DOI: 10.21005/AAPZ2020.53.1.02
FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech. 2020, 354(53)1, 17–28

Received: 11 Oct 2019
Revised: 10 Jan 2020
Accepted: 15 Jan 2020

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EFFECT OF DRYING TEMPERATURE AND METHOD OF EXTRACT PREPARATION ON ANTIOXIDANT ACTIVITY OF EDIBLE FLOWERS OF SOME ORNAMENTAL PLANT SPECIES

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Abstract. Edible flowers are a popular food ingredient in many regional cuisines, especially Asian and Middle Eastern ones. Drying is one of the most popular methods of preserving flowers. On the other hand, a common method of consuming dried edible flowers is to use them for preparing various kinds of beverages, both alcoholic and non-alcoholic ones. The paper presents the results of the laboratory analyses concerning the content of biologically active compounds in dried flowers in three temperature variants (~25°C, 35°C and 70°C), which were used to select the material constituting the basis for obtaining various types of water (infusions, decoctions, macerates) and alcohol extracts (with the use of 50%, 80% and 96% ethanol and repeated extractiong method using 96% EtOH), and then their antioxidant activity evaluation. The research material consisted of ornamental plant species with flowers of high biological value: *Mimulus* × *hybridus* L. ('Magic Yellow' and 'Magic Red'), *Hemerocallis* × *hybrida* Hort., *Monarda didyma* L., *Paeonia lactiflora* Pall. ('Sarah Bernardt', 'Dr. Alexander Fleming' and 'Karl Rosenfield'). The experiment was carried out in the years 2014–2015 in the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. On the base of the chemical analyses results the most favourable drying temperature variant was selected for each tested flower cultivar. For flowers *M.* × *hybridus* L., *M. didyma* L. and *H.* × *hybrida* Hort. it was 35°C; dried flowers were characterised by the highest content of biologically active compounds and the highest antioxidant activity. In the case of three cultivars of *P. lactiflora* Pall. the most favourable drying temperature was ~25°C. Among the water and alcohol extracts of the studied edible flower species, the decoction indicated a higher content of antioxidant compounds. The highest values of antioxidant activity were observed in extracts prepared on the basis of peony flowers.

Key words: *Mimulus, Monarda, Hemerocallis, Paeonia*, vitamin C, carotenoids, polyphenols, DPPH, ABTS, FRAP.

INTRODUCTION

Today, food is becoming increasingly diverse, striving to combine new ingredients with some potential health benefits which can improve consumer health (Leonti 2012; Pires et al. 2017; Zheng et al. 2019). This search for new food products is also a pursuit of the visual and taste attractiveness of dishes that can be achieved by using edible flowers (Grzeszczuk et al. 2016; Matyjaszczyk and Śmiechowska 2019; Rezende et al. 2019). Some restaurant chefs around the world use them in their dishes (Kelley et al. 2001; Łuczaj et al. 2012; Pires et al. 2017). Still, edible flowers are an unexplored niche market while they have been

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applied in many traditional dishes, sauces, oils, salads or desserts since ancient times (Mlcek and Rop 2011; Xiong et al. 2014; Koike et al. 2015; Petrova et al. 2016). In the herbal tradition, fresh and dried herbaceous plants, including their flowers, have been used in phytotherapy for centuries (Adamczak et al. 2015; Śmiechowska 2018). Drying is the oldest and the most popular method of preserving edible flowers. The raw material obtained in this way is commonly used to make water and alcoholic extracts. In European countries, the most common use of flowers in human nutrition is the preparation of hot drinks or alcohols (Chen et al. 2018; Hussain et al. 2019). We drink tea (infusions), decoctions or tinctures also for their therapeutic properties and for our own well-being (Toda 2011; Navarro-González et al. 2015; Ngoitaku et al. 2016).

Over eighty different species of plants with edible flowers can be safely used as food (Stefaniak and Grzeszczuk 2015). We harvest them from ornamental plants as well as herbs, vegetables, shrubs and fruit trees. In addition to their decorative and taste qualities, edible flowers have valuable nutritional and health-enhancing properties (Mlcek and Rop 2011; Lara-Cortés et al. 2014; Grzeszczuk et al. 2016; Zheng et al. 2019). In general, the edible flowers have a similar chemical composition to other parts of plants. However, they are distinguished by their high moisture, low fat and protein content, which makes them a low--caloric raw material (Mlcek and Rop 2011; Rop et al. 2012; Lara-Cortés et al. 2013; Navarro-González et al. 2015). Moreover, they present a wide range of high antioxidant molecules, such as phenolic compounds, carotenoids, vitamins (Nurul and Asmah 2012; Loizzo et al. 2016; Pires et al. 2017). Among other things, it is the colour of flowers that depends mainly on the content of carotenoids and anthocyanins (Friedman et al. 2010; Benvenuti et al. 2016; Matyjaszczyk and Śmiechowska 2019). Natural antioxidants are present in all parts of plants, but flowers have the highest concentrations of these compounds (Kaisoon et al. 2012; González-Barrio et al. 2018). Moreover, they contain many mineral compounds, essential oils and polyphenols – compounds with very high antioxidant activity (Rop et al. 2012; Xiong et al. 2014; Navarro-González et al. 2015; Petrova et al. 2016). The antioxidant activity of flowers is precisely related to their phenolic compounds, which show mechanisms of action that take place in intercepting or blocking chain reactions caused by free radicals. This is the way to avoid the ageing of cells and the emergence of chronic diseases (Araújo et al. 2013; Rezende et al. 2019). Knowledge of the harmfulness of free radicals encourages the search for substances supporting the natural antioxidant defence of the body. The research on secondary metabolites derived from plants with recognized dietary or therapeutic effects is of particular interest (Cybul and Nowak 2008). Consuming food rich in natural antioxidants helps to prevent coronary heart disease, diabetes, cancer and degenerative diseases such as Alzheimer's disease (Toda 2011; Gonzalez-Barrio et al. 2018; Zheng et al. 2019).

Most studies on edible flowers have been focused mainly on the sensory characteristics of flowers and the comparison of their therapeutic values with other parts of the plant. Admittedly, there are some scientific publications on edible flowers, but few studies concerning their conservation, i.e. the selection of appropriate drying temperature and comparison of their potential to be used in various forms of extracts.

The aim of this study is to assess the content of biologically active compounds and antioxidant activity of flower extracts of selected plant species (*Mimulus* × *hybridus* L. 'Magic Yellow' and 'Magic Red', *Hemerocallis* × *hybrida* Hort., *Monarda didyma* L., *Paeonia lactiflora* Pall. 'Sarah Bernardt', 'Dr Aleksander Fleming' and 'Karl Rosenfield'), depending on the way the raw material is obtained (different drying temperatures) and the extraction methods.

MATERIAL AND METHODS

The field experiment was carried out in the years 2014–2015 at 'The Edible Flower Collection' of the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. The laboratory part of the experiment, presented in this paper was conducted in the laboratory of the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. The research material consisted of one annual and three perennial ornamental plant species with edible flowers: *Mimulus* × *hybridus* L. 'Magic Yellow' and 'Magic Red', *Hemerocallis* × *hybrida* Hort., *Monarda didyma* L., *Paeonia lactiflora* Pall. 'Sarah Bernardt', 'Dr Aleksander Fleming' and 'Karl Rosenfield'.

The assumption and the course of the field experiment and the results of analyses of the fresh plant material are presented in two already published original scientific papers: Stefaniak and Grzeszczuk (2017) – *M.* × *hybridus* L., *H.* × *hybrida* Hort.,*M. didyma* L. and Stefaniak and Grzeszczuk (2019) – *P. lactiflora* Pall.

At the next stage of research, the flowers collected in full bloom were dried in 3 variants: ~25°C – natural drying (in shade, dry room) and in the air dryer at 35°C and 70°C. The time of drying the flowers at ~25°C was, depending on the species, from 5 to 8 days, at 35°C from 3 to 5 days, at 70°C from 1 to 3 days. Then the content of vitamin C as L-ascorbic acid (by the method of Tillmans), total carotenoids (Lichtenthaler and Wellburn 1983), total polyphenols and antioxidant activity were determined in the dried plant material. For the determination of total polyphenols content and antioxidant activity, a sample of 1 g of dried and ground plant material was extracted with 80% methanol (MeOH) to a volume of 100 ml. The mixtures were placed in an ultrasonic bath at room temperature and sonificated for 30 minutes (2 × 15 minutes), and then left for 24 hours at room temperature. The obtained extracts were filtered through Whatman No. 1 filter paper. The filtrates were centrifuged at 1500 rpm for 10 minutes. All the extractions were carried out in three replicates. The extracts were kept in 4°C and used for the analyses within 24 hours. In the prepared extracts their antioxidant potential, i.e. total polyphenols, DPPH, ABTS, FRAP, was determined. The total polyphenols content was analyzed spectrophotometrically using the Folin-Ciocalteu colorimetric method described by Wojdyło et al. (2007). The method with DPPH solution (2,2-diphenyl-1--picrylhydrazil) was evaluated according to the process described by Kumaran and Karunakaran (2007) and Wojdyło et al. (2007). The method described by Wojdyło et al. (2007) was used to determine the ferric ion reducing antioxidant property (FRAP). The free-radical scavenging activity was determined by the ABTS radical decoloration procedures described by Re et al. (1999), Wojdyło et al. (2007) and Chew et al. (2011) with some modifications.

On the basis of the obtained results of chemical analyses, the best drying variants were selected for the studied flower species (~25°C for *P. lactiflora* Pall.; 35°C – for all others species). The next stage was the preparation of water extracts (infusions, decoctions,

macerates) and alcoholic extracts (with the use of 50%, 80% and 96% ethanol and repeated extractiong method (96% EtOH) from the selected dried flower. Infusions: 100 mL of boiling distilled water was added to 2 g of the sample and left to stand at room temperature for 10 minutes. Decoctions: 100 mL of hot (95°C) distilled water was added to 2 g of the sample, and heated for 10 minutes from boiling. The mixture was left to stand at room temperature for 10 minutes. Macerates: 100 ml distilled boiled and cooled water was added to 2 g of the sample and left covered for 24 hours at room temperature.

50%, 80% and 96% ethanol extracts: 100 mL 50%, 80% or 96% ethyl alcohol was added to 0.5 g of the sample and left to stand at room temperature for 48 hours. Pouring method several times: 20 mL ethanol 96% was added to 0.5 g of the sample. The extracts were placed in an ultrasonic bath at room temperature and sonicated for 6 minutes and then left for 30 minutes. After this time the extract was poured into a 100 ml flask and the plant residue was flooded again with 20 ml of ethanol. This operation was performed 5 times until the flower petals were discoloured (ethanol with petals no longer coloured).

Water and alcohol extracts were placed in an ultrasonic bath at room temperature and subjected to ultrasonic treatment (sound frequency 40 kHz; heating option was turned off) for 30 minutes (2 x 15 minutes). The obtained extracts were filtered through Whatman No. 1 filter paper. The filtrates were centrifuged at 1500 rpm for 10 minutes. All extractions were carried out in three repetitions. Extracts were kept at 4°C and used for analysis within 24 hours. The antioxidant potential of these extracts was determined, i.e.: total polyphenols, DPPH, ABTS, FRAP.

The results were statistically elaborated using the analysis of one-factor variance by applying FR-ANALWAR software based on Microsoft Excel for the system of random blocks with Tukey's half confidence intervals at the level of significance $p = 0.05$.

RESULTS AND DISCUSSION

Table 1 presents the results of the experiment, which aimed at selecting the optimal drying temperature for the studied species of edible flowers. On the basis of the obtained results it was found that there were significant differences between the temperatures of drying (~25°C, 35°C and 70°C) in selected edible flowers with regard to the content of L-ascorbic acid, total carotenoids, total polyphenols and antioxidant activity.

Analyzing the results on the content of L-ascorbic acid, it was found that in all the studied species, except *H.* x *hybrida* Hort., significantly higher content of this compound was determined in flowers dried at 70°C. This difference was attributed to the reduced drying time under forced convection (Santos and Silva 2008).

In our earlier studies, where the content of vitamin C in fresh plant material was determined before drying, the amount of this component was equal to: *M.* × *hybridus* L. 'Magic Yellow' – average 724.7 mg · 100 g^{-1} DW; *M.* × *hybridus* L. 'Magic Red' – 559.5; *M. didyma* L. – 177.1; *H.* × *hybrida* Hort. – 762.1; *P. lactiflora* Pall. 'Sarah Bernardt'– 846.2, 'Dr Aleksander Fleming' – 637.8, 'Karl Rosenfield'– 794.6 and, after drying, on average for three drying temperatures respectively: *M.* × *hybridus* L. 'Magic Yellow'– 40.6 mg · 100 g^{-1} DW; *M.* × *hybridus* L. 'Magic Red' – 10.8; *M. didyma* L. – 25.5; *H.* × *hybrida* Hort. – 10.7;

P. lactiflora Pall. 'Sarah Bernardt' – 105.2, 'Dr. Alexander Fleming' – 66.5, 'Karl Rosenfield' – 71.6. The losses were therefore very visible and amounted to 92.11% on average for all species. This could be explained by irreversible oxidative processes during drying or rehydratation and water lixiviation of this water-soluble vitamin (López et al. 2013) and has already been shown in many scientific studies. The highest content of vitamin C in dried plant material was recorded in the case of *P. lactiflora* Pall. 'Sarah Bernardt' flowers (147.0 mg · 100 g^{-1} DW).

Table 1. The content of L-ascorbic acid, total carotenoids, total polyphenols and antioxidant activity in selected edible flowers at different drying temperatures

Drying temperature	L-ascorbic acid [mg · 100 g^{-1} DW]	Total carotenoids [μg · g^{-1} DW]	Total polyphenols [mg GAE · g^{-1} DW]	Antioxidant activity [mg TE · g^{-1} DW]		
				DPPH	ABTS	FRAP
Mimulus × *hybridus* L. 'Magic Yellow'						
~25°C	36.0 b	982.3 b	41.3 a	51.8 b	164.3 a	18.2 ab
35°C	34.5 b	1976.1 a	47.6 a	55.2 a	195.1 a	18.5 a
70°C	51.4 a	1980.4 a	41.0 a	50.9 b	171.2 a	18.1b
Mimulus × *hybridus* L. 'Magic Red'						
~25°C	5.5 b	1974.7 a	61.5 a	53.5 b	270.0 ab	19.9 b
35°C	7.0 b	1692.0 c	65.0 a	58.4 a	319.6 a	21.2 a
70°C	19.9 a	1790.8 b	49.5 b	51.6 b	232.4b	19.2 c
Monarda didyma L.						
~25°C	16.3 b	266.7 a	66.7 ab	90.1 a	125.6 a	32.7 b
35°C	16.0 b	351.5 a	78.2 a	148.4 a	118.5 a	33.3 a
70°C	44.4 a	290.5 a	54.6 b	100.9 a	81.9 a	32.5 b
Hemerocallis × *hybrida* Hort.						
~25°C	3.8 c	821.4 a	25.2 b	29.3 a	92.4 a	18.6 b
35°C	19.1 a	912.1 a	27.1 a	30.2 a	66.7 a	19.2 a
70°C	9.0 b	808.0 a	21.9 c	27.8 a	40.4 a	17.6 c
Paeonia lactiflora Pall. 'Sarah Bernardt'						
~25°C	86.1 b	21.8 a	197.9 a	624.0 a	809.4 a	39.5 a
35°C	82.5 b	32.3 a	181.9 a	589.1 a	751.6 ab	38.9 a
70°C	147.0 a	20.0 a	172.7 a	541.8 a	666.2 b	38,0 b
Paeonia lactiflora Pall. 'Dr Aleksander Fleming'						
~25°C	57.6 b	32.3 a	207.1 a	597.0 a	843.3 a	40.2 a
35°C	44.1 b	35.8 a	189.7 a	652.9 a	827.0 a	39.3 b
70°C	97.7 a	29.4 a	185.2 a	641.1 a	734.5 a	38.9 b
Paeonia lactiflora Pall. 'Karl Rosenfield'						
~25°C	42.3c	53.2 a	224.9 a	717.4 a	850.5 a	40.5 a
35°C	78.2 b	72.2 a	204.5 a	659.3 a	879.0 a	39.8 a
70°C	94.3 a	82.2 a	215.3 a	711.6 a	841.9 a	40.5 a

Mean values in columns marked with different letters differ significantly: a–c – $P \leq 0.05$.

Studies on the content of carotenoids in fruit and vegetables show that this is a very stable group of plant colourants and resistant to high drying temperature (Regier et al. 2005; Daood et al. 2006; Nowacka et al. 2011). According to Regier et al. (2005), during carrot drying at 70°C or lower, the total content of carotenoids remains unchanged, lycopene is stable up to 90°C, while β-carotene remains stable only up to 70°C. No significant differences in carotenoid content between drying temperatures have been found in own studies in all species

except *M.* x *hybridus*L. cultivars. The highest carotenoid accumulation was determined in *M.* × *hybridus* L. 'Magic Yellow' flowers dried at high temperature (70°C) – 1980.4 μg · g^{-1} DW. The flowers of 'Magic Red' cultivar had the highest content of these compounds when dried at ~25 °C (1974.7 μg · g^{-1} DW).

Among all the species studied, it was found that *P. lactiflora* Pall. flowers were characterized on average by the highest content of total polyphenols (197.7 mg GAE · g^{-1} DW) and antioxidant activity using DPPH (637.1 mg TE · g^{-1} DW), ABTS (800.4 mg TE · g^{-1} DW) and FRAP (39.5 mg TE · g^{-1} DW) tests. Chen et al. (2015) report that dried flowers of *P. lactiflora* Pall. contained high content of total polyphenols (222.0 mg GAE · g^{-1} DW) and high activity of free radical sweeping in DPPH (599.4 μmol TE · g^{-1} DW), ABTS (2078.3 μmol TE · g^{-1} DW) and FRAP (836.7 μmol TE · g^{-1} DW) tests.

However, the scientific literature lacks information on the content of biologically active compounds in edible flowers subjected to different drying temperatures. In an earlier published study (Stefaniak and Grzeszczuk 2019) the total polyphenol content (calculated on the dry matter of 33.1, 58.5 mg GAE · g^{-1} DW) and the content of the antioxidant assay performed DPPH (33.5, 43.8 mg TE · g^{-1} DW), ABTS (112.1, 149.7 mg TE · g^{-1} DW), FRAP (38.8, 84.9 mg TE · g^{-1} DW) was determined in fresh flowers *M.* × *hybridus* L. 'Magic Yellow' and 'Magic Red'. After drying flowers of the same species and cultivars and averaging the results from three drying temperatures, a higher content of total polyphenols (45.3, 58.7 mg GAE · g^{-1} DW) and antioxidant activity was observed in the DPPH (52.6, 54.5 mg TE · g^{-1} DW) and ABTS (176.8, 274.0 mg TE · g^{-1} DW) tests, whereas in the FRAP test the values were lower (18.3, 20.1 mg TE · g^{-1} DW). A similar relationship was observed in *M. didyma* L. and *P. lactiflora* Pall. 'Dr. Aleksander Fleming', where the flowers after drying contained more polyphenols in total (on average for three drying temperatures by 16.5% and 10.4% respectively), DPPH (by 186.6% and 84.3%) and ABTS (by 53.0% and 46.3%). The flowers of *H.* × *hybrida* Hort. subjected to three drying temperatures were characterized on average by 1.8 times higher content of total polyphenols (on average by 184.0%), whereas in the flowers of *P. lactiflora* Pall. 'Sarah Bernardt' higher antioxidant activity in the DPPH and ABTS tests (on average by 1.8% and 1.5%) was demonstrated. A decrease in antioxidant activity in FRAP was shown in all tested species and cultivars in flowers subjected to three drying temperatures. Drying of *P. lactiflora* Pall flowers 'Karl Rosenfield' decreases the total polyphenol content and also the antioxidant activity in comparison to the content of these compounds in fresh flowers (Stefaniak and Grzeszczuk 2019).

On the basis of the obtained results of chemical analyses, the best drying variants of the studied flower species were identified. For flowers of *M.* × *hybridus* L. (both cultivars), M. *didyma* L. and *H.* × *hybrida* Hort 35°C was assumed as the most favourable drying temperature. Flowers of *M.* × *hybridus* L. dried at this temperature were characterized by a high content of total polyphenols, DPPH, ABTS and FRAP, flowers of *M. didyma* L. contained high content of carotenoids, total polyphenols, DPPH and FRAP, and flowers of *H.* × *hybrida* Hort. additionally were characterized by high content of L-ascorbic acid. In the case of three studied cultivars of *P. lactiflora* Pall. the most favourable drying temperature was ~25ºC. Flowers of *P. lactiflora* Pall. 'Sarah Bernardt' dried at this temperature were characterized by higher content of total polyphenols, DPPH, ABTS

and FRAP, 'Dr Aleksander Fleming' flowers were characterized by higher content of total polyphenols, ABTS and FRAP, while 'Karl Rosenfield' flowers – total polyphenols, DPPH and FRAP.

Extraction methods carried out on the selected material have shown significant differences in total polyphenol content and antioxidant activity based on the ABTS, FRAP and DPPH methods used, as illustrated in Table 2.

Table 2. The content of total polyphenols and antioxidant activity according to the different methods used for the extraction of dried flowers of *Mimulus* × *hybridus* L., *Monarda didyma* L. and *Paeonia lactiflora* Pall.

Extraction method	Total polyphenols [mg GAE · 100 ml^{-1}]	Antioxidant activity [mg TE · 100 ml^{-1}]		
		DPPH	ABTS	FRAP
Mimulus × *hybridus* L. 'Magic Yellow'				
Infusion	46.7 b	65.4 b	144.7 b	16.5 b
Decoction	93.8 a	88.5 a	261.6 a	20.5 a
Maceration	39.2 b	28.4 c	105.2 c	16.4 b
50% EtOH	26.5 c	22.0 d	46.4 d	15.5 c
80% EtOH	24.3 c	21.6 d	52.0 d	15.7 c
96% EtOH	17.1 cd	15.3 e	22.6 e	15.3 c
Repeated flooding method (96% EtOH)	13.4 d	13.3 e	21.2 e	15.6 c
Mimulus × *hybridus* L. 'Magic Red'				
Infusion	57.1 b	77.1 b	138.4 c	18.3 b
Decoction	113.5 a	85.6a	384.9 a	23.9 a
Maceration	63.1 b	50.4 c	223.4 b	19.2 b
50% EtOH	36.1 c	22.3 d	80.3 d	16.4 c
80% EtOH	28.2 d	22.0 d	65.4 de	15.8 cd
96% EtOH	16.0 e	14.3 e	31.9 e	14.7 cd
Repeated flooding method (96% EtOH)	16.5 e	13.2 e	28.0 e	14.2 d
Monarda didyma L.				
Infusion	65.2 b	118.3 b	109.2 bc	17.8 b
Decoction	117.9 a	257.4 a	383.3 a	22.7 a
Maceration	67.1 b	118.3 b	202.3 b	17.8 b
50% EtOH	21.5 c	18.0 c	7.1 c	15.4 b
80% EtOH	18.1 c	18.5 c	8.9 c	15.3 b
96% EtOH	1.7 d	3.0 c	3.8 c	3.4 c
Repeated flooding method (96% EtOH)	0.3 d	1.7 c	1.7 c	1.2 c
Hemerocallis × *hybrida* Hort.				
Infusion	49.0 b	62.4 a	99.8 b	16.1 a
Decoction	57.8 a	63.1 a	100.4 b	16.3 a
Maceration	55.9 a	38.9 b	143.1 a	16.3 a
50% EtOH	15.2 c	14.0 c	24.1 c	14.2 b
80% EtOH	14.1 cd	12.4 cd	23.0 c	13.2 b
96% EtOH	8.7 e	5.7 d	10.5 c	8.2 c
Repeated flooding method (96% EtOH)	10.4 de	5.7 d	10.6 c	6.7 d
Paeonia lactiflora Pall. 'Sarah Bernardt'				
Infusion	117.9 b	527.0 b	669.2 bc	110.5 ab
Decoction	397.1 a	1294.4 a	1553.1 a	122.1 a
Maceration	134.4 b	619.7 b	761.5 b	112.4 ab
50% EtOH	88.1 b	367.2 bc	571.6 bc	93.9 c
80% EtOH	96.3 b	347.7 bc	342.2 bc	100.0 bc
96% EtOH	44.7 c	262.2 bc	172.1 bc	53.8 d
Repeated flooding method (96% EtOH)	18.6 c	69.6 c	45.5 c	28.4 d

Table 2. The content of total polyphenols and antioxidant activity according to the different methods used for the extraction of dried flowers of *Mimulus* × *hybridus* L., *Monarda didyma* L. and *Paeonia lactiflora* Pall. (cont.)

Extraction method	Total polyphenols [mg GAE · 100 ml^{-1}]	Antioxidant activity [mg TE · 100 ml^{-1}]		
		DPPH	ABTS	FRAP
Paeonia lactiflora Pall. 'Dr Aleksander Fleming'				
Infusion	127.6c	588.0 b	557.7 b	111.8 ab
Decoction	351.0 a	1224.8 a	1451.7 a	120.4 a
Maceration	154.8 b	662.4 b	838.6 b	113.5 ab
50% EtOH	86.0 d	406.1 bc	125.2 cd	90.7 bc
80% EtOH	92.7 d	400.2 bc	458.8 bc	67.6 cd
96% EtOH	39.7 e	130.5 cd	100.9 cd	49.3 de
Repeated flooding method (96% EtOH)	18.0 e	89.1 d	43.5 d	32.4 e
Paeonia lactiflora Pall. 'Karl Rosenfield'				
Infusion	99.5 b	468.5 b	435.1 bc	110.0 ab
Decoction	353.6 a	1166.4 a	1216.3 a	120.9 a
Maceration	151.4 b	589.2 b	751.6 b	112.4 ab
50% EtOH	97.9 b	342.8 b	141.2 c	93.1 b
80% EtOH	103.0 b	457.5 b	399.5 bc	103.1 ab
96% EtOH	22.8 b	89.1 b	63.3 c	30.3 c
Repeated flooding method (96% EtOH)	6.0 b	42.7 b	5.9 c	12.2 c

Mean values in columns marked with different letters differ significantly: a–e – $P \leq 0.05$.

It was observed in the conducted experiments that for all investigated species and cultivars the decoction method was the most advantageous because it proved the highest content of antioxidant compounds (Table 2). Moreover, the highest contents of the studied compounds were found in the methods of flower extraction of three cultivars of *P. lactiflora* Pall. *P. lactiflora* Pall. 'Sarah Bernardt' flower decoctions indicate the highest antioxidant activity: total polyphenols – 397.1 mg GAE · 100 ml^{-1}; DPPH – 1294.4 mg TE · 100 ml^{-1}; ABTS – 1553.1 mg TE · 100 ml^{-1}; FRAP – 122.1 mg TE · 100 ml^{-1}. Testing antioxidant activity with FRAP test in *P. lactiflora* Pall. 'Sarah Bernardt' and 'Dr. Alexander Fleming' flowers no statistically significant differences were found between infusion, decoction and macerate, and in the case of 'Karl Rosenfield' flowers, no statistically significant differences were found between water extracts and 80% ethanol extract. Moreover, infusion, macerate and alcohol extracts from 'Karl Rosenfield' flowers did not differ significantly from each other in the case of total polyphenols and antioxidant compounds tested by DPPH test.

In *M. didyma* L. flower decoctions high content of total polyphenols (117.9 mg GAE· 100 ml^{-1}) and high antioxidant activity by DPPH method (257.4 mg TE · 100 ml^{-1}) were observed. Whereas, flower decoctions from *M.* × *hybridus* L. 'Magic Red' showed high antioxidant activity in ABTS (384.9 mg TE · 100 ml^{-1}) i FRAP (23.9 mg TE · 100 ml^{-1}) tests.

In this study it was noted that *H.* × *hybrida* Hort. flowers showed significantly higher antioxidant activity in the ABTS test when extracted by maceration rather than by decoction (29% on average).At the same time, for the investigated species, decoctions and infusions indicated higher antioxidant activity in the DPPH test than macerates (on average 38%), there were no significant differences between infusions, decoctions and macerates in the FRAP test.

Moreover, in dried *H.* × *hybrida* Hort. flowers, decoctions and macerates were the most effective methods to achieve high polyphenol content. A study by Ngoitaku et al. (2016) on the duration of tea brewing from edible flowers of 8 other ornamental plant species showed that *Tagetes erecta* tea brewed at 100°C for 3 minutes contained a high level of total phenol content (35.5 mg GAE · g^{-1} DW). Whereas, *T. erecta* tea drinks brewed at 95°C for 5 minutes showed the highest total reducing capacity (FRAP test – 36.1 μmol FeSO4 · g^{-1} DW).

Based on the results obtained in the research of selected edible flower species, it was found that water extracts indicate higher antioxidant activity than alcohol extracts. The decoction was also the most advantageous extraction method for the tested species of edible flowers. Similar results were obtained by Grzeszczuk et al. (2014). Based on dried plant material (vinca herbs and leaves) the authors had prepared three types of water extracts: infusions, decoctions and macerates. Decoction was found to be the most effective method of water extraction as it resulted in the highest content of biologically active compounds (L-ascorbic acid, total polyphenols) and antioxidant activity.

It should also be emphasized that regardless of the species, extracts with 50% and 80% ethanol were characterized by the higher content of total polyphenols and antioxidant compounds than extracts with 96% ethanol or using multiple flooding with the same high percentage alcohol.

CONCLUSIONS

1. Dried edible flowers demonstrated high content of biologically active compounds, especially total polyphenols, total carotenoids and antioxidant activity. For the flowers of *M.* × *hybridus* L., *M. didyma* L. and *H.* × *hybrida* Hort. the most favourable drying temperature was 35°C, while for the flowers of *P. lactiflora* Pall. ~25°C.
2. Water extracts indicate higher antioxidant activity in comparison with the alcohol extracts.
3. The decoction was the most efficient method of extraction of the studied species of edible flowers.
4. Water-alcoholic extracts (50% and 80% ethanol) indicated better antioxidant properties than alcoholic ones (96% and repeated flooding with 96% ethanol).
5. Among the extracts of the dried edible flowers evaluated in the experiment, the highest antioxidant activity was observed in water and water-alcohol extracts prepared on the basis of peony flowers.

ACKNOWLEDGMENT

Research was financed by West Pomeranian University of Technology in Szczecin as a part of statutory activity.

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WPŁYW TEMPERATURY SUSZENIA ORAZ METODY SPORZĄDZANIA WYCIĄGÓW NA AKTYWNOŚĆ ANTYOKSYDACYJNĄ KWIATÓW JADALNYCH WYBRANYCH GATUNKÓW ROŚLIN OZDOBNYCH

Streszczenie. Kwiaty jadalne są popularnym składnikiem potraw wielu kuchni regionalnych, zwłaszcza azjatyckiej i bliskowschodniej. Suszenie to jedna z najpopularniejszych metod konserwacji kwiatów. Z kolei powszechną metodą spożywania wysuszonych kwiatów jadalnych jest przyrządzanie z ich wykorzystaniem różnego rodzaju napojów – zarówno alkoholowych, jak i bezalkoholowych. W pracy przedstawiono wyniki badań laboratoryjnych dotyczące zawartości związków biologicznie czynnych w kwiatach suszonych, w trzech wariantach temperaturowych (~25°C, 35°C i 70°C), które posłużyły do wyboru materiału stanowiącego podstawę otrzymywania różnego rodzaju wyciągów wodnych (naparów, odwarów, maceratów) i alkoholowych (z użyciem etanolu w ilości 50%, 80% i 96% oraz metodą kilkukrotnego zalewania – 96% EtOH), a następnie oceniono ich aktywność antyoksydacyjną. Materiałem badawczym były gatunki roślin ozdobnych, których kwiaty charakteryzują się wysoką wartością biologiczną: *Mimulus* × *hybridus* L. (‘Magic Yellow’ and ‘Magic Red’), *Hemerocallis* × *hybrida* Hort., *Monarda didyma* L., *Paeonia lactiflora* Pall. (‘Sarah Bernardt’, ‘Dr Aleksander Fleming’ and ‘Karl Rosenfield’). Badania przeprowadzono w latach 2014–2015 w Katedrze Ogrodnictwa na Zachodniopomorskim Uniwersytecie Technologicznym w Szczecinie. Na podstawie uzyskanych wyników analiz chemicznych wytypowano najlepsze warianty suszenia badanych gatunków kwiatów. Dla kwiatów *M.* × *hybridus* L., *M. didyma* L. i *H.* × *hybrida* Hort. najkorzystniejszą temperaturą suszenia było 35°C; wysuszone kwiaty charakteryzowały się największą zawartością związków biologicznie czynnych i największą aktywnością antyoksydacyjną. W przypadku trzech odmian *P. lactiflora* Pall. najkorzystniejszą temperaturą suszenia było ~25°C. Wśród wyciągów wodnych i alkoholowych badanych gatunków kwiatów jadalnych odwar charakteryzował się wysoką zawartością związków antyoksydacyjnych. Największą aktywnością antyoksydacyjną wyróżniały się wyciągi sporządzone na bazie kwiatów piwonii.

Słowa kluczowe: *Mimulus, Monarda, Hemerocallis, Paeonia*, witamina C, karotenoidy, polifenole, DPPH, ABTS, FRAP.