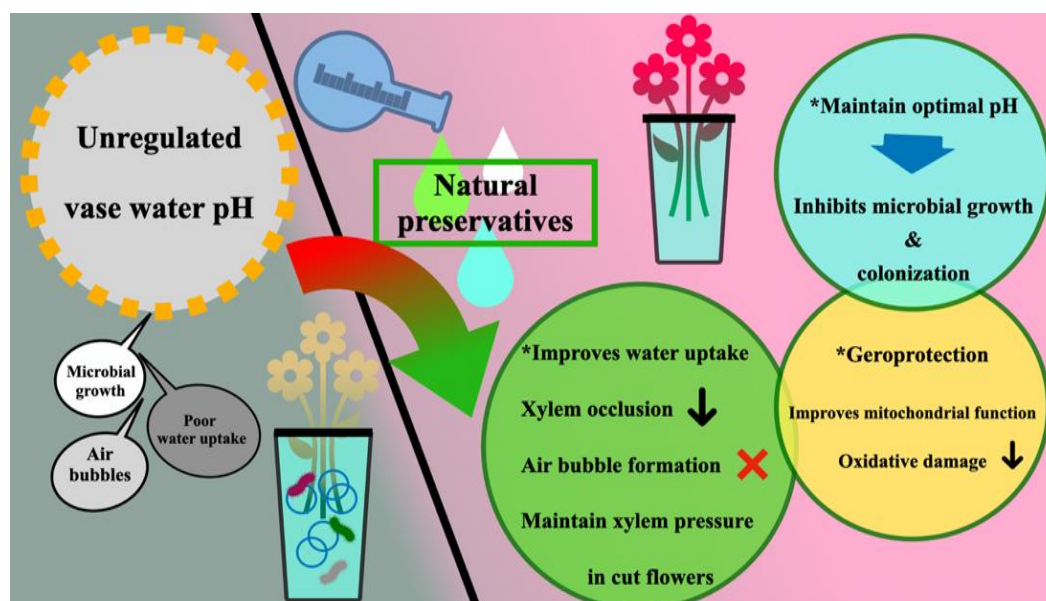


Fig. 5. pH regulation effect of natural preservatives in cut flowers. The figure demonstrates how natural preservatives optimize vase water pH, inhibiting microbial growth while enhancing water uptake and xylem function to prevent oxidative damage and prolong flower freshness.

pH regulation

The longevity of cut flowers is contributed to their vase water pH levels being controlled by natural preservatives. Regulating the vase water's pH prevents the majority of bacteria and fungi from multiplying to create an unmanageable environment for cut flowers (Fig. 5). Low pH improves water uptake by stems and reduces xylem blockage caused by air embolisms and microbial growth at cut sites (Hardenburg et al., 1986; Manzoor et al., 2024). Natural preservatives provide an ideal pH level for cut flowers, which prevents air from forming within the water-conducting tissues and enables cut flowers to absorb water while maintaining

freshness. By inhibiting bacterial growth, low pH will increase the quantity of water flow in the cut flowers and potentially prevent blockage of water pathways. In addition, the increased ability to absorb water resulting from the low pH levels will create enough pressure to minimize the occurrence and build-up of air bubbles within the xylem. Some of the plant extracts that have been analyzed and identified as senotherapeutics contain the properties that can assist in increasing the life span of cut flowers, contribute to improving mitochondrial efficiency, and prevent oxidative damage, which negatively affects the aging process and, in turn, an organism's overall lifespan (Lutchman et al., 2016).

Osmotic regulation

Keeping cut flowers hydrated is key to their structure and how long they last. Different natural preservatives can help balance osmotic pressure (Fig. 6). Osmotic balance happens when the water and dissolved solution levels inside the plant cells match the levels in the vase solution around them (Taiz et al., 2015; Majumder & Sharangi, 2024). EOs is another natural preservative that work by stopping microbes from growing in the vase solution. EOs also upregulate antioxidant Enzymes, helping plants handle stresses. Key enzymes are superoxide dismutase (SOD), polyphenol oxidase (PPO), and peroxidase (POD), which protect plant cells from damage and make the plants more tolerant to osmotic and oxidative stress (Borromeo et al., 2025). The vase life of cut flowers is strongly affected by organic acids and plant growth regulators. These treatments help manage water balance, extend freshness, and delay aging; for example, organic acids like CA and SA are very effective, as research consistently shows that they significantly improve longevity by keeping cut flowers fresh for longer (Alkaç et al., 2023). This regulation of osmotic pressure ensures that cut flowers remain hydrated and metabolically active for longer periods.

Nutrient supplementation

In order for cut flowers to last as long as possible and remain in good condition, having enough nutrition is really important. By using natural preservatives like CA or sugar, it is possible to give them both the nutrients and antioxidants needed to support metabolism and so remaining fresh longer (Fig. 7). One type of antioxidant from EOs is called a phenolic compound, which provides protection for cut flowers by supporting cell membranes and extending the amount of time that the cut flowers remain fresh (Gururani et al., 2023; Moussa et al., 2024).

Natural preservatives increase the longevity of cut flowers by providing multiple mechanisms that protect them. They can help to prevent and mitigate the negative effects of ethylene on cut flowers by providing antioxidant and antimicrobial effects, as well as by regulating overall pH and osmotic balance, and providing additional sources of nutrients. Each of the above activities contributes to the maintenance of the structural integrity of the cut flowers, thereby delaying senescence and supporting the maintenance of the cut flowers' aesthetic properties. Consequently, essential oils, plant extracts, and organic acids are effective natural preservatives for cut flowers. Their use in the floriculture industry opens a path toward more sustainable practices. This approach can help preserve flowers for longer periods and significantly improve their postharvest quality.

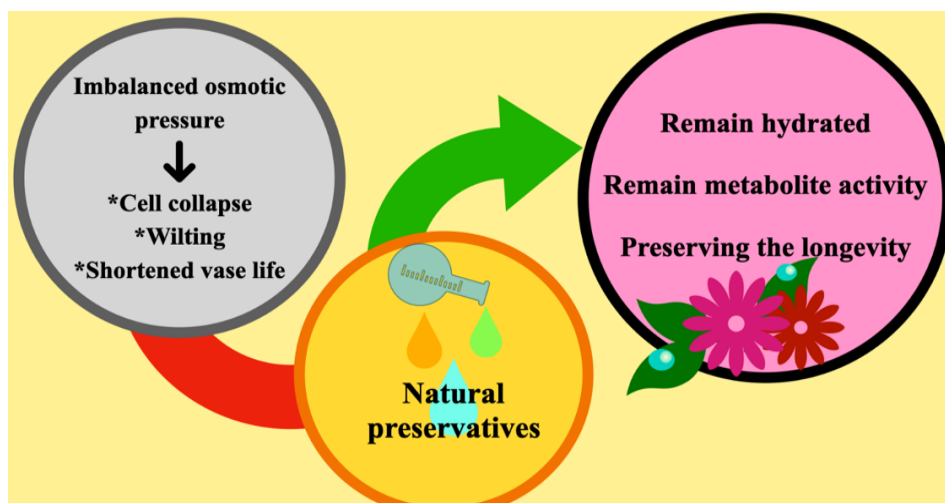


Fig. 6. Osmotic control by natural preservatives in cut flowers. The figure highlights how natural preservatives regulate osmotic pressure in cut flowers, preventing cell collapse and wilting while maintaining hydration and metabolic activity to extend vase life.

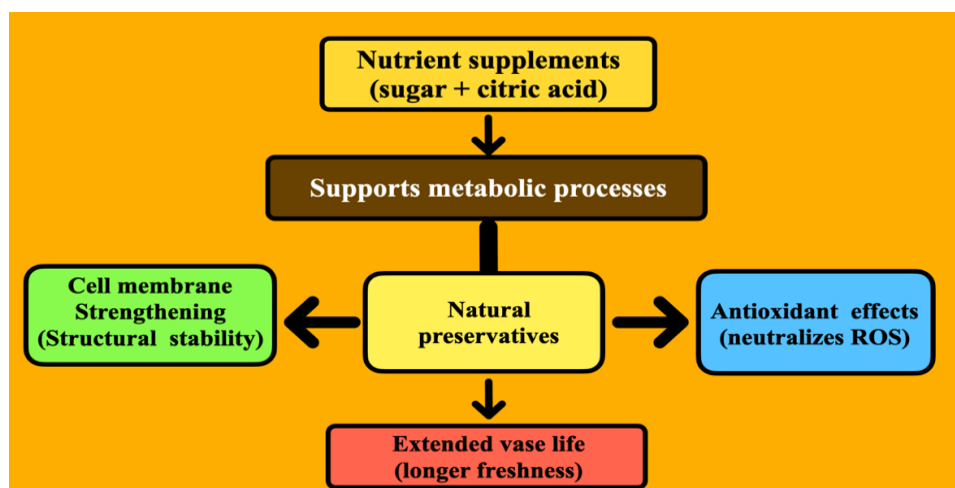


Fig. 7. Role of natural preservatives in nutrient supplementation for cut flower longevity. ROS: Reactive Oxygen Species. The figure demonstrates how natural preservatives enhance cut flower longevity by supporting metabolism, strengthening cell membranes, and neutralizing reactive oxygen species (ROS) to prolong freshness.

Limitations of existing studies

Research confirms that natural preservatives can extend the vase life of cut flowers. The findings, however, are qualified by several important limitations, like: (1) Many studies used small samples of just 10-20 flowers, so the results may not be strong or widely applicable. They also rarely repeated tests with different types of flowers. (2) The findings rely on stable, ideal laboratory conditions, a gap which means there is a lack of essential data on how the preservatives perform in the more variable conditions encountered *in vivo*. (3) Economic and stability issues present major hurdles. The high cost of extracting key natural compounds hinders their economic viability. Furthermore, their rapid degradation in solution presents a major problem to widespread commercial use. Another issue is the unpreservability of these compounds. Research on stabilizing natural preservatives is limited. Methods like microencapsulation are not yet practical for wide use. (4) These preservatives are often considered eco-friendly, but their true environmental impact is unclear. Important studies on their long-term effects on soil and water are still missing. (5) There is also very little data on

how different preservatives interact with each other. Combining ingredients, such as EOs with organic acids, may greatly improve their effectiveness, but studies on these synergistic effects remain sparse. This gap represents a significant missed opportunity for developing more robust natural solutions.

CONCLUSIONS

Based on the evidence reviewed, natural plant-based compounds have been proven to be an effective option to replace chemical preservatives that are currently used in the care of cut flowers. Some examples of these natural preservatives are essential oils, plant extracts, and organic acids. When added to the vase solution, they all help cut flowers last longer by preserving freshness and quality and by stopping harmful microbes from growing, which directly improves how the flowers look and extends their vase life. Furthermore, these products provide a variety of options to overcome common post-harvest problems and to prevent or reduce the shortening of the vase life or quality of cut flowers. These eco-friendly agents have multifunctional action, as they slow down aging, fight microbes, and nourish the flower. Their capability in these fields makes them especially effective at keeping cut flowers fresh for longer. The floriculture industry faces significant barriers in adopting natural preservatives. Therefore, targeted research should prioritize solving several practical challenges. The priority is to identify novel natural compounds with more severe efficacy and safety. Research should broaden to investigate underutilized plant species as novel sources. Agricultural by-products also represent a logical and sustainable category for exploration. Next, researchers should establish standardized protocols for extraction, formulation, and application. These standards guarantee that results remain reliable, whether in the lab or in a commercial warehouse. Scaling up production should be proven sustainable, both for the environment and as a business model. The practical use of natural preservatives requires proving they work reliably outside the lab. This proof depends on meeting three key conditions: consumer approval, commercial practicality, and verifiable environmental sustainability. A focused research effort in these areas is therefore essential. This approach provides a practical path to reducing the floriculture industry's reliance on synthetic chemicals. It also enhances cut flower quality and longevity, contributing to a more sustainable model. Ultimately, it supports a shift toward a more sustainable model for floriculture.

Conflict of interest

The authors declare that they have no conflict of interest.

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