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Postharvest of edible flowers

Abstract – The objective of this work was to evaluate the changes in the physicochemical properties of different species of edible flowers in the postharvest period. Flowers of *Viola cornuta* (light or dark colored), *Viola tricolor*, *Antirrhinum majus*, *Dianthus chinensis*, and *Tagetes patula* were selected, packed, and placed in a cold chamber of the BOD type, at 5±1°C and 90–95% relative humidity. Every two days, fresh weight loss, visual quality using a scale score, and total longevity were evaluated. The total soluble solids (SS) content, titratable acidity (TA), the SS/TA ratio, and pH were also evaluated at the time of harvest and at the end of postharvest life. There was a significant increase in the SS contents of light-colored *V. cornuta*, *V. tricolor*, and *D. chinensis*. A significant reduction in TA was observed in light-colored *V. cornuta*, *V. tricolor*, *A. majus*, and *D. chinensis* at the end of postharvest life. The pH value increased significantly only in *T. patula* flowers. The studied species of edible flowers have a short commercial longevity, which varies from 4 to 10 days, while the maximum total longevity varies from 6 to 14 days.

Index terms: *Antirrhinum majus*, *Dianthus chinensis*, *Tagetes patula*, *Viola cornuta*, *Viola tricolor*, longevity.

Pós-colheita de flores comestíveis

Resumo – O objetivo deste trabalho foi avaliar as alterações das propriedades físico-químicas de diferentes espécies de flores comestíveis, no período pós-colheita. Flores de *Viola cornuta* (de cor clara ou escura), *Viola tricolor*, *Antirrhinum majus*, *Dianthus chinensis* e *Tagetes patula* foram selecionadas, embaladas e acondicionadas em câmara frigorífica do tipo BOD, a 5±1°C e 90–95% de umidade relativa. A cada dois dias, avaliou-se a perda de massa de matéria fresca, a qualidade visual por escala de notas e a longevidade total. Também avaliou-se o teor de sólidos solúveis (SS) totais, a acidez titulável (AT), a relação SS/AT e o pH, no momento da colheita e ao final da vida pós-colheita. Houve aumento significativo nos valores de SS em *V. cornuta* de cor clara, *V. tricolor* e *D. chinensis*. Observou-se a redução da AT de *V. cornuta* de cor clara, *V. tricolor*, *A. majus* e *D. chinensis* ao final da vida pós-colheita. O valor do pH aumentou significativamente apenas em flores de *T. patula*. As espécies de flores comestíveis estudadas têm longevidade comercial curta, que varia de 4 a 10 dias, enquanto a longevidade total máxima varia de 6 a 14 dias.

Termos para indexação: *Antirrhinum majus*, *Dianthus chinensis*, *Tagetes patula*, *Viola cornuta*, *Viola tricolor*, longevidade.

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Introduction

Many flowers have been incorporated into culinary since ancient times (Janarny et al., 2021). Recently, the consumption of edible flowers is all the rage, as they are increasingly favored in gourmet cuisine because they add a fresh aroma, improving the appearance of dishes (Kou et al., 2012; Cunningham, 2015). Beyond the aesthetic, the nutraceutical properties of edible flowers are beneficial to human health and established an important market niche, leading the food industry to invest in fresh product market (Navarro-González, et al., 2015; Chen & Wei, 2017). Edible flowers stand out for their nutritional value, as they contain carbohydrates, proteins, fibers, macroelements and microelements, being low-calorie foods; in addition, these flowers have also phytochemicals with antioxidant and hypoglycemic effects to human health (Mlcek & Rop, 2011; Pinedo-Espinoza et al., 2020; Zheng et al., 2021).

The consumption of edible flowers worldwide becomes even more attractive when edible flowers show a good appearance, combined with aroma and flavor, and when they have healthy nutritional properties and low energy content (Chen & Wei, 2017; Rodrigues et al., 2017; Tuladhar, 2021).

Due to the growing consumption of edible flowers, the technical improvement for production and harvesting is essential, in addition to the setting up of an efficient process of packaging, transport, and sale, due to the rapid perishability of flowers (Koike et al., 2017; Fernandes et al., 2018). The senescence of flowers is a natural and irreversible process that involves a series of physiological, biochemical, and metabolic changes, which is accompanied by a decline of color, flavor, nutrition factors, texture, and other sensory attributes, shortening the flowers shelf life (Pires et al., 2019). Over the years, research on the half-life of agricultural products has focused on vegetables and fruits; therefore, the postharvest of edible flowers has not been thoroughly studied. Moreover, because of their relative low productivity and more specialized market, most studies have focused on their nutraceuticals proprieties (Kou et al., 2012).

The edible flowers are very sensitive and contain high humidity; therefore, the loss of turgidity is one of the main characteristics that reduce the aesthetics value of such flowers, which can lead to loss of market quality. This effect has been reported for many ornamental species, such as carnations and snapdragons, nasturtium viola, pansy, borage and scarlet (Kelley et al., 2003; Kou et al., 2012). Other changes to be considered during the postharvest storage of edible flowers are the variations of nutritional properties, which can occur with the progressive senescence (Souza et al., 2020).

Because of the new growth trends in the edible flower market, it is necessary to know the longevity and physicochemical changes that occur during the postharvest storage; thus, this information can contribute to future strategies to improve storage conditions and to extend the longevity of these products.

The objective of this work was to evaluate the changes in the physicochemical proprieties of different edible flowers in the postharvest period.

Materials and Methods

Flowers produced in greenhouse, in organic production system – light or dark-colored pansy (*Viola cornuta*), mix-colored giant pansy (*Viola tricolor*), mix-colored snapdragon (*Antirrhinum majus* L.), mix-colored chinese pink (*Dianthus chinensis*), orange marigold (*Tagetes patula* L.) were used in the present study. The production area is located in the horticulture sector (22°45'47.646"S, 43°41'50.321"W) of Instituto de Agronomia of Universidade Federal do Rio de Janeiro.

Edible flowers with petals completely open were harvested early in the morning (at 8:00 a.m.) and immediately taken to the postharvest laboratory, where they were selected; plants which were mechanically damaged, or visibly attacked by pests and diseases, were put out. Then, the flowers were disinfested by immersion in 15 mL L^{-1} sodium hypochlorite solution for 15 min.

Each edible flower type was packaged in commercial plastic clamshell containers of 250 mL capacity. The number of flowers per plot were 103 light-colored pansies (21 g), 88 to dark-colored pansies (20 g), 32 mix-colored giant pansies (16 g), 70 mix-colored snapdragons (43 g), 60 mix-colored Chinese pinks (38 g), and 30 orange-colored marigolds (49 g). Next, the edible flowers were stored in a type BOD refrigeration chamber at 5±1°C and 90–95% relative humidity.

A visual quality scale was established to determine the commercial longevity and the total longevity of the edible flowers. The appearance of edible flowers was determined by the scale of notes ranging from 5 (best appearance) to 1 (worst appearance), as follows: 5, totally turgid; 4, slightly turgid; 3, beginning of withering; 2, withered; 1, completely wilted. In this work, the commercial longevity was considered as the time (in days) in which the flowers lost quality, until reaching the score 3. The total longevity was considered as the time (in days) in which the flowers lost quality, until reaching the score 1. The flowers were analyzed every two days, when the fresh weight of each sample was also obtained. The mass loss was obtained using the following equation: mass loss = [(initial mass - final mass)/initial mass) × 100], and the results were expressed as percentage (%).

The chemical characteristics were determined at harvest (0 days) and at the end of total longevity, for each of the studied species. The samples used in all chemical determinations were composed of macerated flower petals. Titratable acidity was obtained from 10 g of the sample diluted in 100 mL of distilled water under moderate agitation. This solution was titrated with 0.1 N NaOH until the pH range of 8.2 to 8.4 (Zenebon et al., 2008) was attained, and the results were expressed in milligrams of citric acid/100 g of petals). The pH reading was carried out using 10 g of macerated petals in 100 mL of distilled water by using a digital pH meter. Total soluble solids were determined through the direct reading in a manual refractometer of drops obtained from the maceration of the petals, and the results were expressed in Brix degrees (Zenebon et al., 2008).

The experiments were arranged in a completely randomized design, with six edible flowers type, and four replicates per plot. Data on the commercial longevity and total longevity of the flowers were subjected to the analysis of variance and to the Tukey's test, at 5% probability. The weight loss and score of quality were expressed as mean ± standard deviation. The significant difference between the chemical proprieties was determined by the Student's t-test, at 5% probability. The software used for the statistical analysis was the Sisvar for Windows, version 4.0 (Ferreira, 2014).

Results and Discussion

The commercial longevity of pansy is relatively short, up to 4 days, which requires efficient steps for harvesting, packaging, and transport selection, aiming at the least loss of products on the market. The total longevity of pansy showed a slight increase in light-colored flowers (Table 1).

Snapdragon flowers have an average commercial longevity of eight days, followed by Chinese pink and marigold which showed 10 days average, which is the highest average of commercial longevity. Marigold flowers showed the highest total longevity.

It is important to highlight that, in general, the flowers showed short commercial longevity, which potentially limits the commercialization to more distant markets, or shows that the transport and storage logistics are deficient. This fact reinforces the indications that these edible flowers are more suitable to be sold in local or regional markets, which may enable the supply of fresher flowers, promoting the strengthening of local production. Recent studies indicate that consumers have a greater preference for buying edible flowers in supermarkets; however, the sale in fairs for organic products and small businesses, which is a, alternative market, allows of direct sales between the rural producer and the consumer, offering a higher quality product (Guiné et al., 2020, 2021; Alves et al., 2021).

Previous studies reported that although consumers prefer edible flowers with mixed coloring (Kelley et al., 2001, 2003), in the present study we observed that there is a significant difference in the final longevity of pansy according to color. Edible flowers such as pansy, dahlia, and nasturtium show differences for the levels of antioxidants, depending on the petal colors, and this may be one of the factors that influence the senescence of the flowers (Friedman et al., 2005; Skowyra et al., 2014; Rivera-Espejel et al., 2019).

The loss of commercial quality was proportional to the loss of fresh weight for all the edible flowers studied (Figure 1). Visually, the flowers showed the

Table 1. Storage time (days) based on the visual grade scale for edible flowers to reach commercial longevity and total longevity[(1)].

Edible flower	Commercial longevity	Total longevity
	---------------------(day)---------------------	
Light-colored pansy	4.0c	8.0c
Dark-colored pansy	4.0c	6.0d
Mix-colored giant pansy	4.0c	6.0d
Snapdragon	8.0b	12.0b
Chinese pink	10.0a	12.0b
Marigold	10.0a	14.0a
CV (%)	9.9	3.5

[(1)]Means followed by equal letters, in the columns, are not statistically different, by Tukey's HSD test, at 5% probability.

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beginning of withering when the fresh weight (FW %) loss was 38, 36, 52, 57, 75, and 62% of the initial moisture in light-colored pansy, dark-colored pansy, giant pansy mix-colored, snapdragon, Chinese pink and marigold, respectively. It is empathized that the moisture loss was progressive until the total loss of visual quality, which is considered in this work as complete wilting.

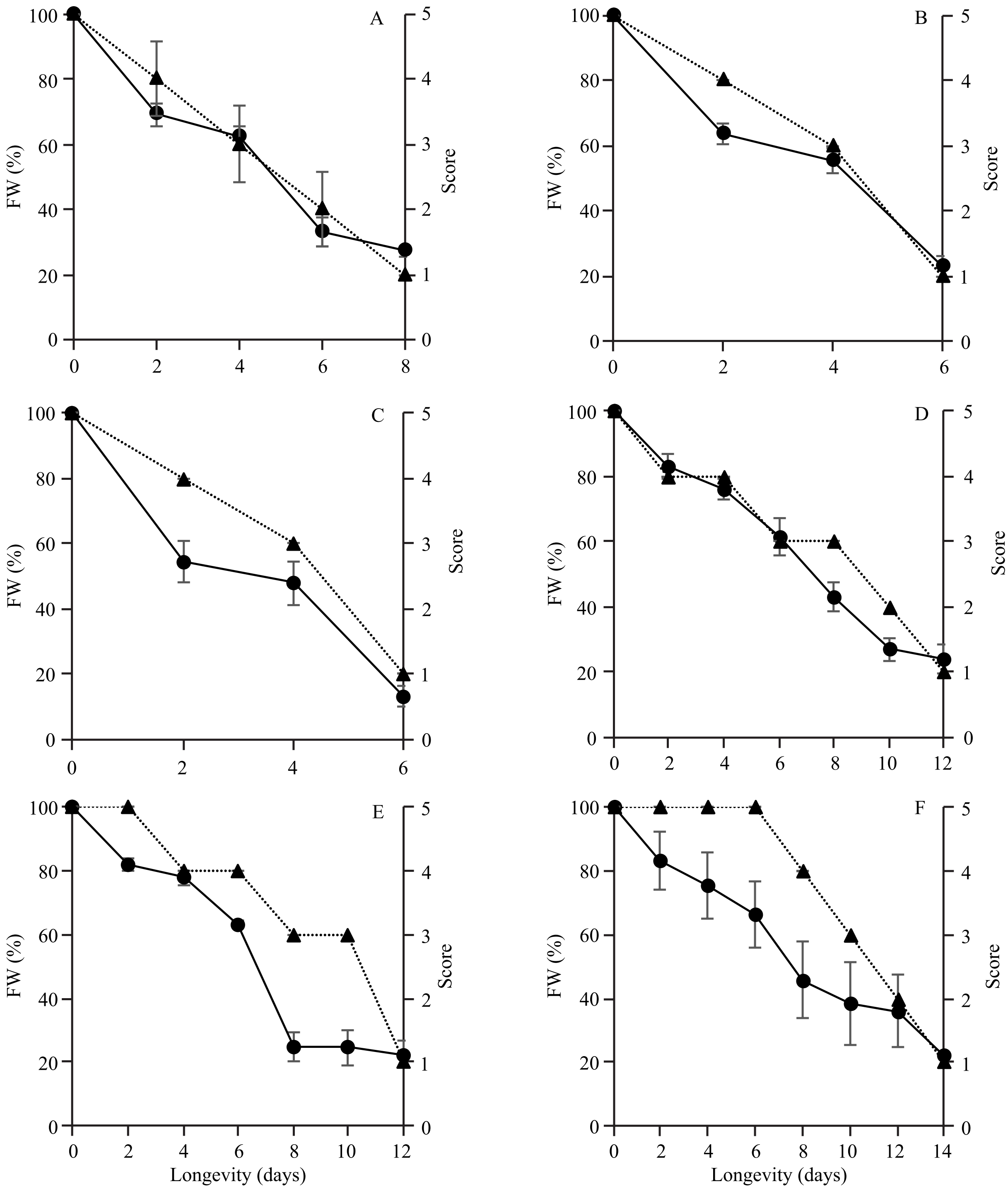

Figure 1. Weight loss (FW) and visual quality score, in the postharvest storage, for the following edible flower species: A, light-colored pansy; B, dark-colored pansy; C, giant pansy; D, snapdragon; E, chinese pink; and F, marigold. The barrs refer to the standard deviation.

Visual quality is extremely important for the edible flower market because appearance is one of the main characteristics for consumers, for instance, flowers that are wilted, damaged, or attacked by insects, were depreciated (Villavicencio et al., 2018; Takahashi et al., 2020). However, despite the lowest visual quality at the end of the postharvest longevity, the same bioactive compounds, such as antioxidants and phenolics, were not significantly affected in the postharvest period, evidencing that the loss of quality of edible flowers is primarily affected by the loss of water turgor than by the chemical properties (Landi et al., 2018).

Variations of chemical components depend on the edible flower species. The analyses showed that no significant differences occur for total soluble solids in the edible flowers of dark-colored pansy, snapdragon, and marigold (Table 2). There was a significant increase of total soluble solid contents in light-colored pansy flowers until the eighth day; however, it seems that the changes depend on the color of the flowers because this change was not observed for dark-colored pansy. Furthermore, it appears that the change of the total soluble solid content is also influenced by the plant variety because a significant reduction for giant pansy was observed. Significant reductions on the titratable acidity of light-colored pansy, giant pansy, snapdragon, and Chinese pink were observed in the last day of the postharvest.

In previous researches, the biochemical analyses of pansies have shown that the flowers contained 3.24% of total soluble sugars, and 0.55 of titratable acidity; for this species, malic acid was the most extracted organic acid, followed by levulinic acid (Grzeszczuk et al., 2016; Fernandes et al., 2020). For snapdragon 'Cavalier' and Chinese pink 'Chianti', total soluble sugar values were 5.55 and 4.56 and titratable acidity (% citric acid FW) values were 0.29 and 0.35, respectively (Stefaniak & Grzeszczuk, 2019).

The SS/AT ratio increased during the postharvest for snapdragon and pink Chinese flowers. There is evidence that the increasing ratio does not affect the flower longevity or the visual quality because, in marigold flowers, which had the longest longevity among the studied species, there was no significant differences for SS/AT. Longevity is likely associated with various nutraceutical components present in edible flowers, such as flavonoids, carotenoids, and terpenoids, among others (Landi et al., 2018; Fernandes et al., 2020; Janarny et al., 2021). According to Chitarra & Chitarra (2005), the equivalent between the contents of organic acids and sugars is indicative of flavor.

In the present study, pH variations of the edible flowers were observed only for marigold flowers. The variations of pH values in postharvest can occur due to metabolic processes and reactions that occurred during the postharvest storage, which continues to convert acids into sugar (Mannozzi et al., 2017; Yokosawa et al., 2017).

Studies on chemical components of edible flowers have focused on identifying bioactive compounds, indicating their importance for human health, or as a potential for nutraceutical food production. However, few studies have considered whether postharvest storage time affects the quality of such compounds.

Table 2. Variations of the content of total soluble solids (SS), titratable acidity (TA), SS/TA ratio, and pH of edible flowers in the first (0 day) and last days of postharvest storage[(1)].

Flower	Days	SS (°Brix)	TA (% citric acid FW)	SS/TA	pH
Light-colored pansy	0	3.33*	1.33*	2.50ns	5.73ns
	8	6.00	0.58	10.34	5.83
Dark-colored pansy	0	4.00ns	2.17ns	1.84ns	5.77ns
	6	4.67	0.92	5.08	6.07
Giant pansy	0	2.97*	0.50*	5.94ns	5.63ns
	6	1.3	0.33	3.94	5.8
Snapdragon	0	3.33ns	1.08*	3.08*	6.2ns
	12	4.33	0.15	28.87	5.73
Chinese pink	0	5.33*	1.42*	3.75*	5.23ns
	12	3.67	0.08	45.88	5.63
Marigold	0	2.33ns	1.33ns	1.75ns	5.17*
	14	1.50	1.33	1.13	5.57

*Significant difference by Student's t-test, at 5% probability. nsNonsignificant differences.

Conclusions

1. The total longevity of edible flowers varies from 6 to 14 days; the commercial longevity of the studied pansy species is short (4 days), and that of marigold is long (10 days).
2. Light-colored pansy, giant pansy, and Chinese pink show a significant increase of total soluble solid contents during the postharvest storage.
3. There is a reduction of titratable acidity of light-colored pansy, giant pansy, snapdragon, and Chinese pink, during the postharvest storage.
4. The pH value increases only in marigold flowers, during the postharvest storage.

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