Acta Sci. Pol. Technol. Aliment. 17(1) 2018, 5–10

www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2018.0533

ORIGINAL PAPER

Received: 16.10.2017
Accepted: 5.12.2017

THE EFFECT OF DIFFERENT POST-HARVEST TREATMENTS ON THE QUALITY OF BORAGE (*BORAGO OFFICINALIS*) PETALS

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ABSTRACT

Background. Borage is an edible flower with a very limited shelf-life (approx. 1 day). After harvest, flowers dry and shrink rapidly and become darker. Extending the shelf life of borage will make it more appealing for commercialization and it will enable borage growers to expand their market. The aim of the present work is to evaluate the effect of three post-harvest technologies.

Material and methods. Freeze-drying, hot air convective drying and alginate edible coating were applied to borage petals, and the visual appearance, water activity (a_w) and weight loss was evaluated.

Results. Hot air-dried samples had an unsatisfactory visual appearance. Freeze dried flowers were less shrunken and dried while showing the lowest a_w (0.25 ±0.01). Alginate coated flowers had a good visual appearance, like fresh flowers, which was maintained during refrigerated storage (for 5 days), four days longer than those which were uncoated. Nevertheless, the flowers became fragile and it was difficult to handle them without causing damage.

Conclusion. Freeze drying may be applied to produce dried borage flowers for infusions, while alginate coating is a promising treatment to increase shelf-life subject to further development.

Keywords: borage, drying, alginate edible coating, quality, storage

INTRODUCTION

Borage (*Borago officinalis*) is a medicinal and culinary herb native to the Mediterranean region, although presently it is commercially cultivated mainly for its seed oil (Hafid et al., 2002). Edible flowers, such as borage flowers, are increasingly attracting interest from gourmet chefs and consumers. The borage flower has five petals, which have a triangular-pointed shape (Ramandi et al., 2011), and one of two colors: blue (wild variety) or white (Montaner et al., 2001). Their cucumber taste with a hint of sweetness from the stamens make them an interesting choice to garnish salads and summer fruit drinks. However, edible flowers have a limited shelf life, with senescence progressing rapidly after harvest; protein content falls, protease activity and respiration rate increase, and the fluidity of lipids in membranes declines (Silva et al., 2003). These phenomena in the flower's metabolism are accompanied by morphological and biochemical deterioration; petal

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abscission and discoloration, wilting, dehydration and tissue browning (Serek and Reid, 2000). Generally, the majority of edible flowers must be used within 2 to 5 days of harvest (Kou et al., 2012), although this time period varies for each flower, and borage has a particularly short shelf-life (approx. 1 day). Therefore, it is necessary to find technologies able to maintain the quality of the flowers over an extended period of time. The effect of temperature during the storage of borage flowers has been studied by Kelley et al. (2003), showing that flowers stored at 0–5°C were marketable after 1 week, and stored at –2.5°C were still marketable after 2 weeks. Regarding the application of hot air convective drying, freeze-drying and edible coatings to this flower, to our knowledge no study has been performed until now. Thus, the objective of our work was to evaluate the effect of three post-harvest technologies (hot air drying, freeze-drying and edible coating) on the visual appearance of borage in order to increase its shelf-life. Water activity (a_w) and weight loss were measured. Furthermore, a visual scale was developed in order to be used in the future to easily evaluate the appearance of this edible flower.

MATERIAL AND METHODS

Samples

Fully-developed fresh borage petals (*Borago officinalis*) were collected from the greenhouse of the School of Agriculture, Polytechnic Institute of Bragança, Portugal. Full development was established based on the flower's size, degree of opening and colour (Rop et al., 2012). After harvest, the fresh flowers were immediately transported to the laboratory under refrigeration.

Post-harvest treatments

Hot air convective drying. Borage petals were distributed uniformly in a thin layer on trays and dried in a hot air convective oven (Memmert, Schwabach) at 50°C for 60, 90, 105 and 120 minutes. This temperature was chosen because it is a common temperature used in other drying studies of flowers and herbs (Balladin and Headley, 1999; Chen et al., 2000; Mao et al., 2006). Relative humidity and temperature values were measured at different points in the hot air convective oven with portable thermo-hygrometers (Hanna Instruments, HI 9564, Woonsocket) and digital thermometers (Hanna Instruments, HI 98509, Woonsocket), respectively. The relative humidity at 4.3 ±1.2% and temperature 49.6 ±2.4°C were kept constant throughout all experiments.

Freeze-drying. Petals were kept frozen at −20°C for a period of 24 h and lyophilized in a freeze-dryer (Scanvac, Coolsafe, Lynge, Denmark) for 24 h.

Edible coatings. The edible coating treatment was applied according to the method used by Tay and Perera (2004). Borage petals were immersed in a 0.5% alginate solution (made with sterile distilled water) for 30 min. Residual alginate was allowed to drain for 5 min before the samples were immersed in a 1% $CaCl_2$ solution (w/v) for 30 min to induce spontaneous cross-linking reactions. Surface water was carefully blotted using paper towels.

Storage of fresh and coated flowers. As the flowers subjected to hot air convective drying and freeze drying had an unsatisfactory appearance, they were discarded. Conversely, the alginate coated ones exhibited a good visual appearance and so they were stored under refrigeration (4°C) in plastic containers, until they presented an unsatisfactory visual appearance. Every day, at the same time, photos of the flowers were taken and the water activity and weight loss were measured. At the same time uncoated fresh flowers were also subjected to the same storage conditions (control).

Water activity (a_w), weight loss, color and petal width

Water activity (a_w) was determined with a portable water activity meter (Novasina, LabSwift-aw, Lachen, Switzerland). Weight was measured in a digital balance (Kern ACJ/ACS, Balingen, Germany) and weight loss (WL) was determined according to Equation 1:

$$WL = \frac{M_0 - M}{M_0} \times 100 \quad (1)$$

where M_0 and M are the masses of the flowers before and after treatment, respectively.

The color was evaluated with a colorimeter Minolta CR-400 (Osaka, Japan), using the CIE*Lab* scale. L^*, a^* and b^* coordinates, as well as, Chroma (C^*) and

Hue Angle (h^*) values, were determined. The width of borage petals was measured with a digital caliper (Powerfix, Berlin, Germany).

Statistical analysis

All statistical tests were performed by SPSS Statistical software, v. 18.0 (SPSS Inc., Chicago, IL). The level of significance was set at $p < 0.05$. The evaluation of statistical significance was determined by ANOVA, followed by Tukey's HSD *Post-hoc* test, since data normality was observed and the variances of the groups were identical. The normality and variance homogeneity were evaluated by the Kolmogorov-Smirnov and Levene's tests, respectively.

RESULTS AND DISCUSSION

Proposal of a visual scale for borage

A visual scale to be used in the future to evaluate the appearance of borage was developed and is shown in Figure 1. Based on these observations, a classification based on three categories classes is suggested:

Excellent = flowers retain their freshness and intense color
Satisfactory = flowers begin to wither and shrink
Unsatisfactory = petals are very wilted and dried and there is a loss of color.

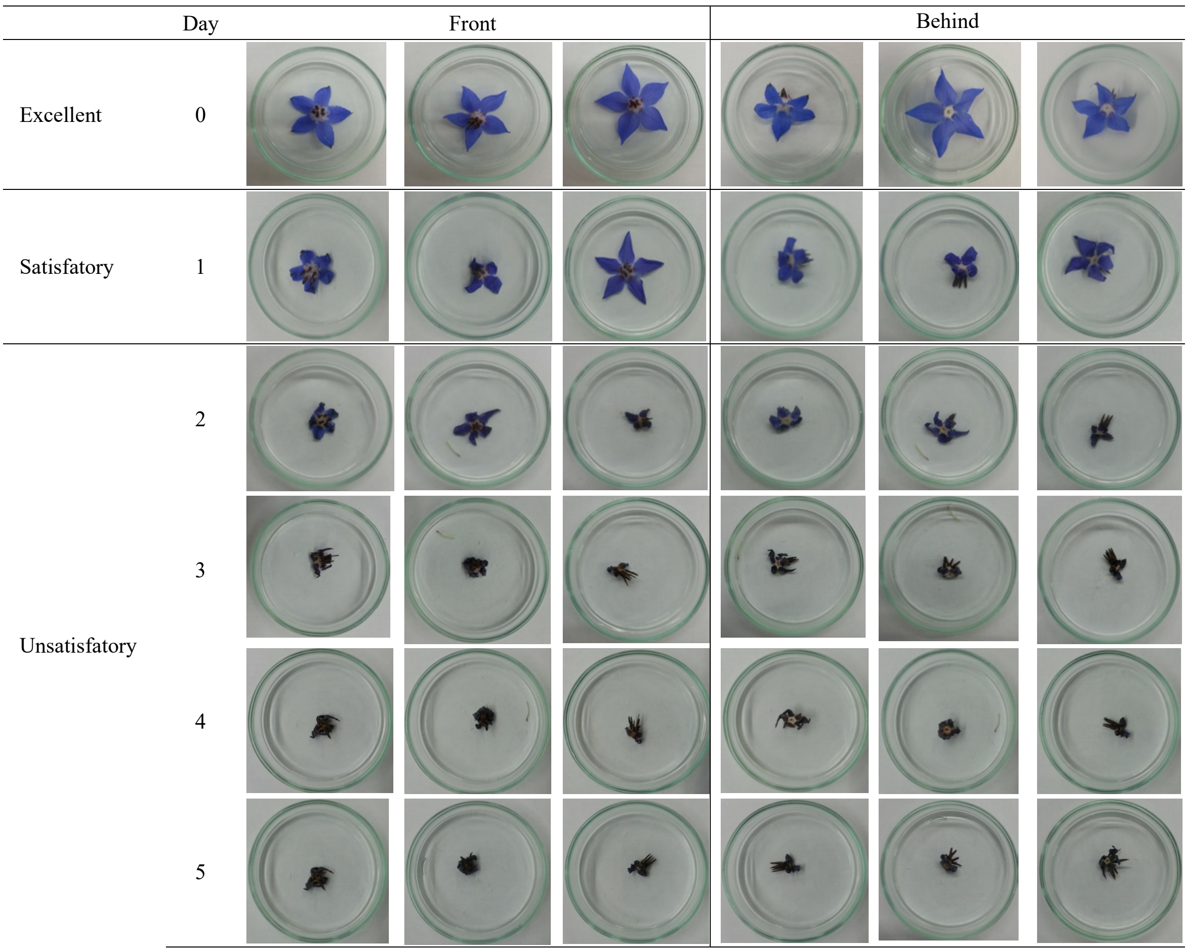


Fig. 1. Visual scale developed to evaluate the appearance of borage flowers stored at 4°C

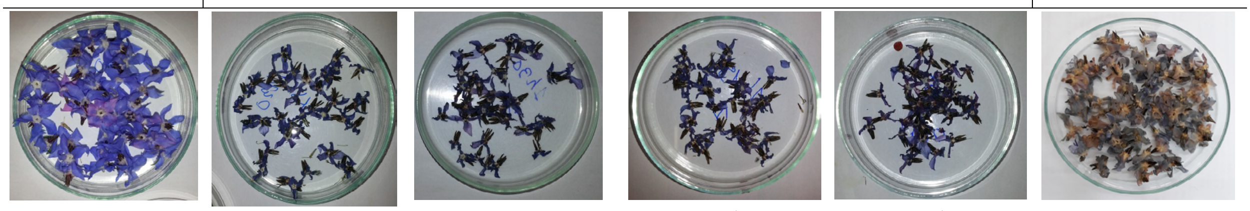
Based on the assayed samples, only day zero flowers were classified as excellent and satisfactory appearance was only observed on day 1. From day 2 to 5 all flowers were classified as unsatisfactory. These results confirmed the short shelf-life of borage at 4°C; approximately one day.

The effect of treatments on the characteristics of borage

Visual appearance, color and petal width. Figures 2 and 3 show the visual appearance of borage flowers after the three treatments. With all drying treatments (Fig. 2), the flowers were found to be shrunken and dried, with an unsatisfactory appearance. Still, freeze-dried samples had a better appearance than hot air dried ones. They were less shrunken, which was confirmed by measuring petal width (3.42 mm for hot air convective drying for 120 min and 5.36 mm for freeze dried versus 26.76 mm for fresh). Furthermore, the loss of the flowers' blue color after both drying treatments was observed (b^* equal to 4.71 for hot air convective dried and –6.39 for freeze dried compared to –24.19 for fresh). As has been suggested, freeze dried flowers can be used in infusions and it could be interesting to study their compositional changes in terms of bioactive compounds, in order to determine if their bioactivity is retained with this preservation method, as well as the expected shelf life.

Regarding Figure 3, on the appearance of borage flowers treated with alginate edible coating, on day 0 they retained their fresh-like appearance. During storage, alginate-coated flowers maintained a better

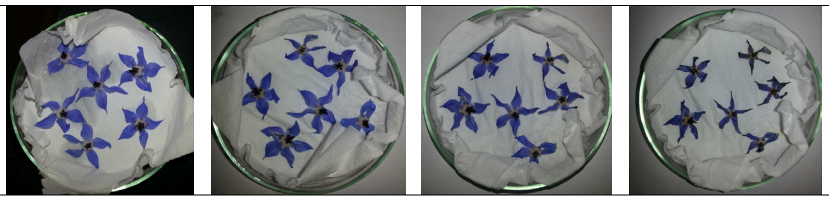
Treatments					
Fresh	Hot air convective drying				Freeze drying
	60 min	90 min	105 min	120 min	24 h



Fresh	60 min	90 min	105 min	120 min	24 h
a_w: 0.96 ±0.01^{c} L^*: 56.37 ±5.11^{c} a^*: 15.49 ±3.63^{b} b^*: –24.19 ±7.28^{a} C^*: 28.74 ±8.04^{b} h^*: 303.20 ±2.78^{a} Petal's width, mm: 26.76 ±4.42^{b}	a_w: 0.90 ±0.01^{c} WL, %: 69.2 ±0.8^{a}	a_w: 0.78 ±0.17^{c} WL, %: 80.3 ±5.8^{b}	a_w: 0.51 ±0.01^{b} WL, %: 86.9 ±0.1^{b,c}	a_w: 0.44 ±0.02^{b} WL, %: 87.3 ±0.8^{b,c} L^*: 45.30 ±1.12^{b} a^*: 5.10 ±0.27^{a} b^*: 4.71 ±0.53^{c} C^*: 6.97 ±0.17^{a} h^*: 42.69 ±4.71^{b} Petal's width, mm: 3.42 ±0.34^{a}	a_w: 0.25 ±0.01^{a} WL, %: 91.7 ±0.3^{c} L^*: 32.41 ±0.20^{a} a^*: 5.90 ±0.30^{a} b^*: –6.39 ±1.68^{b} C^*: 8.74 ±1.39^{a} h^*: 309.58 ±6.50^{b} Petal's width, mm: 5.36 ±0.87^{a}

Fig. 2. Borage in fresh and after being subjected to two drying methods: hot air convective drying and freeze drying

	Along storage, days			
	0	3	5	7
Edible coating				



0	3	5	7
a_w: 0.99 ±0.01^{b} WL, %: –74.5 ±38.9^{a}	a_w: 0.98 ±0.17^{a} WL, %: 54.7 ±16.5^{b}	a_w: 0.99 ±0.01^{a,b} WL, %: 76.0 ±14.3^{b,c}	a_w: 0.99 ±0.01^{a,b} WL, %: 86.9 ±6.0^{c}

Fig. 3. Visual appearance of borage during storage (4°C) after applying an edible coating

appearance than fresh ones. In more detail, after 3 and 5 days, the coated flowers were found to be less dried and with a more intense color than fresh samples (Figures 1 and 3). Nevertheless, it must be stated that the coated flowers were quite fragile and difficult to handle after treatment.

Water activity (a_w) and weight loss. Water activity has its most useful application in controlling the growth of bacteria, yeasts and molds. For edible flowers, as with other kind of fresh foods, water activity (a_w) reduction can be used as a tool to increase shelf life during storage. According to Yan et al. (2008), a water activity of nearly 0.6 inhibits the growth of most microorganisms. Only flowers subjected to freeze-drying for 24 h and hot air convection drying for 105 and 120 min achieved a_w values lower than 0.6. However, the borage flowers were not visually appealing, particularly those which had undergone air convective drying. On the other hand, all alginate coated flowers were found to have very high values of water activity (between 0.98–0.99), which did not change during storage, indicative of their increased susceptibility to microbial growth.

Concerning WL, both drying methods caused a drastic decrease in the weight of the flowers, due to water loss, although it was more pronounced in the freeze-dried sample (91.7%), followed by the sample which had undergone hot air convective drying for 120 min (87.3%), but it had a strong impact on the appearance of the final product. The alginate coated borage flowers showed a negative WL on the first day of storage, due to the weight gain caused by the incorporation of alginate onto the surface of the flowers. After 3, 5 and 7 days of storage, the alginate coated borage showed WLs equal to 54.7, 76.0 and 86.9%, indicating that the flowers were wilting in the same way as the fresh ones, despite their protective coating, indicating that it does not act as a barrier to water loss.

CONCLUSIONS

In summary, the present work showed that borage petals are highly perishable, with only one day of shelf-life at 4°C. When applying drying methods to borage petals, those subjected to hot air convective drying (50°C; 60–120 min) and freeze drying did not present a fresh-like appearance. In fact, hot air convective drying applied to borage petals caused them to shrink and lose their characteristic blue color. On the other hand, freeze-dried petals maintained a better appearance than did hot air convective dried petals, so they can be used for applications which require dried flowers, such as infusions, but not for garnishing dishes. On other hand, alginate-coated borage showed a good appearance after 5 days of storage, 4 days more than fresh flowers; however, the petals were fragile and maintained high values of a_w. Alginate coating of borage could be a promising technology to increase its shelf-life. Nevertheless, in the future it is necessary to improve this technology in order to increase the flowers' resistance and to allow them to be more easily handled.

ACKNOWLEDGEMENTS

The authors acknowledge the Portuguese Foundation for Science and Technology (FCT, Portugal) for the financial support provided by the research grant [SFRH/BD/95853/2013] and FCT/MEC for the financial support to QOPNA research Unit [FCT UID/QUI/00062/2013], through national funds and when applicable co-financed by the FEDER, within the PT2020 Partnership Agreement, and to REQUIMTE through the Project PEst/UID/QUI/50006/2013. The authors are also grateful to FCT (Portugal) and FEDER under Programme PT2020 for financial support to CIMO (UID/AGR/00690/2013).

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