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Scientific Article

Bromatological characterization and storage of edible flowers produced in an aeroponic system

Caracterização bromatológica e armazenamento de flores comestíveis produzidas em sistema de aeroponia

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ABSTRACT - The consumption of edible flowers has increased in recent years because, in addition to their aesthetic appeal, they provide flavors and aromas that diversify gastronomy and have high nutritional potential. Aeroponics is a cultivation system that presents itself as a viable alternative to optimize agricultural production in urban centers, contributing to greater access and quality of the final product. This study aimed to evaluate the bromatological characteristics and storage time of three species of edible flowers produced using an aeroponic system. The experiment consisted of installing an aeroponic system in which the species China pink, Torenia, and Begonia were cultivated for 45 days in a completely randomized design with 14 repetitions. The flowers produced were collected and characterized in terms of pH, soluble solid content, proximate composition, and mineral profile. The storage period of flowers in plastic trays under refrigeration was also evaluated. The results suggest that the evaluated edible flower species present significant nutritional characteristics, in addition to the sensory characteristics of edible flowers. Refrigeration of the species in plastic trays ensured approximately 20 days of storage for China pink and Begonia and nine days for Torenia. Aeroponics allows the production of edible flowers with good nutritional quality and storage viability.

Keywords: China Pink. Torenia. Begonia. Plant nutrition.

RESUMO - O consumo de flores comestíveis tem crescido nos últimos anos, pois além do efeito estético, também proporcionam sabores e aromas que diversificam a gastronomia, e alto potencial nutricional. A aeroponia é um sistema de cultivo que se apresenta como uma alternativa viável para otimizar a produção agrícola nos centros urbanos, contribuindo para maior acesso e qualidade do produto. O objetivo do trabalho foi avaliar características bromatológicas e o tempo de armazenamento de três espécies de flores comestíveis produzidas em sistema de aeroponia. O experimento constou na instalação do sistema de aeroponia, no qual as espécies Cravina, Torênia e Begônia foram cultivadas pelo período de 45 dias, em delineamento inteiramente casualizdo, com 14 repetições. As flores produzidas foram coletadas e caracterizadas quanto ao pH, teor de sólidos solúveis, composição proximal e perfil de minerais. Também foi avaliado o período de armazenamento das flores em bandejas plásticas sob refrigeração. Os resultados sugerem que as espécies de flores comestíveis avaliadas apresentam características nutricionais significativas, além das características sensoriais das flores comestíveis. A refrigeração das espécies em bandejas plásticas assegurou aproximadamente 20 dias de armazenamento para Cravina e Begônia e 9 dias para Torênia. A aeroponia permite a produção de flores comestíveis com qualidade nutricional e viabilidade de armazenamento.

Palavras-chave: Cravina. Torênia. Begônia. Nutrição de plantas.

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INTRODUCTION

Edible flowers have aroused increasing gastronomic and scientific interest in recent decades, not only for their aesthetic appeal and sensory enhancement of dishes but also for their nutritional and functional potential. Several species contain significant levels of minerals, proteins, vitamins, and bioactive compounds, such as flavonoids, carotenoids, and anthocyanins, which are associated with antioxidant activity and potential health benefits. In addition to their nutritional aspects, their use is aligned with sustainability practices, food diversification, and adding value to ecology-based production systems, making them a promising alternative in the context of contemporary food (PEREIRA; BARROS; FERREIRA, 2020; SANTOS; GRACIANO, 2022; ASSIS et al., 2025).

The consumption of flowers in human food is a practice that dates back to ancient civilizations, and today, species such as nasturtium, pansy, sunflower, and begonia have been explored for the diversification of gastronomy (ASSIS et al., 2025).

Reports in the literature suggest that the consumption of edible flowers should be done with care, since there is variability in species, which require correct identification for use in food, in addition to incipient data on production and food safety. In contrast, the dissemination of relevant information on the consumption of these species can contribute to sustainability by valuing and conserving biodiversity and developing urban production systems and practices (RIGHI; BIONDO, 2024).

Vertical cultivation systems, for example, with the use of technology and control of factors such as light, humidity, temperature, and nutrients, allow for better use of cultivation areas, in addition to increasing production efficiency and the final quality of plant species (GUNDIM; LIMA, 2023).

Aeroponics is a cultivation system in which nutrient solutions are sprayed onto the roots of plants at regular intervals throughout the day (MOBO, 2025). In addition to optimizing space, the aeroponic system offers significant water savings and accelerates the growth and development of plant species owing to greater efficiency in nutrient absorption, favoring flowering and product composition (DINESHI, 2025). In the context of floriculture, aeroponics has been reported as a more efficient cultivation system, with its main advantage being the enhanced oxygenation of the root system, which accelerates plant metabolism and consequently shortens the flowering cycle (MARAPPAN et al., 2025).The application of aeroponics to the production of crops such as edible flowers may represent a significant advance in productive efficiency, nutritional quality, and postharvest storage potential, all of which are highly relevant to the edible flower production chain.

Begonia, Torenia, and China pink are edible flowers valued for their nutritional and antioxidant properties. They are increasingly used as functional ingredients in modern gastronomy, providing unique organoleptic characteristics and bioactive phytochemicals that contribute to human health and food innovation (MARCHIONI et al., 2024; MORAIS et al., 2022; BENVENUTI; MAZZONCINI, 2021).

Therefore, the present study aimed to analyze the bromatological characteristics and storage time of three species of edible flowers produced in an aeroponic system.

MATERIAL AND METHODS

The experiment involved the installation of an aeroponic system with two nutrient solutions (Table 1) and three species of edible flowers: torenia (*Torenia fournieri*), china pink (*Dianthus chinensis*), and begonia (*Begonia semperflorens*).

The species were cultivated in a greenhouse at the University of Rio Verde, located in Rio Verde, GO.

After 45 days of cultivation in the aeroponic system, the flowers produced were collected for nutritional characterization at the Bromatology Laboratory of the University of Rio Verde – GO. Flowers were also collected to evaluate the storage period of the species using a senescence scale.

Preparation of the aeroponic system and plant growth

For the preparation of the aeroponics system, six PVC pipes with a diameter of 100 mm and a length of 1 m were used, two pipes for each species, one for each nutrient solution tested. Each PVC pipe was prepared with fourteen standardized holes in a diametrically opposite and staggered pattern, forming a spiral.

Nutrient solutions were prepared and stored separately for each pipe and species, totaling six nutrient solution reservoirs. The solution was distributed into the PVC pipes using a system containing a suction pump, transport hose, and sprayers located in the spaces intended for the seedlings.

The daily irrigation system was configured to be activated every 20 minutes, that is, the solutions were sprayed for 20 minutes, and the system was turned off for 20 minutes, to ensure moisture, nutrition, and root respiration. During the day, the system started operating at 7:00 AM and ended at 6:00 PM. During the night, the system was activated twice to maintain root moisture at 10:00 PM and 2:00 AM. An automated controller was used to ensure the proper functioning of the irrigation schedule.

The experiment was set up with two nutrient solutions (HOAGLAND; ARNON, 1950; LANDGRAF et al., 2015) however, after three attempts, plants of the three species failed to develop in the Landgraf solution. Consequently, the experiment was conducted exclusively with the Hoagland and Arnon nutrient solution, using three treatments corresponding to the three edible flower species, with fourteen replicates per treatment. Each plant was considered an experimental unit.

It should be noted that the Landgraf et al. (2015) solution is commonly recommended for producing fruit vegetables, and the Hoagland and Arnon (1950) solution is considered a conventional solution for production in hydroponic systems. The concentrations of nutrients in the nutrient solutions are presented in Table 1.

Table 1. Composition of the nutrient solution according to Hoagland and Arnon (1950) and Landgraf et al. (2015).

Nutrient	Hoagland and Arnon Solution	Landgraf Solution
	------------------ mg L^{-1} ------------------	
N	210	169
P	31	62
K	234	311
Ca	200	153
Mg	48	43
S	64	50
B	0.5	0.2
Cu	0.02	0.03
Fe	5	4.3
Mn	0.5	1.1
Mo	0.01	0.05
Zn	0.05	0.3

Bromatological evaluations of flowers

The flowers were harvested manually in the morning. Four flowers were collected from each replicate. Sampling was standardized by selecting fully opened, flowers two days after flower bud opening. Samples of each species were packaged in insulated containers for transport to the Bromatology laboratory. All evaluations were performed using the same set of samples, which was sufficient for all analyses.

Physicochemical analyses

The pH was determined using a benchtop digital potentiometer with 2 g of sample diluted in 100 mL of distilled water. The electrode was then inserted into the beaker for pH reading, aiming for greater precision (IAL, 2005).

The soluble solids content was determined using a Krüss Optronic®/DR 301-95 digital refractometer after dilution in distilled water at a 1:100 ratio. After reading the filtrate, a correction was made using a multiplication factor of 100, and the result was expressed in °Brix (IAL, 2005).

Proximal composition

The quantification of fixed mineral residue was performed in a muffle furnace at 550°C, using the same samples previously dried for the determination of water content. The method followed the protocols described by the AOAC (2005), with the results expressed as a percentage of ash in relation to the dry mass of the sample (Equation 1).

$$Ashes = \frac{ashes\ (g)}{wetsample\ (g)} \quad (1)$$

The crude protein content was determined using quantitative method nº 920.87 in a micro-Kjeldahl distiller (Tecnal®/TE-0363), based on the total nitrogen content, with a conversion factor of 5.75 for vegetable proteins (AOAC, 2000).

Mineral profile

Macro-and micronutrient mineral analyses of edible flowers were performed. For phosphorus analysis, the sample (FCG) was digested with a nitroperchloric mixture, and the element was determined by colorimetry with ammonium molybdate and ascorbic acid. For potassium analysis, the sample (FCG) was digested with a nitroperchloric mixture, and the element was determined using flame photometry. To determine the Ca, Mg, and micronutrient (Cu, Fe, Mn, and Zn) contents, the samples were digested with a nitroperchloric mixture, and the elements were determined by atomic absorption (AOAC, 1995).

Flower storage

The flowers produced by the three species were harvested and stored in rigid, transparent polypropylene trays with lids made of the same material and sealed, simulating the conventional method used for the commercial packaging of edible flowers. The trays containing the flowers were stored under refrigeration at 5°C. Four trays, each containing seven flowers, were used for each species. The flowers were daily evaluated on a scale of 1 to 5, following the senescence scale proposed by Souza et al. (2016). The scores followed the following senescence parameters: 1) no symptoms; 2) up to 25% of the petals with symptoms; 3) 26–50% of the petals with symptoms; 4) 51–75% of the petals with symptoms; and 5) more than 76% of the petals with symptoms.

Statistical analysis

The data were analyzed using a completely randomized design consisting of three species (Begonia, China pink, and Torenia) with fourteen repetitions, totaling 42 experimental units (plants). Flower storage was evaluated descriptively and therefore not included in the statistical analysis. Analysis of variance (ANOVA) was conducted using the F-test, with a significance level of 5%. When a significant effect of species was identified, the means and their respective standard deviations were compared using Tukey's test ($p<0.05$) with the aid of the SISVAR statistical software (FERREIRA, 2019).

RESULTS AND DISCUSSION

The results obtained in this study corroborate recent research that highlights the nutritional relevance of edible flowers, especially regarding their mineral, protein, and bioactive compound content.

Physicochemical composition and proximate

The physicochemical composition (pH and soluble solids (SS)) and proximate composition (ash and protein) of the edible flower species China pink, Begonia, and Torenia showed significant differences between the species ($p<0.05$), indicating variability in nutritional potential and technological characteristics (Table 2). These differences demonstrate that each species exhibits distinct physicochemical properties that may influence not only its nutritional quality but also its stability, sensory acceptance, and potential applications as a functional food ingredient. The pH ranged from 4.71 (Begonia) to 6.94 (China pink), with Begonia being significantly more acidic than other species. China pink and Torenia did not differ significantly, exhibiting pH values close to neutrality. The observed variation is consistent with previous reports describing considerable differences in the pH of edible flowers, which influence their flavor, microbiological stability, and culinary applications (FERNANDES et al., 2017; PINHEIRO; RODRIGUES; CARVALHO, 2021).

The lower pH of Begonia may contribute to improved microbiological stability by limiting the growth of spoilage and pathogenic microorganisms, thereby extending the shelf life of fresh edible flowers. Furthermore, pH influences enzyme activity, pigment stability, and the preservation of bioactive compounds during storage and processing. More acidic conditions also favor anthocyanin stability, preserving the red and pink pigmentation while helping to maintain the antioxidant capacity of edible flowers (PEREIRA et al., 2024). From a sensory perspective, acidity enhances the perception of freshness and may improve flavor balance in salads, desserts, and gourmet dishes. Therefore, the more acidic pH observed in Begonia may represent an important technological and sensory advantage for its commercial use. In terms of soluble solids (SS), Begonia exhibited the highest content (0.40 °Brix), followed by Torenia (0.35 °Brix) and China pink (0.26 °Brix), with significant differences among all species. Although the values are relatively low, they indicate the presence of soluble sugars, organic acids, amino acids, vitamins and other low-molecular-weight compounds that contribute to the nutritional and sensory properties of edible flowers (Table 2).

Soluble solids are primarily composed of products of primary plant metabolism and represent readily available energy sources, while also serving as precursors for the biosynthesis of secondary metabolites, including phenolic compounds with antioxidant activity. From a technological perspective, SS are associated with flavor intensity, sweetness perception, and overall consumer acceptance (FAN, et al., 2021). Therefore, the higher SS content observed in Begonia, combined with its lower pH, may contribute to a more distinctive sensory profile, highlighting its potential for fresh consumption and high-value gastronomic applications.

Table 2. Average values and standard deviations of pH, soluble solids (SS), ash, and protein content of the edible flower species China pink, Begonia, and Torenia.

Edible flower species	pH	SS	Ash	Protein
	in H_2O	Brix	g 100 g^{-1}	g 100 g^{-1}
China pink	6.94±0.87a	0.26±0.03c	1.37±0.16b	1.82±0.22a
Begonia	4.71±0.57b	0.40±0.04a	1.03±0.11c	1.05±0.12b
Torenia	6.93±0.87a	0.35±0.04b	1.70±0.20a	0.94±0.11b
CV (%)	2.78	2.57	3.41	4.92

CV = coefficient of variation. Means followed by the same letter in the column do not differ from each other according to Tukey's test ($p<0.05$).

Regarding proximate composition, Torenia exhibited the highest ash content (1.70 g 100 g⁻¹), followed by China pink and Begonia. As ash content is an indirect measure of the total mineral fraction in plant tissues, the higher value observed in Torenia suggests a greater proportion of inorganic constituents compared with the other species. These constituents may include minerals involved in essential physiological processes in plants and, when consumed, contribute to the mineral intake of the diet. Minerals play important roles in several biological processes, including osmotic regulation, enzyme activation, electrolyte balance, bone metabolism, and antioxidant defense (GUSH; SHAH; GILANI, 2021). Therefore, although edible flowers are generally consumed in small quantities, the higher ash content observed in Torenia may indicate a greater potential contribution to dietary mineral intake, particularly when these flowers are incorporated into fresh culinary preparations.

In terms of protein content, China pink showed the highest value (1.82 g 100 g^{-1}), which was significantly higher than those observed for the other species. These results suggest that China pink had the highest protein content among the edible flowers evaluated, whereas Torenia exhibited the highest ash content, indicating a greater proportion of inorganic constituents (Table 2). Plant proteins provide amino acids required for tissue maintenance and metabolic functions and may also include proteins and peptides with potential biological activities, such as antioxidants, antimicrobial, and anti-inflammatory effects. Therefore, although edible flowers are not consumed as primary sources of protein, their protein fraction may contribute to the overall nutritional value of meals, particularly when incorporated into fresh culinary preparations. In relation to proximate composition, the protein levels found, especially in China pink, are within the range reported for edible ornamental flowers (1-3 g 100 g^{-1}), as described by Pereira, Barros and Ferreira (2018) and Grzeszczuk; Stefaniak an Pachlowska (2016). Although they are not significant protein sources compared to legumes, these flowers can contribute to nutritional diversification, especially when used in fresh preparations. Their incorporation into the diet may also increase the diversity of plant-derived nutrients and bioactive compounds consumed, an important aspect of healthy dietary patterns that are associated with improved metabolic health and reduced risk of chronic non-communicable diseases.The higher ash content in Torenia compared to Begonia and China pink is due a higher total mineral concentration, which is consistent with recent studies highlighting the great variability in mineral content among floral species (FERNANDES et al., 2017; PINHEIRO; RODRIGUES; CARVALHO, 2021). This variability can be attributed to genetic factors, edaphoclimatic conditions, and agronomic management. In addition to these factors, mineral accumulation in flowers is influenced by species-specific mechanisms of nutrient uptake, transport, and storage, which ultimately determine the mineral composition of edible tissues. These differences highlight the importance of species selection when edible flowers are intended for nutritional or functional applications.

The coefficients of variation (CV%) were low for all variables (2.57-4.92%), indicating low data variability and good experimental precision (Table 2). The low variability among replicates further supports the consistency of the observed differences, suggesting that the variation in nutritional characteristics was predominantly associated with species differences rather than experimental variability.

Mineral profile

In the mineral profile referring to the levels of macronutrients (nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S)) of edible flowers of China pink, Begonia, and Torenia, it was observed that China pink presented the highest levels of all macronutrients evaluated (N, P, K, Ca, Mg, and S), differing statistically from the other species. N (28.47 g kg^{-1}) and K (20.88 g kg^{-1}) were the most abundant nutrients in this species, reflecting greater protein accumulation and potential for use in human food (Table 3).

Table 3. Average values referring to the levels of macronutrients. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) were expressed in (g kg^{-1}) of the edible flower species China pink, Begonia, and Torenia.

Edible flower species	N	P	K	Ca	Mg	S
	g kg^{-1}					
China pink	28.47±3.47a	2.72±0.34a	20.88±2.49a	6.28±0.71a	1.74±0.21a	2.34±0.29a
Begonia	16.53±1.90b	0.80±0.09b	4.26±0.45c	1.45±0.18c	0.72±0.08c	2.26±0.28c
Torenia	14.76±1.67b	0.89±0.10b	12.70±1.42b	3.80±0.40b	1.15±0.13b	2.21±0.27b
CV (%)	4.99	9.77	8.76	8.40	5.67	0.38

CV = coefficient of variation. Means followed by the same letter in the column do not differ from each other according to Tukey's test ($p<0.05$).

The high nitrogen concentration is directly associated with the synthesis of amino acids, proteins, nucleic acids, and other nitrogen-containing compounds that are essential for plant metabolism. From a nutritional perspective, this characteristic is consistent with the higher protein content previously observed in China pink and may contribute to its greater nutritional value among the evaluated species.Torenia presented intermediate values for most macronutrients, whereas Begonia presented the lowest contents, especially for K (4.26 g kg^{-1}) and Ca (1.45 g kg^{-1}). The high Ca content in China pink (6.28 g kg^{-1}) indicates a greater concentration of this essential mineral compared with the other species (Table 3). In addition to its structural role in bone tissue, calcium is involved in muscle contraction, nerve impulse transmission, blood coagulation, intracellular signaling, and enzyme regulation, making adequate dietary intake essential for normal physiological functions (GUSH; SHAH; GILANI, 2021). In plants, calcium also contributes to cell wall stability and membrane integrity, properties that may influence tissue firmness and postharvest quality.

Regarding macronutrients, the high K and Ca content in China pink follows the pattern described by Fernandes et al. (2017), who identified K as the predominant macronutrient in several edible flowers. The K plays a essential roles in osmotic balance, nerve impulse transmission, fluid and electrolyte homeostasis, blood pressure regulation, and normal cardiac and muscle function, whereas calcium is involved in bone mineralization, muscle contraction, blood coagulation, intracellular signaling, and enzyme regulation. Phosphorus is another essential macronutrient that participates in energy metabolism through adenosine triphosphate (ATP), nucleic acid synthesis, phospholipid formation, and bone mineralization. Magnesium acts as a cofactor in numerous enzymatic reactions and is essential for ATP metabolism, protein synthesis, glucose utilization, and neuromuscular function. Sulfur, in turn, contributes to the synthesis of sulfur-containing amino acids, such as methionine and cysteine, as well as glutathione, an important endogenous antioxidant involved in cellular redox homeostasis (GUSH; SHAH; GILANI, 2021). Therefore, the presence of these macronutrients contributes to the nutritional composition of China pink and highlights its potential as a source of dietary minerals, although the actual nutritional contribution depends on the amount consumed.The coefficients of variation ranged from 0.38% (S) to 9.77% (P), indicating relatively low variability among the evaluated macronutrients (Table 3). The consistency of these values supports the reliability of the differences observed among species and strengthens the interpretation of their distinct macronutrient profiles. In the mineral profile referring to the levels of micronutrients (iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B)) of edible flowers of China pink, Begonia, and Torenia, it was observed that China pink and Torenia presented the highest levels of Fe (113.84 and 118.06 mg kg^{-1}, respectively), which did not differ from each other but exceeded that of Begonia. This micronutrient is of great nutritional relevance and is associated with the prevention of anemia, highlighting the potential of these flowers as functional ingredients (Table 4).

Table 4. Average values referring to micronutrient content. Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and boron (B) were expressed in (mg kg^{-1}) of the edible flower species China pink, Begonia, and Torenia.

Edible flower species	Fe	Mn	Cu	Zn	B
	mg kg^{-1}				
China pink	113.84±12.92a	7.71±1.00a	2.70±0.34a	21.08±2.46a	10.98±1.41a
Begonia	38.83±3.78b	1.69±0.23b	0.45±0.04c	4.68±0.46c	1.94±0.29c
Torenia	118.06±13.47a	1.69±0.23b	0.99±0.11b	10.63±1.11b	3.79±0.49b
CV (%)	6.58	12.52	11.30	9.11	11.44

CV = coefficient of variation. Means followed by the same letter in the column do not differ from each other according to Tukey's test ($p<0.05$).

Beyond its well-established role in hemoglobin synthesis and oxygen transport, iron is an essential component of numerous enzymes involved in mitochondrial respiration, energy metabolism, DNA synthesis, immune function, and antioxidant defense. Although non-heme iron from plant sources generally has lower bioavailability than heme iron, its intake as part of a diversified plant-based diet can contribute to overall dietary iron intake. Moreover, consuming iron-rich plant foods together with sources of vitamin C may enhance non-heme iron absorption and improve the nutritional value of meals (GUSH; SHAH; GILANI, 2021). China pink presented the highest contents of Mn, Cu, Zn, and B, differing from the other species for most of the evaluated micronutrients. . Begonia presented the lowest contents of all micronutrients analyzed, whereas Torenia presented intermediate values, except for Fe (Table 4). The higher accumulation of these micronutrients in China pink highlights differences in mineral composition among species and may contribute to its nutritional potential as an edible flower. Zinc is involved in the activity of numerous enzymes and transcription factors related to protein synthesis, cell division, immune function, wound healing, and antioxidant defense. Manganese acts as a cofactor for enzymes associated with carbohydrate and amino acid metabolism, as well as for manganese superoxide dismutase (Mn-SOD), a mitochondrial antioxidant enzyme that protects cells against oxidative stress. Copper participates in oxidative metabolism, connective tissue formation, iron metabolism, and antioxidant enzyme systems. Boron, although not currently recognized as an essential nutrient for humans, has been associated with bone metabolism, calcium utilization, cognitive function, and modulation of inflammatory processes (GUSH; SHAH; GILANI, 2021). Therefore, the higher concentrations of these micronutrients contribute to the distinct nutritional composition of China pink and highlight its potential for applications where mineral -rich edible flowers are desired. The high iron content observed in China pink and Torenia corroborates recent studies indicating that certain edible flowers may have iron concentrations comparable to those of traditional leafy vegetables (PEREIRA; BARROS; FERREIRA, 2018; PINHEIRO; RODRIGUES; CARVALHO, 2021). In addition, the Zn, Cu, and Mn contents observed in the evaluated species were within the ranges reported in the literature, supporting their potential as sources of essential minerals. Beyond their nutritional role, these micronutrients participate in interconnected physiological processes, including antioxidant defense, immune function, energy metabolism, and maintenance of cellular homeostasis (GUSH; SHAH; GILANI, 2021). Therefore, edible flowers with favorable micronutrient profiles may represent valuable additions to diversified diets, although their actual nutritional contribution depends on consumption levels and mineral bioavailability.The coefficients of variation ranged from 6.58 to 12.52%, indicating acceptable experimental variability for mineral analyses (Table 4). These values support the consistency of the mineral composition data and confirm the suitability of the results for comparing the differences observed among species. In general, China pink stood out for its higher protein content and the highest concentration of macro and micronutrients, indicating high nutritional potential among the species studied. Torenia stood out in terms of ash and iron content, whereas Begonia was characterized by higher acidity and higher soluble solids content. These findings demonstrate that each species possesses unique nutritional and physicochemical attributes that may be valuable for different dietary and technological applications. China pink may be particularly relevant for applications where higher mineral and protein contents are desired, while Torenia represents a potential source of mineral compounds, especially iron. Begonia, in turn, presents sensory-related characteristics, such as higher acidity and soluble solids, that may influence flavor perception and its suitability for fresh culinary preparations.

Systematic reviews published in recent years have also highlighted that edible flowers contain not only minerals and proteins, but also phenolic compounds and exhibit considerable antioxidant activity, expanding their potential as functional food ingredients (GONZÁLEZ-BARRIO et al., 2021). Phenolic compounds are recognized for their ability to neutralize reactive oxygen species, mitigate oxidative stress, and modulate inflammatory pathways, mechanisms that have been associated with the prevention of chronic non-communicable diseases. Therefore, the presence of essential minerals, proteins, and antioxidant phytochemicals suggests that edible flowers may provide complementary nutritional attributes beyond their traditional ornamental value (GONZÁLEZ-BARRIO et al., 2021). The results obtained in this study reinforce the importance of nutritional characterization of these species, contributing to the advancement of scientific knowledge and the valorization of edible flowers as emerging food resources.

The evaluated edible flowers exhibited distinct nutritional profiles and may be explored in a complementary manner according to their nutritional and sensory attributes. The variability observed among species indicates that the combination of different edible flowers may contribute to greater dietary diversity by providing a broader range of minerals, proteins, and bioactive compounds, while also enhancing the visual and sensory characteristics of food preparations.

Storage

During refrigerated storage the evaluated species markedly in their ability to maintain flower quality. Torenia reached complete senescence after 9 days of storage (Figure 1), whereas China Pink and Begonia remained viable for longer periods, with complete senescence occurring after 19 and 22 days, respectively. Although all species exhibited a progressive decline in visual quality and eventual senescence, the rate of symptom development varied considerably among species, suggesting differences in their intrinsic capacity to maintain postharvest quality under refrigerated conditions.

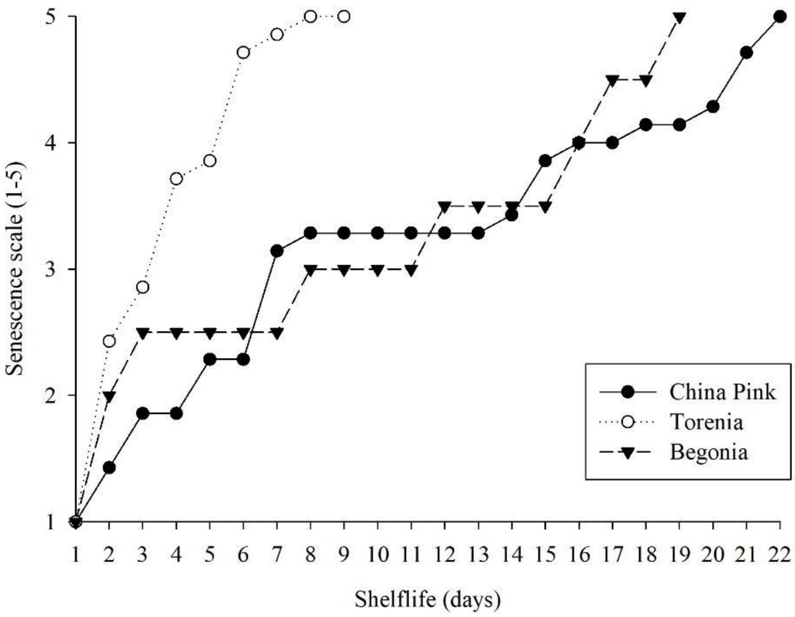

Figure 1. Storage period for China pink, Begonias, and Torenia grown in an aeroponic system, based on senescence notes.

Torenia exhibited rapid senescence, indicating greater susceptibility to postharvest deterioration. The main factors contributing to the loss of postharvest quality in plant tissues include high respiration rates, depletion of carbohydrate reserves, and increased ethylene production or sensitivity (COSTA et al., 2021). The rapid progression of senescence symptoms may also be associated with an imbalance in the antioxidant defense system, resulting in the accumulation of reactive oxygen species (ROS). Excessive ROS accumulation can promote oxidative damage to cell membranes, pigment degradation, increased membrane permeability, and loss of cellular turgor, ultimately accelerating tissue deterioration. In general, low temperature storage reduces metabolic activity and respiration rates, limits water loss, and consequently delays senescence and preserves postharvest quality (MA et al., 2024).

Begonia and China pink exhibited lower levels of senescence during the initial days of postharvest storage, suggesting greater physiological stability during the early stages of refrigerated storage compared with Torenia. This greater stability may be related to a slower decline in membrane integrity, water status, and antioxidant defense capacity, although these physiological mechanisms were not directly evaluated in the present study.

The marked differences in postharvest longevity observed among the three species highlight the species-specific nature of floral senescence. Senescence is a complex physiological process involving the interaction of hormonal signaling, metabolic changes, and oxidative stress responses, and its progression can be strongly influenced by the genetic characteristics of each species (SHIBUYA, 2018). Therefore, the differences observed in the present study may reflect intrinsic physiological characteristics that determine the capacity of each species to maintain tissue integrity and visual quality during refrigerated storage.

From a commercial perspective, these findings are particularly relevant because the ability to maintain low levels of senescence over an extended period is an important quality attribute for the edible flower market. Species with greater postharvest longevity provide greater logistical flexibility for storage, transportation, and commercialization, while potentially reducing losses throughout the supply chain. In this context, the longer storage life observed for Begonia and China pink indicates greater potential for commercialization in distant markets and distribution systems requiring longer storage periods. In contrast, the rapid senescence observed in Torenia suggests the need for additional postharvest preservation strategies to delay tissue deterioration and extend its marketable life.

CONCLUSION

Aeroponically produced edible flowers differed significantly in their physicochemical characteristics, proximate composition, mineral profile, and refrigerated storage life. Among the evaluated species, China pink showed the highest protein content, the highest concentrations of most macro- and micronutrients and the longest refrigerated storage period, whereas Torenia presented the highest ash content. Begonia was distinguished by its lower pH and higher soluble solids content. Under the conditions of this study, China pink and Begonia maintained postharvest quality for approximately 22 and 19 days under refrigeration, respectively, whereas Torenia reached complete senescence after 9 days.

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