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Antioxidant power, anthocyanin content and organoleptic performance of edible flowers

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ABSTRACT

The growing need for nutraceutical new foods has generated interest in edible flowers. This flower trait inspired us to conduct experiments aimed at evaluating both the antioxidant activity and anthocyanin content in twelve species commonly used as ornamental plants. The antioxidant power of the edible flowers was very high compared to common vegetables and/or fruits. Except for the low values of *Borago officinalis* (only 0.5 mmol $FeSO_4$ 100 g^{-1} fresh weight; FW), the antioxidant power in the edible flowers ranged from 3.6 for *Calendula officinalis* to 70.4 for *Tagetes erecta*. Part of this high antioxidant activity is often due to their high anthocyanin content at least in the case of the more pigmented flowers (red or blue). For example in the red varieties of *Viola* × *wittrockiana, Dianthus* × *barbatus, Pelargonium peltatum* the high anthocyanin content (12.4, 13.3, 12.5 mg cyn-3-glu eq. 100 g^{-1} FW, respectively) was associated to a high antioxidant activity. Indeed the best nutraceutical performances (antioxidant and/or anthocyanin values) were shown by more pigmented flowers. A panel test was also carried out in order to evaluate the different degree of the flower's palatability. This taste evaluation showed a high biodiversity of sensory profiles showing the greatest appreciation for *Trapaeolum majus*, *Ageratum houstonianum* and *Viola* × *wittrockiana*. Finally, the overlap between nutraceuticals and organoleptic aspects highlighted promising species for a potential market targeting new foods aimed at satisfying both taste and health.

1. Introduction

The growing interest in nutraceuticals and functional foods has increased research into new foods that are beneficial to health. Thus the studies on fruits (Amagase et al., 2009), herbs (Wojdyło et al., 2007) and seeds (Jayaprakasha et al., 2001) characterized by antioxidant, free radical scavenging and anti-aging activities assume a crucial importance, since these properties are strongly linked to the prevention and care of chronic illnesses such as cardiovascular diseases (Vivekananthan et al., 2003) and cancer (Greenlee et al., 2012).

Although flowers were already used as food in ancient Greece and Rome (Melillo, 1994), they have only recently sparked off nutraceutical research (Mlcek and Rop, 2011), focusing on new agronomic and economic horizons (Kelley and Biernbaum, 2000). Their rich pigmentation, which evolved to attract pollinators (Grotewold, 2006), suggests a high antioxidant activity that is of interest for human nutrition.

Anthocyanin pigments are primarily involved in this color-mediated attraction strategy and consequently their antioxidant activity (Stintzing and Carle, 2004) makes the flowers an important resource that could be agronomically and nutritionally enhanced. Indeed these pigmented flavonoids are considered a very important category of phytochemicals in plant foods due to their strong antioxidant activity and other beneficial physicochemical and biological properties (De Pascual-Teresa and Sanchez-Ballesta, 2008).

Highly pigmented fruits, particularly small berries such as blueberry, blackberry, cherry, raspberry and strawberry fruits, have been studied greatly due to their anthocyanin content and their consequent strong antioxidant activity. The interest in these phytochemicals has grown significantly in recent years due to the evidence that they play a crucial role in counteracting the oxidative stress related to chronic diseases (Li et al., 2012).

They are water-soluble compounds that impart color in plants (leaves, stems, roots, flowers and fruits) to appear red, purple or blue according to the pH and their structural features (Fossen and Andersen, 2003). Despite the fact that the main gastronomic use of flowers stems from their attractive color (Kelley et al., 2001a, 2002), there is growing evidence of their role as anti-free radical functional-foods, as is well demonstrated in several ornamental species (Barros et al., 2010; Kaisoon et al., 2011;

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Navarro-González et al., 2014; Shi et al., 2009). As a source of antioxidants (Chanwitheesuk et al., 2005), edible flowers have also been shown to be effective as antitumor (Ukiya et al., 2002), anti-inflammatory (Ukiya et al., 2006) and antimutagenic (Wongwattanasathien et al., 2010) biological agents.

Although the beneficial effects of flowers as a new promising source of mineral elements in human nutrition should not be neglected (Rop et al., 2012), care needs to be taken regarding the anti-nutritional substances that are sometimes produced by some species (Sotelo et al., 2007). In any case, there is an increasing number of ornamental (Mlcek and Rop, 2011) and wild species (Kucekova et al., 2013) grown as edible flowers.

Unfortunately, despite their agronomic potential, the idea of eating flowers is still viewed with suspicion. Indeed it involves a kind of neophobia (the reluctance to try novel foods) since often a new food generates an innate distrust (Pliner and Hobden, 1992) especially in children (Dovey et al., 2008). Consequently it is necessary, first of all, to develop nutrition education aimed at proposing flowers as a common food. It is also important to verify consumer tastes when selecting flowers for human nutrition.

Although there are some encouraging results on the nutraceuticals of edible flowers, there is little information on their organoleptic appreciation by consumers.

The aim of this work is twofold: (i) to analyze the content of antioxidants and anthocyanins in some well-known ornamental species, and (ii) test their organoleptic appreciation by free-tasters.

2. Material and methods

2.1. Plant material

Twelve species of cultivated edible flowers (Table 1) were studied. The fresh flowers (Fig. 1) were collected during autumn 2011 (October) and spring 2012 (April) from a greenhouse cultivation in Torre del Lago (LU) in north-west Tuscany, near the sea (43° 85′N, 10° 27′E), in an area called Versilia, where flowers have been grown for ornamental purposes for many decades. The plants were kindly provided by a floriculture company (Carmazzi Farm), which for several years has specialized in the cultivation and sale of edible flowers grown with organic agricultural systems. In brief, this cultivation was carried out in unheated greenhouses during autumn and spring (mean temperature about 15–25 °C) in sandy soil using organic fertilizers and without pesticides. In addition, the agronomic management was conducted without pesticides and/or growth regulating substances.

The fully open flowers were collected between 08.00 and 10.00 AM and placed in special plastic containers (the same as those used for the packets on sale). Absorbent paper was placed at the bottom of these containers to prevent any lymph leakage due to guttation, thus ensuring optimal conservation. The packs were immediately placed in refrigerator bags and stored at −80 °C on the same day (within 12.00 A.M.). The material was then analyzed within 3–4 weeks from collection.

2.2. Laboratory analysis

Both the antioxidant activity and the total content of anthocyanins were expressed on a fresh weight (FW) basis. Flower samples (1 g) were extracted with 10 mL methanol 80% (v/v), containing 1% of HCl, for 12 h at 4 °C.

Antioxidant activity was determined on the extracts by the FRAP (ferric ion reducing antioxidant power) assay following Pellegrini et al. (2003). A calibration curve was prepared with increasing concentrations of $FeSO_4$ (reagent grade, Sigma–Aldrich), and results were expressed as mmol $FeSO_4$ 100 g^{-1} FW.

Total content of anthocyanins was determined spectrophotometrically (UV-1204 Shimadzu, Tokyo, Japan). by measuring the absorbance of the extracts at 535 nm (Hrazdina et al., 1982). Data were expressed as mg cyn-3-glu eq. 100 g^{-1} FW.

For some of the species under examination (*Viola* × *wittrockiana*, *Petunia* × *hybrida*, *Antirrhinum majus* and *Dianthus* × *barbatus*), three or four cultivars were available which differed only by the color of the flower. Therefore, the relationship between the color and the antioxidant activity or the concentration of anthocyanins could also be investigated.

2.3. Sensory analysis

The sensory panel was carried out in April 2012. Eighty-seven free-tasters (37 males and 50 females, mean age 38 years) were recruited by adverts among the university community (students, teachers, other staff, etc.) from the Department of Agriculture, Food and Environment of Pisa University.

In order to evaluate only the real sensory profile of the various flowers, it was decided to get the tasters to examine the flowers without any condiments, bread, crackers, etc. After a careful evaluation of the perceived flavors, the tasters were asked to fill out a questionnaire aimed at determining the performances of the edible flowers. These experiments were based on previous experiences of taste evaluation performed on vegetables (Zhao et al., 2007) and/or fruits (Tobin et al., 2013).

Five different organoleptic characteristics (spiciness, sweetness, softness, scent, bitterness) were included in the evaluation scheme and were expressed in a scale of 1–100. The data enabled the sensory profile to be highlighted with spider plots (Johansson et al., 1999). A synthetic evaluation (scale 1–10) for each flower was also required in order to establish the effective degree of appreciation of each species. Finally, tasters were also asked to determine which known food each of the flowers resembled.

2.4. Statistical analyses

The experiments were replicated three times in each experimental period (autumn and spring).

Analysis of variance (ANOVA) in a completely randomized design and the Student–Newman–Keuls test were used to compare any significant differences between samples. The confidence limits used were based on 95% ($P < 0.05$). The lack of significance between the data of the laboratory analyses in the autumn and spring enabled them to be grouped into a single media. For the synthetic taste evaluation (scale 1–10), values were expressed as means ± standard deviations. For each statistical analysis, commercial software (CoHort software, Minneapolis, MN) was used.

3. Results

3.1. Nutraceutical analysis

Table 2 shows the antioxidant activity and the anthocyanin content of the various edible flowers. The antioxidant power of the edible flowers varied within a very wide range, encompassing two orders of magnitude. The strongest antioxidant activity was displayed by *Tagetes erecta*, which reached 70.4 mol $FeSO_4$ 100 g^{-1} FW. Similarly, *Fuchsia hybrida* showed a very high value (although significantly lower), which reached almost 50 mmol $FeSO_4$ 100 g^{-1} FW. Other rather high values were also shown by the red-flowered cultivars of *D. barbatus, V. wittrockiana* and *Pelargonium peltatum,* with antioxidant powers of 38.6, 36.5 and 34.7 mmol $FeSO_4$ 100 g^{-1} FW, respectively.

Values of the antioxidant power in the range 20–30 mmol $FeSO_4$ 100 g^{-1} FW were found in the pink cultivar of *D. barbatus* (29.1),