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ARTICLE

Physiological effects of pulsing on torch ginger stems

Análise fisiológica e do sistema antioxidante de bastão-do-imperador pós-colheita

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Abstract: Sucrose pulsing solutions are employed for hydrating and maintaining the turgor of flower stems by influencing respiratory processes, supplementing natural sugars, and reducing transpiration. Additionally, sucrose pulsing can impact the physiology of flower stems, altering metabolism, postharvest quality, and durability. However, these effects are unknown for many tropical species. The objective was to elucidate the physiological and biochemical effects of pulsing torch ginger inflorescences with varying sucrose concentrations postharvest. To achieve this, floral stems of torch ginger were collected and immersed in sucrose solutions with concentrations of 15%, 20%, and 25% for 24 hours. Following this period, the stems were transferred to water, and every 3 days, assessments were made for visual quality, the percentage of true flowers, absorption rate, water content, fresh and dry mass, and colorimetric parameters. The activation of the antioxidant system and measurement of macromolecule content were also conducted. Pulsing with 20% and 25% sucrose accelerated the emergence of true flowers, in addition to increasing the absorption rate and fresh mass values of the stems. At these concentrations, an increase in lipid peroxidation was also observed. No SOD or CAT expression was noted, but pulsing led to increased reserves of proteins and sugars. Pulsing with 15% sucrose is recommended for torch ginger to maintain higher visual quality up to the 9th day after harvest.
Keywords: durability, *Etlingera elatior*, preservative solution, quality, sucrose.

Resumo: Soluções de pulsing com sacarose são utilizadas para hidratar e manter o turgor de hastes florais, influenciando processos respiratórios, suplementando açúcares naturais e reduzindo a transpiração. Além disso, o pulsing com sacarose pode impactar a fisiologia das hastes florais, alterando o metabolismo, a qualidade pós-colheita e a durabilidade. No entanto, esses efeitos são desconhecidos para muitas espécies tropicais. O objetivo foi elucidar os efeitos fisiológicos e bioquímicos do pulsing de inflorescências de gengibre-tocha com diferentes concentrações de sacarose após a colheita. Para isso, hastes florais de gengibre-tocha foram coletadas e imersas em soluções de sacarose com concentrações de 15%, 20% e 25% por 24 horas. Após esse período, as hastes foram transferidas para água, e a cada 3 dias, avaliações foram feitas para qualidade visual, porcentagem de flores verdadeiras, taxa de absorção, conteúdo de água, massa fresca e seca, e parâmetros colorimétricos. A ativação do sistema antioxidante e a medição do conteúdo de macromoléculas também foram realizadas. O pulsing com 20% e 25% de sacarose acelerou o surgimento de flores verdadeiras, além de aumentar a taxa de absorção e os valores de massa fresca das hastes. Nessas concentrações, também foi observado um aumento na peroxidação lipídica. Não foi notada a expressão de SOD ou CAT, mas o pulsing levou ao aumento das reservas de proteínas e açúcares. Recomenda-se o pulsing com 15% de sacarose para gengibre-tocha, a fim de manter uma maior qualidade visual até o 9º dia após a colheita.
Palavras-chave: durabilidade, *Etlingera elatior*, qualidade, sacarose, solução conservante.

Introduction

In the postharvest phase of flowers, one of the techniques utilized to enhance durability is pulsing. Pulsing involves a swift treatment performed immediately after harvesting to achieve rehydration and provide sucrose to reduce water stress and delay senescence (Costa et al., 2021; Krause et al., 2021; Malakar et al., 2023).

The solutions employed for pulsing, either individually or in combination, encompass organic acids with ethylene synthesis inhibitors, bactericidal properties for sanitary control, and, notably, sucrose solutions (Nascimento et al., 2019). Sucrose solution serves as the primary substance employed for pulsing, as it aids in maintaining turgor in flower stems. This solution acts as a substrate for respiratory processes, supplements natural sugars, reserves to activate metabolism, and reduces transpiration through osmotic regulation and stomatal closure (Menegaes et al., 2020).

The use of sucrose also prevents cell damage and death, consequently delaying the senescence of flower stems. Additionally, sucrose solutions increase carbohydrate content and water absorption, uphold flower turgidity, prevent xylem blockage, and enhance mechanical stiffness and cell wall thickening (Sales et al., 2021; Cunha Neto et al., 2023).

The concentration of sucrose may vary depending on the species and harvest stage. For torch ginger cv. Porcelana harvested at the semi-open stage, a concentration of 20% is recommended (Carneiro et al., 2014). However, it's worth noting that this recommendation is based solely on visual and fresh mass analyses, and the physiological and biochemical effects during the vase life period remain unknown. Pulsing solutions have also been tested for other tropical species, such as *Zingiber spectabile*, involving the use of silver nitrate followed by gibberellic acid (Santos et al., 2008; Coelho et al., 2012).

High concentrations of sucrose pulsing can have an inhibitory or toxic effect on post-harvest floral stems due to the osmotic imbalance and physiological stress they induce in plant cells. Excess sucrose can lead to cellular dehydration, impairing the uptake of water and nutrients and promoting the accumulation of toxic compounds, resulting in a reduction in the quality and shelf life of the flowers. Moreover, osmotic stress can interfere with cellular metabolism and enzymatic functions, compromising the maintenance of turgidity and accelerating the senescence of the floral stems (Liu et al., 2024).

Given the above, the aim was to evaluate the ideal sucrose concentration for postharvest pulsing of torch ginger. Additionally, the objective was to elucidate the effects of sucrose on the commercial quality, antioxidant system, and macromolecules of torch ginger stems, and how these effects contribute to extending vase life. Furthermore, it was determined whether pulsing with sucrose can accelerate metabolism to promote the emergence of true flowers or induce physiological stress.

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Materials and Methods

Effect of different sucrose concentrations

For the experiment, flower stems of *Etlingera elatior* cv. Porcelana were obtained from the Floriculture and Landscaping Sector of the Federal University of Lavras (21°13'25"S 44°58'17"W) and harvested at the semi-open stage following the descriptions provided by Carneiro et al. (2014) and Nogueira et al. (2023), ensuring the absence of true flowers. After harvesting, the inflorescences were rinsed in water, and the stems were standardized to a length of 45 cm, a diameter of 1.2 cm ± 2 mm, and an average weight of 250 g. The stems were then placed upright in containers, each containing 3 stems and 1 L of various sucrose concentrations (0%, 15%, 20%, and 25%) for 24 hours. Following this period, the flower stems were transferred to containers with 1 L of distilled water, sealed, and maintained at a temperature of 21 °C in darkness with a relative humidity of 70%. The concentrations employed in this study were determined based on the work of Carneiro et al. (2014), who also investigated sucrose pulsing for torch ginger cv. Porcelana.

Commercial quality of flower stems

For the evaluation of the visual quality of torch ginger inflorescences, scores were assigned by three evaluators every three days until the 9th day of assessment after pulsing, following the criteria established by Carneiro et al. (2014) as presented in Table 1.

Table 1. Criteria for evaluating the visual quality of torch ginger inflorescences by assigning scores.

Score	Quality	Description
4	Excellent	Stem and turgid inflorescences, bracts with bright and characteristic color.
3	Good	Beginning of turgor loss (only sensitive to touch) with or without the beginning of fading and/or wilting of the edges of the bracts and stems.
2	Regular	Decline of bracts due to visible loss of turgor and brightness of inflorescence and stem. Borders of the bracts exhibit a soggy appearance.
1	Bad	Loss of pronounced turgor of bracts and/or stems, translucent edges of bracts, the central part of the inflorescence softened.
0	Worst	Discard: soft and/or dry bracts and/or soggy appearance, with rotting of the central part of the inflorescence and abscission of the bracts.

Source: Carneiro et al. (2014)

Scores were assigned for visual quality, which helped determine whether the flower stems met commercialization criteria. When the score was below three, the flower stems lacked the required qualitative characteristics, rendering them unsuitable for commercialization. Consequently, the control group, represented by stems immediately after collection, received a score of four.

In addition to the visual aspects, the percentage of stems with true flowers after harvest, the rate of absorption by the inflorescence, and the fresh (g) and dry mass (g) of the torch ginger specimens were also assessed every three days using a precision analytical balance. The absorption rate was calculated by determining the volume of water consumed in mL stem $^{-1}$day^{-1}, and the water content (%) was determined using the formula [(fresh weight (g) - dry weight (g))/fresh weight (g)] × 100% (Sales et al. 2021).

Colorimetric analyses

To quantitatively monitor visual changes in the color of the bracts and compare them with the results of the visual assessments, colorimetric analyses were conducted using a colorimeter (Konica Minolta®, CM-5, Osaka, Japan). Measurements were taken every three days on the central portions of three fully expanded bracts positioned in the second outermost row of each inflorescence. The evaluated parameters included (Lago et al., 2020): a* (dimensionless), corresponding to red (positive values) and green (negative values) wavelengths; b* (dimensionless), referring to yellow (positive values) and blue (negative values) wavelengths; L* (dimensionless), which signifies the luminosity of the sample (the more positive L*, the lighter the sample; the more negative, the darker); Chroma (dimensionless), measuring the purity of the color: the stronger and brighter the color, the further the parameter is from the origin of the coordinates; Hue (degrees), indicating the hue.

Quantification of hydrogen peroxide and lipid peroxidation

Samples consisting of 0.2 g of fully expanded bracts, positioned in the second outermost row of each inflorescence, were macerated in liquid nitrogen supplemented with 20% polyvinylpolypyrrolidone (PVPP) (w v^{-1}), homogenized in 1.5 mL of 0.1% (w v^{-1}) trichloroacetic acid (TCA), and then centrifuged at 12,000 × *g* for 15 minutes at 4 °C. The hydrogen peroxide (H_2O_2) content was determined by measuring the absorbance at 390 nm in a reaction medium containing 100 mM potassium phosphate buffer (pH 7.0) and 1 M potassium iodide (Velikova et al., 2000).

Lipid peroxidation was assessed through the quantification of species reactive to thiobarbituric acid, as described by Buege and Aust (1978). The extract was obtained following the procedure outlined by Velikova et al. (2000). Aliquots (250 µL) of the supernatant were added to a reaction medium containing 0.5% (w/v) thiobarbituric acid (TBA) and 10% (w v^{-1}) TCA, followed by incubation at 95 °C for 30 minutes. The reaction was halted by rapid cooling on ice, and the readings were measured using a spectrophotometer at 535 nm and 600 nm.

Proteomic analyses

The expression of enzymatic activities of superoxide dismutase (SOD) and catalase (CAT) was assessed through electrophoresis, with 1 g of fresh material (FM) extracted in 0.2 M Tris-HCl buffer (pH 8.0) containing 0.1% beta-mercaptoethanol. The material was vortexed and stored in the refrigerator for 12 hours, followed by centrifugation at 14,000 rpm for 30 minutes at 4 °C. Electrophoresis was conducted using a discontinuous polyacrylamide gel system with a 7.5% separating gel and a 4.5% concentrating gel. The running buffer used was Tris-glycine at pH 8.9. A total of 60 µL of the sample supernatant was applied to the gel, and electrophoresis was performed at 150 V for 5 hours. After the run, the gels were analyzed for the presence of the enzymes SOD and CAT, following the procedure outlined by Silva Neta et al. (2020) with some modifications.

Determination of the content of total soluble sugars, reducing sugars and proteins

For the assessment of macromolecules associated with primary metabolism, 0.2 g of dry matter was extracted using 0.1 M potassium phosphate buffer (pH 7.0) and incubated in a water bath at 40 °C for 30 minutes. Subsequently, the extract was centrifuged at 10,000 × g for 20 minutes, and the supernatant was collected. The centrifugation process was repeated after additional buffer was added. Immediately following the collection of the supernatant, the material was stored at -80 °C.

For the quantification of total soluble sugars, reducing sugars, and proteins, the anthrone, dinitrosalicylic acid (DNS), and Bradford spectrophotometric methods were employed. These protocols were originally recommended by Yemm and Willis (1954), Miller (1959), and Bradford (1976), respectively, with some modifications.

Statistical analyses

The experiment was replicated twice in a completely randomized design with three replicates in a (4x3) + 1 factorial arrangement, comprising four sucrose concentrations, three days of data collection, and a control group represented by flower stems harvested on the day of harvest. The data underwent analysis of variance, and when significant

differences were detected, post hoc mean comparison tests were conducted. For the factorial arrangement, the Scott–Knott test was applied at a 5% significance level, and for comparing the control group with the treatment groups resulting from the factorial arrangement, the Dunnett test was performed at a 5% significance level using Sisvar software version 5.6 (Ferreira, 2019).

Results and Discussion

After being maintained in various concentrations of sucrose, on the 3rd day of evaluation, the flower stems still received a maximum score. On the 6th day, torch ginger treated with 15% sucrose pulsing maintained a score of 4, while those conditioned only in water received a score of 3. In contrast, stems subjected to concentrations of 20% and 25% sucrose received scores below 3, indicating a loss of quality and rendering commercialization unfeasible.

On the 9th day after harvest, the evaluations remained similar to those on the 6th day, with the best scores attributed to the stems maintained in 15% sucrose, followed by the stems stored only in water. However, all treatments received scores below 3, suggesting that the 9th day marks the commercialization limit for torch ginger flower stems (Fig. 1).

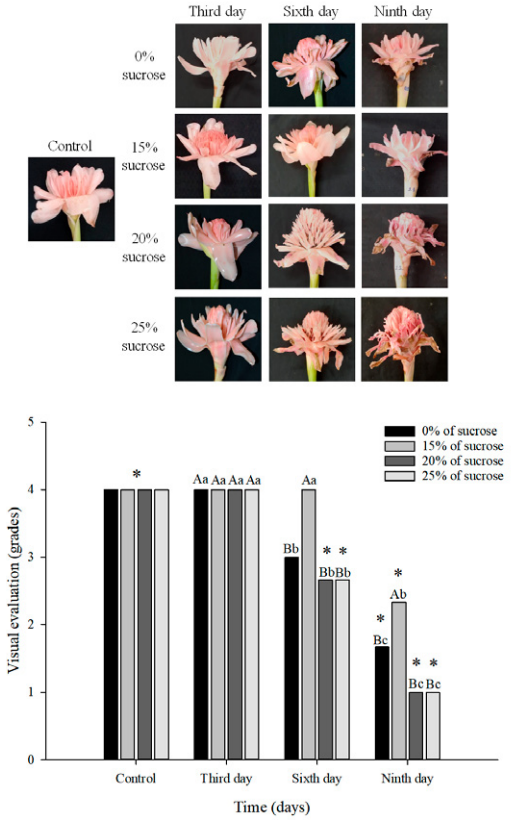

Fig. 1. Visual assessment of the quality (grade) of torch ginger flower stems subjected to varying sucrose concentrations over different postharvest time intervals. Means sharing the same uppercase letter (comparing sucrose concentrations) and lowercase letter (comparing time in days) do not exhibit significant differences according to the Scott–Knott test at a 5% error probability. Values marked with an asterisk (*) differ from the control group as determined by the Dunnett test at a 5% error probability.

Visual quality relies on the evaluation of subjective characteristics, and the senescence scale provides an alternative for estimating postharvest quality, enabling the estimation of stem longevity in the market (Mattos et al., 2020). Accordingly, in accordance with the senescence scale, torch ginger stems treated with 15% sucrose during pulsing exhibited higher visual quality and greater longevity for up to 6 days after pulsing.

The presence of true flowers was assessed, with stems specifically chosen at the semi-open stage and devoid of true flowers. On the 3rd day after undergoing pulsing, stems immersed in the highest sucrose concentrations displayed a higher percentage of true flowers, with values exceeding 55%. Stems treated with 15% sucrose exhibited the lowest percentage of true flowers, at 11%. On the 6th and 9th days, the percentage of stems with true flowers reached 100% in the treatments with the highest concentrations, while conditioning with water and 15% sucrose showed between 50% and 60% true flowers (Fig. 2).

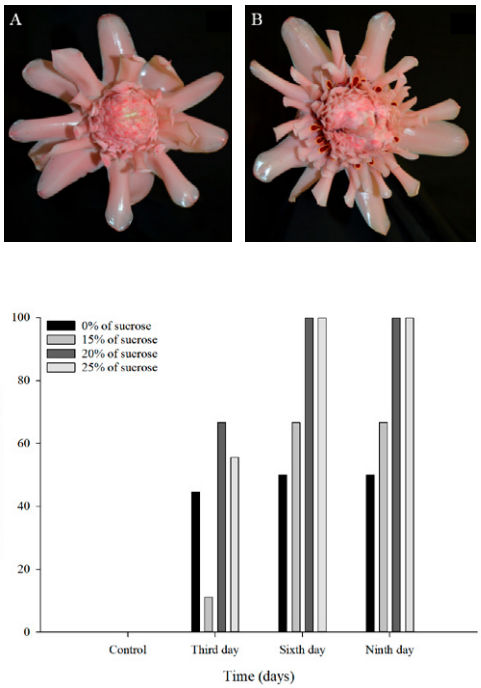

Fig.2. Percentage of true flowers (%) on torch ginger flower stems exposed to various sucrose concentrations during postharvest periods. (A) Floral stem from the control group (evaluation conducted at harvest) without the presence of a true flower. (B) Floral stem from pulsing treatments, displaying true flowers on the 3rd day.

When the outer bracts of true flowers of torch ginger began to open, the upper part of the peduncle changed colors, and the water content decreased due to the reduction in total soluble sugars. At this stage, the sucrose absorbed from the pulsing solution decreased due to the action of invertases and sucrose synthase, releasing glucose and fructose, suppressing floral stem metabolism, and increasing the concentration of solutes in the flowers (Araújo et al., 2018).

Considering that the cells forming the petal wall structure use sugars as a substrate for cellular respiration, the reduction in carbohydrate content during storage triggers senescence events, leading to a decrease in vase life (Costa et al., 2021). This explains why stems treated with 20% and 25% sucrose concentrations entered senescence faster, accompanied by a decrease in visual quality, as these concentrations induced a quicker appearance of true flowers that utilized the available sugar reserves.

The absorption rate (Fig. 3 A) was highest during the first evaluation, which started on the 3rd day, followed by the 6th and 9th days, with lower rates. Initially, among the concentrations, stems subjected to 20% and 25% sucrose pulsing displayed the highest absorption rates. However, on the final day, the 25% sucrose treatment exhibited the lowest rate. Regarding water content (Fig. 3 B), the percentage increased with stem rehydration and showed differences after the 6th day; the control group had a lower percentage than the pulsing treatments, irrespective of concentration. Similar behavior was observed for the fresh mass (Fig. 3 C) and dry mass (Fig.3 D) of torch ginger flower stems. Higher masses were recorded on the 3rd day of evaluation, with values decreasing until the 9th day.

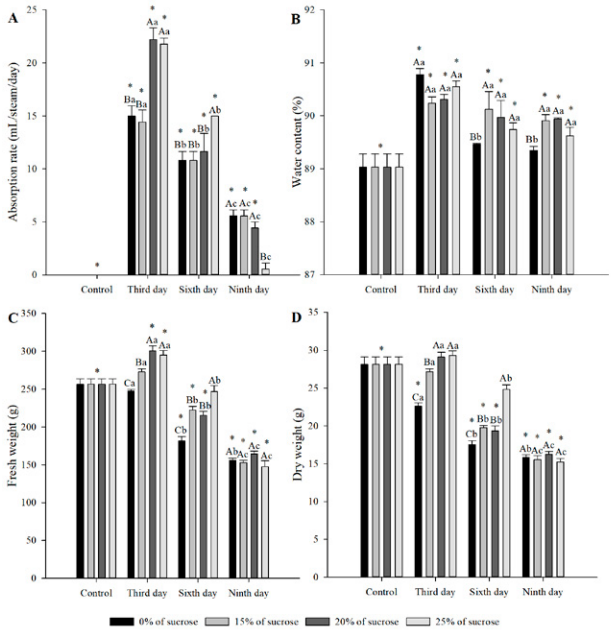

Fig. 3. (A) Absorption rate, (B) water content (%), (C) fresh weight, and (D) dry weight of torch ginger flower stems exposed to various sucrose concentrations during postharvest periods. Means sharing the same uppercase letter (comparing sucrose concentrations) and lowercase letter (comparing time in days) do not exhibit significant differences according to the Scott–Knott test at a 5% error probability. Values marked with an asterisk (*) differ from the control group as determined by the Dunnett test at a 5% error probability. Error bars represent the standard errors.

Only for the stems in the treatment without sucrose were the values on the 6th day statistically equivalent to those on the 9th. Among the treatments, initially, the stems subjected to 20% and 25% sucrose concentrations had the highest masses. On the 6th day, the stems exposed to a 25% concentration retained the highest mass, and on the 9th day of evaluation, there was no significant difference between the treatments.

The water content of cut stems is maintained by sucrose, as sucrose accumulates within the floral stem between the stem and the bracts, increasing the osmotic concentration of active solutes and, consequently, aiding in the maintenance of water content and cell turgidity (Krause et al., 2021). The durability of cut flowers is influenced by water absorption, retention capacity, transport, and loss in the tissues; thus, a decrease in water in the tissues is directly related to the longevity of the plant (Nascimento et al., 2019).

Sucrose serves as an osmolyte and an energy source that plays a crucial role in preserving the quality of cut flowers. This function is associated with extending the vase life, as observed in torch ginger, where the fresh mass, like the absorption rate, increased in the first few days after harvest due to reduced osmotic potential and stomatal closure. Consequently, with the onset of senescence, both weight and absorption decreased due to the loss of turgidity, cavitation of xylem vessels, and impaired cellular respiration (Nascimento et al., 2019).

Although solution uptake increased, the elevated sucrose concentrations created a hyperosmotic environment, hindering the effective water absorption by the cells of the floral stems. This osmotic imbalance may have led to cellular dehydration and reduced turgidity, resulting in lower water content despite the higher solution uptake. Additionally, the high sucrose concentration may have caused further physiological stress, negatively affecting the cells' ability to maintain adequate hydration (Sales et al., 2021)

Colorimetry enables the quantitative assessment of parameters related to color and brightness, which are associated with the perception of wavelengths visible to humans. The parameter a* (Fig. 4 A), associated with the green color range (negative values) and red color range (positive values), diverged from the control starting on the 6th day, except for the stems subjected to a 15% sucrose concentration. Regarding a*, differences between treatments occurred on the 9th day, where stems at a 15% concentration exhibited the least change in a*, while the 25% concentration induced the most significant increase; the highest red color values were observed on the 9th day of evaluation when compared to the previous days. For the L* parameter (Fig. 4 B), the highest values were observed on the 6th and 9th days, differing from the control, with no differences between treatments.

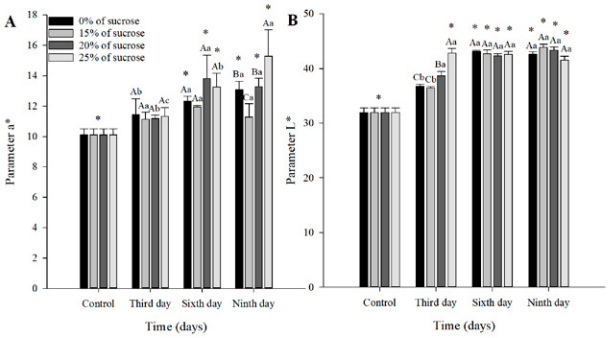

Fig. 4. (A) a* (dimensionless) and (B) L* (dimensionless) parameters of torch ginger flower stems exposed to various sucrose concentrations during postharvest periods. Means sharing the same uppercase letter (comparing sucrose concentrations) and lowercase letter (comparing time in days) do not exhibit significant differences according to the Scott–Knott test at a 5% error probability. Values marked with an asterisk (*) differ from the control group as determined by the Dunnett test at a 5% error probability. Error bars represent standard errors.

On the 3rd day of evaluation, the stems immersed in water and in a 15% sucrose solution did not differ, while the stems subjected to a 25% sucrose solution exhibited the highest values for the L* parameter and differed from the control.

The h° parameter determines the color quadrant in which a sample falls. Values ranging from 0° to 90° are within the red color range; torch ginger samples had an average of 43.90°, justifying the analysis of a*, and indicating that the analysis of b* is not significant because it corresponds to the blue (negative values) and yellow (positive values) range. The mean C* value obtained for the stems was 14.06, with no differences between treatments.

Based on the results for a*, a change in the color of torch ginger began on the 6th day. This change occurred on the same day that quality deterioration started, suggesting that the color change is a process related to senescence. In the case of anthurium senescence, a color change was observed on the 9th day due to an advanced stage of stem senescence (Mattos et al., 2020).

The preservation of color is an important factor in determining the commercial value of horticultural products. L* quantifies the luminosity reflected by the bracts, and the decline in this parameter with prolonged postharvest time is associated with the browning of the bracts or petals. An increase in this parameter is linked to the whitening of the bracts, which is related to mass loss, senescence, and pigment degradation (Fernando-Santos et al., 2020), as observed in torch ginger stems on the 6th day, regardless of the treatment, corresponding to a loss in stem quality.

Lipid peroxidation (Fig. 5 A) was higher on the 3rd day in the treatment with 25% sucrose. On the 6th and 9th days of evaluation, the 20% and 25% treatments exhibited higher peroxidation values. However, on the 9th day, there was less peroxidation in the stems exposed to 15% sucrose. Among the treatments, the highest concentration of hydrogen peroxide (Fig. 5 B) was significant only from the 6th day for the 25% sucrose treatments. The absence of lipid peroxidation in the control plants over time can be attributed to several factors. In this study, torch ginger stems were harvested and immediately subjected to controlled conditions to minimize stress and delay senescence. These controlled conditions included keeping the stems in the dark at a constant temperature and high humidity, which is crucial for reducing stress and accurately assessing the actual effect of sucrose pulsing.

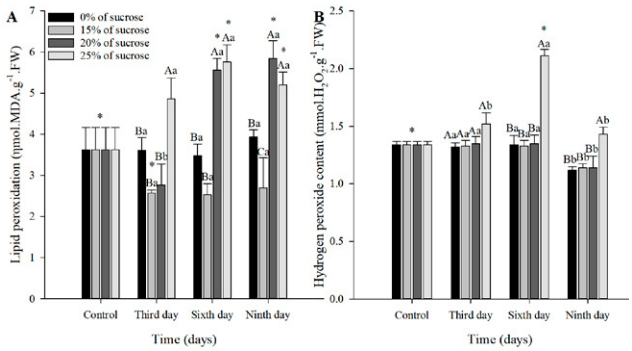

Fig. 5. (A) Lipid peroxidation and (B) hydrogen peroxide content of torch ginger flower stems exposed to various sucrose concentrations during postharvest periods. Means sharing the same uppercase letter (comparing sucrose concentrations) and lowercase letter (comparing time in days) do not exhibit significant differences according to the Scott–Knott test at a 5% error probability. Values marked with an asterisk (*) differ from the control group as determined by the Dunnett test at a 5% error probability. Error bars represent standard errors.

During the senescence process of the stems, the production of reactive oxygen species (ROS), such as hydrogen peroxide and superoxide anions, is expected to increase (Fernando-Santos et al., 2020). However, in this study, the increase in H_2O_2 in torch ginger floral stems was directly correlated with the stress caused by higher concentrations of sucrose and not senescence, as lower concentrations did not show a similar increase at the onset of senescence (Fig. 5).

The accumulation of these molecules in the cell causes oxidative stress and damages membranes and macromolecules, leading to plant death. High concentrations of substances applied in pulsing, including sucrose, can induce negative effects related to visual quality characteristics. These effects are directly related to the increases in hydrogen peroxide and oxygen free radicals that can induce stress (Pourzarnegar et al., 2020).

Torch ginger stems subjected to pulsing with 20% and 25% sucrose increased lipid peroxidation due to the overproduction of radicals and oxidative stress, which consequently caused tissue damage and reduced vase life. The increase in lipid peroxidation indicates the stress induced by higher concentrations of sucrose tested, leading to the production of H_2O_2, which consequently activates the enzymatic and nonenzymatic antioxidant system (Mattos et al., 2023).

The electrophoresis results showed that the flower stems of torch ginger did not express SOD or CAT activity regardless of the treatment. The antioxidant system plays an essential role in preventing the oxidative effects of ROS in plants. An increase in this system delays senescence due to the breakdown of ROS, which can degrade lipids, proteins, and nucleic acids (Pourzarnegar et al., 2020; Nogueira et al., 2023).

The effect of pulsing with different concentrations of sucrose on Polianthes tuberosa L. induced low activity of enzymes without changes during the senescence process (Fernando-Santos et al., 2020).

SOD is usually found in chloroplasts, peroxisomes, mitochondria, and cytosol, and this enzyme is responsible for reducing the superoxide anion to H_2O_2 and O_2 (Fernando-Santos et al., 2020; Mattos et al., 2023). Thus, it is suggested that the short vase life of torch ginger stems has a direct correlation with the absence of expression of these enzymes; therefore, the loss of quality occurs quickly starting on the 6th day.

On the 3rd day after harvest, the stems subjected to the sucrose treatments had higher average protein contents (Fig. 6 A) regardless of the concentration, compared to the control treatment. This difference was maintained until the 9th day of evaluation. Throughout the conditioning period, there was no protein consumption in the torch ginger specimens, regardless of the treatment.

Total soluble sugars (Fig. 6 B) were consumed at the beginning of the conditioning period, with a decrease of 50% on the 3rd day of evaluation. After this period, the floral stems maintained similar values, with the exception of the treatment conditioned only with water at 9 days. Reducing sugars (Fig. 6 C) in the floral stems showed a similar response pattern for all treatments, being consumed on the 3rd day of evaluation, with lower consumption in the treatment with 25% sucrose. Constant values were maintained at 6 days for all treatments, and in the last evaluation, the control treatment showed higher consumption, differing from the treatments with sucrose.

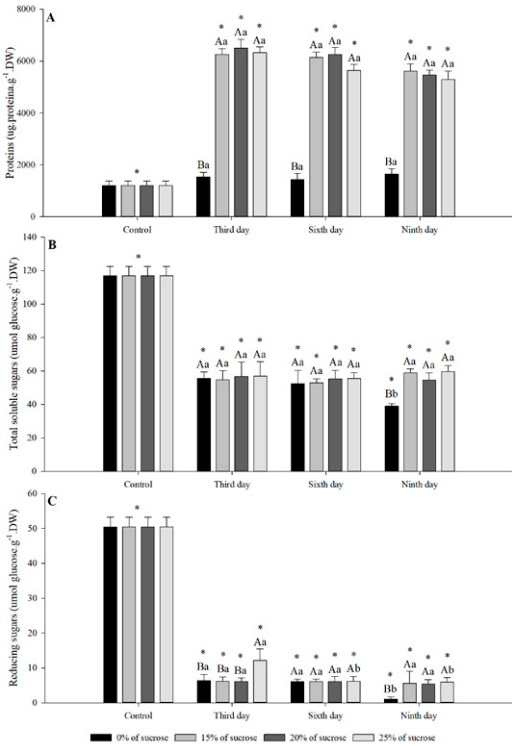

Fig. 6. (A) Proteins, (B) total soluble sugars, and (C) reducing sugars of torch ginger flower stems subjected to different concentrations of sucrose in relation to postharvest time. Means followed by the same uppercase letter (comparing sucrose concentrations) and lowercase letter (comparing time in days) do not differ by the Scott–Knott test at a 5% error probability. Values marked with an asterisk (*) differ from the control by the Dunnett test at a 5% error probability. Bars represent standard errors.

The senescence process occurs due to the mobilization and consumption of reserves throughout vase life. It is also common for the content of some reserves to increase as a way to avoid senescence; however, they are soon consumed, and thus, a reduction occurs (Mattos et al., 2018). For torch ginger, it was observed that sugars are the first reserves mobilized immediately after harvesting. Proteins in torch ginger were not mobilized during the senescence process, as evidenced by the control treatment, and pulsing led to a significant increase in this molecule after stem harvest, also indicating a lack of consumption.

The increase in the percentage of true flowers of torch ginger in the treatments with the two highest concentrations of sucrose is directly related to the opening of the inflorescence and thus to cell expansion. For cells to expand, it is necessary to expend energy that comes from the breakdown of molecules such as reducing sugars that are already available for use and soluble sugars that are reserve sources (Mattos et al., 2018; Cunha Neto et al., 2023).

The sugar content is also directly related to the absorption rate and water content because the mobilization of these reserves not only changes cellular respiration but also changes the osmotic potential and the water inflow that maintains the pressure potential, which are phenomena involved in floral opening and the onset of senescence (Fernando-Santos et al., 2020; Mattos et al., 2018).

These molecules were consumed after cutting the torch ginger specimens since the content decreased significantly. It is also evident that sucrose pulsing helps in maintaining the contents of these reserves because available sugars were consumed in the control treatment at different times, while the sugar content remained constant in the other treatments after harvest.

Conclusions

Thus, pulsing with 15% sucrose is recommended for torch ginger to maintain higher visual quality. It is noteworthy that when using this concentration, the stems remained viable for commercialization for up to 9 days post-harvest. Pulsing with higher sucrose concentrations, 20% and 25%, accelerates the emergence of true flowers, besides increasing the absorption rate and fresh mass of stems. These concentrations also increase lipid peroxidation, thus reducing the visual quality of torch ginger. Pulsing increases protein reserves, and the reserves consumed by torch ginger are sugars. After harvesting, torch ginger stems do not express SOD or CAT.

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Author Contribution

ARCN: data curation; formal analysis; investigation; methodology; writing - original draft. **PDOP:** conceptualization; data curation; funding acquisition; project administration; writing - review & editing. **MRN:** data curation; formal analysis; investigation; methodology; writing - original draft. **AMPN:** data curation; formal analysis; investigation; methodology; writing - original draft. **COT:** formal analysis; methodology. **MVR:** conceptualization; data curation; funding acquisition; project administration; writing - review & editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request

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