Skrajda Marta Natalia. Phenolic compounds and antioxidant activity of edible flowers. Journal of Education, Health and Sport. 2017;7(8):946-956. eISSN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.995637
http://ojs.ukw.edu.pl/index.php/johs/article/view/4877

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part B item 1223 (26.01.2017).
1223 Journal of Education, Health and Sport eISSN 2391-8306 7

Received: 05.08.2017. Revised: 10.08.2017. Accepted: 31.08.2017.

Phenolic compounds and antioxidant activity of edible flowers

Marta Natalia Skrajda

Chair of Plant Food Chemistry and Processing
Faculty of Food Science, University of Warmia and Mazury in Olsztyn

University of Warmia and Mazury in Olsztyn
Chair of Plant Food Chemistry and Processing
Pl. Cieszyński 1, 10-726 Olsztyn
e-mail: marta.skrajda@uwm.edu.pl
ORCID: 0000-0001-9297-1610

Abstract

Introduction: Edible flowers has been used for thousands of years. They increase aesthetic appearance of food, but more often they are mentioned in connection with biologically active substances. The main ingredient of the flowers is water, which accounts for more than 80%. In small amounts, there are also proteins, fat, carbohydrates, fiber and minerals. Bioactive substances such as carotenoids and phenolic compounds determine the functional properties of edible flowers.

Aim: The aim of this work was to characterize the phenolic compounds found in edible flowers and compare their antioxidant activity.

Results: This review summarizes current knowledge about the usage of edible flowers for human nutrition. The work describes the antioxidant activity and phenolic compounds of some edible flowers. Based on literature data there is a significant difference both in content of phenolic compounds and antioxidant activity between edible flowers. These difference reaches up to 3075-fold in case of antioxidant potential. Among described edible flowers the most distinguishable are roses, peonies, osmanthus fragans and sambuco nero.

Conclusions: Edible flowers are the new source of nutraceuticals due to nutritional and antioxidant values.

Keywords: antioxidant activity, phenolic compounds, edible flowers

Introduction

Reactive oxygen species (ROS) are synthesized as a result of naturally occurring processes in the body. Their excessive production is a result of external factors and causes an oxidative-antioxidant balance in the body. This results in DNA damage, oxidation of cell membranes, inflammation and cell death. As a result, free radicals accelerate the aging process and contribute to development of chronic diseases (cardiovascular, cancer, neurodegenerative, diabetes) (Uttara et al. 2009, Pham-Huy et al. 2008, Waris and Ahsan 2006). In addition, their effect causes lipid oxidation, resulting in deterioration of food quality during processing and storage. Therefore naturally occurring antioxidants have become an important food ingredient, increasing the stability of food products, as well as supporting antioxidant mechanisms in the body (El-Shourbagy and El-Zahar 2014, Sunil 2014, Lobo et al. 2010). Vegetables, fruits, cereals, herbs and microalgae are already well known for their antioxidant properties. Edible flowers may also be the source of these valuable compounds (Benvenuti et al. 2016).

The consumption of edible flowers has been known for hundreds of years. For culinary purposes they were used by Romans, Chinese and Greeks (Newman et al. 2009). In ancient Rome, roses were used, as additives for puree and omelets. Medieval France used calendula officinalis flowers as a component of salads. Crocus flowers and violets (viola odorata) were used as pigments (Mlcek and Otakar 2011). However, it should be noted that not all flowers are edible. Some edible flowers may contain compounds with anti-nutritional properties, such as trypsin inhibitors, or harmful, like cyanogenic glycosides and alkaloids.

The main ingredient of the flowers is water, which accounts for more than 80%. In small amounts, there are also proteins, fat, carbohydrates, fiber and minerals. The content of these compounds varies depending on the species being analyzed. Bioactive substances such as carotenoids and phenolic compounds, constituting to 230 mg/g, determine the functional properties of edible flowers (Navarro-González et al., 2014). Nowadays, there is a wide range of edible flowers that vary in color, shape and taste. In meals they improve the taste, color and nutritional value (Mlcek and Otakar 2011).

Aim

The aim of this work was to characterize the phenolic compounds found in edible flowers and compare their antioxidant activity.

Sources of edible flowers

Edible flowers are becoming more popular due to increasing recipes that are appearing in cook books, tv shows and magazine articles. They can be used in many different ways, for example in salads, desserts, soups drinks and stir-fry dishes (Kelly et al. 2001). Many flowers are edible, sources of them are inflorescences of fruit plants, vegetables, medicinal plants and ornamental plants. Popular ornamental plants include: chrysanthemum, daylily, lilac, nasturtium, pansy, rose, tulip, violet, anise hyssop, begonia, pot marigold, dianthus and marigold (Fernandez et al. 2017, Mlcek and Rop 2011). According to Chen and Wei (2017) the greatest influences on attitude towards the consumption of flowers have specific curiosity and aroma. They also found that health consciousness affects attitude towards the consumption of flowers. However some of flowers are poisonous, thus detailed identification is essential. Until now, any international body, including Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), Food and Drug Administration (FDA), or European Food Safety Authority (EFSA) did not made official lists of edible and non-edible flowers. However, the European Regulation (EC) No. 258/97, concerning novel foods and novel food ingredients, provides some information on the safety of flowers. Accordingly, there are not any legal requirements for edible flowers marketing (Chen and Wei 2017). Not only kind of flowers are important but also source. Flowers originating from non-tested cultivars and/or florist's shops can be affected by fertilizers, herbicides and other kinds of pesticides (Mlcek and Rop 2011).

Phenolic compounds in edible flowers

Phenolic compounds are a broad group of phytochemicals classified as secondary metabolites. They occur in three forms: free soluble, conjugated and insoluble bound. In the body, they exhibit a broad spectrum of properties, including: protective against oxidation of DNA, prevent platelet aggregation, protect collagen, thus maintaining the flexibility of blood vessels, prevent the oxidation of LDL cholesterol, and reduce the risk of cancer, cardiovascular disease and neurodegenerative diseases.

The main phenolic compounds found in flowers are phenolic acids, and flavonoids (Kaisoon et al. 2011, Navarro-González et al. 2014). In Table 1 is presented content of phenolic compounds and their main homologues in selected edible flowers in comparison to blueberry.

Li et al. (2014) showed phenolic content in 51 analyzed types of Chinese flowers. They found significant, nearly 57-fold, difference between the highest and lowest content of phenolic compound (0.63 vs. 35.84 mg GAE/g d.m.). Among analyzed flowers the highest content was found for *Rosa hybrids*, *Limonium sinuatum*, *Pelargonium hortorum*, *Jatropha integerrima* and *Osmanthus fragrans*. The authors found that the total content of phenolic compounds in these flowers is higher in comparison with the majority of fruits and vegetables. Main homologues identified in analyzed samples were: protocatechuic acid, gallic acid, catechin and epicatechin. Large variations according to the type of flowers are also confirmed by Chen et al. (2015). In 23 flower types, the difference was about 46-fold between the highest (Chinese peony - 222.01 mg GAE/g s.m.) and the lowest phenolic content (spherical gomphrein - 4.83 mg GAE/g s.m.). From the identified compounds, the most common was routine and isoquercitrin. Kaisoon et al. (2011) analyzing 12 types of flowers also showed significant differences depending on the type of flowers, but compared to the above cited results, the range is quite narrow. The authors determined both free and bound forms of phenolic compounds. In most of the analyzed flowers, phenolic compounds occurred mostly in bound forms (up to 76% of total phenolic content), except the telosma minor (about 33% of bound forms). In contrast Xiong et al. (2014) showed that phenolic compounds in 10 edible flowers from china existed mostly in free forms. Bound forms did not exceed 19% of total phenolic content.

Table 1. Phenolic compounds in selected edible flowers

Common name	Scientific name	Total phenolic content (in dry matter)	Main phenolic compounds	References
Chrysanthemum	*Chrysanthemum spp.*	20.01 mg GAE/g	Flavones (acaciin, luteolin) and flavone glycosides, coumarins	Cai et al. 2004
Daylily	*Hemerocallis spp.*	160.42 mg GAE/g	Flavonoids (catechin, rutin), phenolic acids (gallic acid)	Que et al. 2007, Mao et al. 2006
Nasturtium	*Tropaeolum*	12.95 mg GAE/g	flavonol-glycosides, hydroxycinnamic acid, anthocyanin	Navarro-Gonzales et al. 2015
Rose	*Rosa hybridis*	35.84 mg GAE/g	Flavonoids (quercetin, catechin, anthocyanins), phenolic acids (gallic acid), tannins	Cai et al. 2004, Li et al. 2014
Sambuco nero	*Sambucus nigra*	228.5 mg CAE/g	Flavonoids (rutin, quercetin)	Loizzo et al. 2015
Chinese peony	*Paeonia lactiflora Pall.*	222.01 mg GAE/g	Phenolic acids (gallic acid, ferulic acid), flavonoid (quercitrin, epicatechin, rutin)	Chen et al. 2015
Sea lavender	*Limonium sinuatum*	34.17 mg GAE/g	Phenolic acids (homogentisic) acid), flavonoid (catechin)	Li et al. 2014
Sweet osmanthus	*Osmanthus fragrans*	16.00 mg GAE/g	Phenolic acids (homogentisic acid protocatechuic acid), flavonoid (catechin)	
Garden geranium	*Pelargonium hortorum*	25.68 mg GAE/g	Phenolic acids (homogentisic acid), flavonoid (catechin, cyanidin-3-	

			glucoside)	
Peregrina	*Jatropha integerrima*	17.22 mg GAE/g	Phenolic acids (homogentisic acid), flavonoid (cyanidin-3-glucoside, epicatechin)	
Blueberry	*Cyanococcus*	9.44 mg GAE/g	Phenolic acids (p-hydroxybenzoic acid, vanillic acid), anthocyanidins (malvidin-3-galactoside, malvidin-3-glucoside), proanthocyanidins (condensed tannins)	Huang et al. 2012

Antioxidant activity

Several methods are used to evaluate antioxidant activity, for example: FRAP (Ferric Reducing Ability of Plasma), DPPH (diphenylpicrylhydrazyl), ABTS (2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid)), ORAC (oxygen radical absorption capacity) (Fernandez et al 2017, Kaisoon et al 2011).

Most of the assays employ the same principle: a synthetic colored radical or redox-active compound is generated; and the ability of a biological sample to scavenge the radical or to reduce the redox-active compound is monitored by spectrophotometer. Furthermore, there are two types of assays. One approach is based on an electron transfer and involves reduction of a colored oxidant, e.g. in ABTS, DPPH and FRAP assay. The other approach involves a hydrogen atom transfer in which antioxidants and substrate compete for thermally generated peroxyl radicals. The ABTS assay is based on the generation of a blue/green $ABTS^{\cdot +}$ that can be reduced by antioxidants; whereas the DPPH assay is based on the reduction of the purple color to yellow. Both assays are convenient in their application and thus most popular; nevertheless they are limited as they use non physiological radicals. In contrast, the ORAC assay measures the decrease in fluorescence caused by a free radical attack. The FRAP assay is different from the others as there are no free radicals involved. FRAP assay is a method, that compares the absorbance change at 593 nm in test reaction mixtures with those containing ferrous ions in known concentration. Ferric to ferrous ion reduction at low pH causes a colored ferrous-tripyridyltriazine complex to form. Absorbance changes are linear over a wide concentration range with antioxidant mixtures. When applied to food analysis, the antioxidant capacity measurements may be different depending on the assay used (Floegel et al. 2011, Benzie and Strain 1996).

Antioxidant activity of some edible flowers is presented in Table 2. The antioxidant potential of edible flowers between the various publications may vary, both due to the methods used, as well as the method of bioactive substances extraction or used standards (Fernandez et al., 2017). However, the results obtained in publications comparing the different types of flowers show significant differences. Li et al. (2014) analyzed antioxidant activity of 51 flower types and indicated, that antioxidant activity, depending on method, was in a range of 0.17 to 629.64 μmol Fe (II)/g (FRAP) and 0.23 to 175.39 μmol of Trolox/g (TEAC method). In turn, Chen et al. (2015) studied antioxidant activity of 23 edible flowers and indicated ranges: 8.08-913.58 μmol Trolox / g (FRAP method), 21.14599.49 μmol Trolox/g (DPPH method) and 46.46 - 2078.34 μmol Trolox/g (ABTS method). Also Navarro-González et al. (2015) confirm the high diversity of antioxidant activity of edible flowers, as well as differences depending on the method used. Values obtained by the authors were in the range of 10.82-266.07 μmol Trolox/g (ORAC) and 9.51-66.16 μmol of Trolox/g (TEAC). Many authors suggested that this differences are related to the content of phenolic compounds. Chen et al. (2015) confirmed that correlation between phenolic compounds content and antioxidant activity was significant (r = 0.96).

Although numerous studies have been reported on the properties of edible flowers, there is little information about their antioxidant capacity measured by *in vitro* methods. The objective of Chen et al. (2015) study was to evaluate the stability of the antioxidant activity of the 23 edible flowers by an *in vitro* digestion model. The authors used two digestion models: gastric and duodenal. In the gastric digestion model increased antioxidant activity was observed. Depending on the method used antioxidant activity was higher for 22 (DPPH method), 20 (ABTS method) and 8 (FRAP method) flowers extracts. In turn, the duodenal digestion decreased antioxidant activity compared to the previous digestion phase. Three flowers, Osmanthus fragrans (Thunb.) Lour, Paeonia lactiflora Pall, and Rosa rugosa Thunb showed the strongest antioxidant activities before or after the digestion, which implied that these flowers are important natural sources for the prevention of oxidative stress diseases.

Table 2. Antioxidant activity of selected edible flowers

Common name	Scientific name	Type of antioxidant activity test	Antioxidant activity	Reference
Rose	*Rosa hybrida*	FRAP	629.64 µmol Fe (II)/g	Li et al. 2014
Fringed iris	*Iris japonica*		0.17 µmol Fe (II)/g	
Rose	*Rosa hybrida*	TEAC	175.39 µmol of Trolox/g	
Fringed iris	*Iris japonica*		0.23 µmol of Trolox/g	
Sweet osmanthus	*Osmanthus fragrans (Thunb.) Lour.*	FRAP	913.58 µmol of Trolox/g	Chen et al. 2015
Globe amaranth	*Gomphrena globosa Linn.*		8.08 µmol of Trolox/g	
Sweet osmanthus	*Osmanthus fragrans (Thunb.) Lour.*	DPPH	599.49 µmol of Trolox/g	
Globe amaranth	*Gomphrena globosa Linn.*		21.14 µmol of Trolox/g	
Sweet osmanthus	*Osmanthus fragrans (Thunb.) Lour.*	ABTS	2078.34 µmol of Trolox/g	
Globe amaranth	*Gomphrena globosa Linn.*		46.46 µmol of Trolox/g	
Mexican marigold	*Tagetes erecta*	ORAC	266.11 µmol of Trolox/g	Navarro-González et al. 2015
Toothache plant	*Spilanthes oleracea*		10.82 µmol of Trolox/g	
Mexican marigold	*Tagetes erecta*	TEAC	66.22 µmol of Trolox/g	
Toothache plant	*Spilanthes oleracea*		5.52 µmol of Trolox/g	
Tree peony	*Paeonia suffruticosa*	ABTS	2065 µmol of Trolox/g	Xiong et al. 2014
Chinese rose	*Rosa chinensis*		1954 µmol of Trolox/g	
Sambuco nero	*Sambucus nigra*	FRAP	83.8 µmol Fe (II)/g	Loizzo et al. 2015
Rosemary	*Rosmarinus officinalis*		59.9 µmol Fe (II)/g	
Chicory	*Cichorium intybus*		52.4 µmol Fe (II)/g	

Conclusions

Edible flowers are gaining an increased interest among consumers. Depending on the type of edible flowers, there are significant differences in both content of the phenolic compounds and the antioxidant activity of the extracts. However, they are considered to be a valuable source of bioactive compounds such as phenolic acids, flavonoids, anthocyanins and other phenolic compounds. Due to, these natural antioxidants edible flowers can be considered as novel functional food. Among described flowers the highest phenolic content was found in chinese peony and sambuco nero flowers. In comparison to blueberry content of phenolic compounds in above mentioned flowers is about 25-fold higher. In terms of antioxidant activity the most outstanding were flowers of roses, peonies, sweet osmanthus and sambuco nero.

References

Benvenuti, S., Bortolotti, E., Maggini, R. Antioxidant power, anthocyanin content and organoleptic performance of edible flowers. Scientia Horticulturae, 2016, 199, 170-177.

Benzie, I. F., Strain, J. J. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Analytical Biochemistry, 1996, 239, 70-76.

Cai, Y., Luo, Q., Sun, M., Corke, H. Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer. Life Sciences, 2004, 74, 2157-2184.

Chen, G. L., Chen, S. G., Xie, Y. Q., Chen, F., Zhao, Y. Y., Luo, et al. Total phenolic, flavonoid and antioxidant activity of 23 edible flowers subjected to in vitro digestion. Journal of Functional Foods, 2015, 17, 243-259.

El-Shourbagy, G. A., El-Zahar, K. M. Oxidative stability of ghee as affected by natural antioxidants extracted from food processing wastes. Annals of Agricultural Sciences, 2014, 59, 213-220.

Fernandes, L., Casal, S., Pereira, J. A., Saraiva, J. A., Ramalhosa, E. Edible flowers: A review of the nutritional, antioxidant, antimicrobial properties and effects on human health. Journal of Food Composition and Analysis, 2017, 60, 38-50.

Floegel, A., Kim, D. O., Chung, S. J., Koo, S. I., Chun, O. K. Comparison of ABTS/DPPH assays to measure antioxidant capacity in popular antioxidant-rich US foods. Journal of Food Composition and Analysis, 2011, 24, 1043-1048.

Huang, W. Y., Zhang, H. C., Liu, W. X., Li, C. Y. Survey of antioxidant capacity and phenolic composition of blueberry, blackberry, and strawberry in Nanjing. Journal of Zhejiang University-Science B, 2012, *13*, 94-102.

Kaisoon, O., Siriamornpun, S., Weerapreeyakul, N., Meeso, N. Phenolic compounds and antioxidant activities of edible flowers from Thailand. Journal of Functional Foods, 2011, 3, 88-99.

Kelley, K. M., Behe, B. K., Biernbaum, J. A., Poff, K. L. Consumer preference for edible-flower color, container size, and price. HortScience, 2001, 36, 801-804.

Li, A. N., Li, S., Li, H. B., Xu, D. P., Xu, X. R., et al. Total phenolic contents and antioxidant capacities of 51 edible and wild flowers. Journal of Functional Foods, 2014, 6, 319-330.

Lobo, V., Patil, A., Phatak, A., Chandra, N. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews, 2010, 4, 118-126.

Loizzo, M. R., Pugliese, A., Bonesi, M., Tenuta, M. C., Menichini, F., Xiao, J., et al. Edible flowers: a rich source of phytochemicals with antioxidant and hypoglycemic properties. Journal of Agricultural and Food Chemistry, 2015, 64, 2467-2474.

Mao, L. C., Pan, X., Que, F., Fang, X. H. Antioxidant properties of water and ethanol extracts from hot air-dried and freeze-dried daylily flowers. European Food Research and Technology, 2006, 222, 236-241.

Mlcek, J., Rop, O. Fresh edible flowers of ornamental plants–a new source of nutraceutical foods. Trends in Food Science & Technology, 2011, 22, 561-569.

Navarro-González, I., González-Barrio, R., García-Valverde, V., Bautista-Ortín, A. B., Periago, M. J. Nutritional composition and antioxidant capacity in edible flowers: characterisation of phenolic compounds by HPLC-DAD-ESI/MSn. International Journal of Molecular Sciences, 2015, 16, 805-822.

Newman, S. E., O'Conner, A. S., Badertscher, K. B. Edible flowers. Gardening series. Flowers, 2009, 7237, 1-5.

Pham-Huy, L. A., He, H., Pham-Huy, C. Free radicals, antioxidants in disease and health. International Journal of Biomedical Science: IJBS, 2008, 4, 89-96.

Que, F., Mao, L. C., Zheng, X. J. In vitro and vivo antioxidant activities of daylily flowers and the involvement of phenolic compounds. Asia Pacific Journal of Clinical Nutrition, 2007, 16, 196-203.

Robu, S., Aprotosoaie, A. C., Miron, A., Cioancă, O., Stănescu, U., Hăncianu, M. *In vitro* antioxidant activity of ethanolic extracts from some Lavandula species cultivated in Romania. Cell, 2012, 60, 394-401.

Sunil, K. The Importance of Antioxidant and their role in Pharmaceutical science. Asian Journal of Research in Chemistry and Pharmaceutical Sciences, 2014, 1, 27-44.

Uttara, B., Singh, A. V., Zamboni, P., Mahajan, R. T. Oxidative stress and neurodegenerative diseases: a review of upstream and downstream antioxidant therapeutic options. Current Neuropharmacology, 2009, 7, 65-74.

Waris, G., Ahsan, H. Reactive oxygen species: role in the development of cancer and various chronic conditions. Journal of Carcinogenesis, 2006, 5, 14-21.

Xiong, L., Yang, J., Jiang, Y., Lu, B., Hu, Y., Zhou, F., et al. Phenolic compounds and antioxidant capacities of 10 common edible flowers from China. Journal of Food Science, 2014, 79, C517-C525.