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ORIGINAL PAPER

COMPOSITION OF ESSENTIAL OILS AND SOME ANTIOXIDANTS IN FLOWERS OF THREE *CHRYSANTHEMUM* CULTIVARS*

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Abstract

Essential oils isolated from flowers of three *Chrysanthemum* cultivars were analysed by gas chromatography-mass spectrometry (GC/MS). Overall, 82, 68 and 61 components were identified in *C. arcticum* cv. Schwefelglanz, *C. parthenium* cv. Aureum, *C. parthenium* cv. Snowball, respectively. In *Chrysanthemum arcticum* Schwefelglanz, the main components were chrysanthenone (13.98%), *α*-thujone (9.56%), tetradecane (6.90%), camphor (6.20%) and *α*-cadinol (5.70%), while in *Chrysanthemum parthenium* Aureum they were camphor (38.51%), *trans*-chrysanthenyl acetate (25.04%), camphene (6.44%) and bornyl acetate (3.54%). Similarly, camphor (39.98%), *trans*-chrysanthenyl acetate (22.30%), camphene (7.20%) and bornyl acetate (2.98%) dominated in *Chrysanthemum parthenium* Snowball. Also, the biological value of *Chrysanthemum* flowers was determined and compared. Moreover, the chemical analyses of raw plant material were conducted, including determinations of the content of dry matter, vitamin C as L-ascorbic acid, titratable acidity, total chlorophyll, chlorophyll *a* and *b*, total carotenoids, total polyphenols and antioxidant activity. The flowers of both cultivars of *Chrysanthemum parthenium* (Aureum and Snowball) were characterised by the higher content of dry matter, titratable acidity, total polyphenols and antioxidant activity in comparison with *Chrysanthemum arcticum* Schwefelglanz. However, the highest content of total carotenoids was determined in essential oils from the flowers of *Chrysanthemum parthenium* Aureum.

Keywords: edible flowers, *Asteraceae*, camphor, *trans*-chrysanthenyl acetate, carotenoids, polyphenols.

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INTRODUCTION

The genus *Chrysanthemum,* which belongs to the *Asteraceae* family, comprises about 300 species of herbs and undershrubs (Kumar et al. 2005). The flowers of some *Chrysanthemum* species were applied in Chinese natural medicine owing to their anti-inflammatory, analgesic and antipyretic properties (Basta et al. 2007). Several recent studies indicate that chrysanthemums produce anticancer, antimicrobial, immunomodulatory, hepatoprotective and neuroprotective effects (Kim et al. 2012, Lawal et al. 2014, Amrani et al. 2016). These aromatic plants are also used in the flavour and fragrance industries, because of the diversity of volatile components in the essential oils (Sharma et al. 2011). In Japan and China, green leaves, stems and flowerheads of numerous chrysanthemums are consumed as vegetables or used as herbal infusions (Teixeira da Silva 2004, Lograda et al. 2013). *Chrysanthemum arcticum* L. (arctic daisy), also known as *Arctic Chrysanthemum* or *Arctanthemum arcticum*, is a leathery-leaved, hard, almost woody perennial, native to the Arctic regions. Flowers are white to lilac. *Chrysanthemum parthenium* L. (feverfew, *Tanacetum parthenium* L.), a daisy-like perennial plant, is widely cultivated around the world for both ornamental and medicinal purposes (Sharopov et al. 2015). Its yellow-green leaves are used in salads, omelets and cakes (Mohsenzadeh et al. 2011). Feverfew has been used in traditional medicine for treatment of fever, headache, migraine, bronchitis, rheumatoid arthritis and menstruation related problems (Pourianezhad et al. 2016). Moreover, anticancer, anti-inflammatory, cardiotonic, antispasmodic and antioxidant properties of this plant have been also well documented (Hanganu et al. 2016).

The aim of the present study was to determine the composition of essential oils isolated from flowers of three *Chrysanthemum* cultivars (*C. arcticum* Schwefelglanz, *C. parthenium* Aureum, *C. parthenium* Snowball). The biological value of *Chrysanthemum* flowers was also compared. To the best of our knowledge, there are no literature data concerning this topic. Moreover, there are no previous reports of detailed chemical analysis of arctic daisy (*C. arcticum*).

MATERIAL AND METHODS

A field experiment was carried out in 2014 at The Edible Flower Collection of the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. The laboratory part of the research was conducted in the Department *of Organic and Physical Chemistry and the Department of Horticulture of* the West Pomeranian University of Technology in Szczecin. The research material consisted of flowers (anthodiums) of *Chrysanthemum arcticum* L. Schwefelglanz, *Chrysanthemum parthenium* (L.) Bernh. Aureum

and *Chrysanthemum parthenium* (L.) Bernh. Snowball. The field experiment was set in a randomized block design with three replications, on typical pararendzina soils, with pH in H_2O of 6.8 and the following nutrient content: $N\text{-}NO_3$ – 27, P – 80, K – 163, Ca – 2932, Mg – 153, Cl – 12 mg dm^{-3}. A single plot was 1.20 m^2 in area (30 × 25 cm, 16 plants per plot). Seedlings of *C. parthenium* cultivars were produced in a greenhouse. Seeds were sown on 18th March. The seedlings were transplanted into a field on 20st May. The planting material of *C. arcticum* Schwefelglanz was bought in an ornamental plant nursery and planted on the experimental plots on 20th May. The mean daily temperature over the growing season period was 17°C for *C. parthenium* cultivars (May-July) and 16°C for *C. arcticum* cultivar (May--October). The field was prepared in line with the appropriate technology for the tested plant species. Mineral fertilization was quantified according to the results of the chemical analysis of the soil. Nitrogen (30 kg N ha^{-1}), phosphorus (40 kg P_2O_5 ha^{-1}) and potassium (80 kg K_2O ha^{-1}) fertilizers were applied during the field preparation, and the other half dose of nitrogen (30 kg N ha^{-1}) was supplied in a top dressing fertilization treatment in early June. During the growing season, crop management included mainly irrigation, weeding and soil cultivation. The flower harvest was done at the full-bloom stage: on 24th July for *C. parthenium* Aureum and Snowball, and on 21st October for *C. arcticum* Schwefelglanz.

The chemical analyses of raw plant material included determinations of the dry matter content (drying at 105°C to constant weight), vitamin C as L-ascorbic acid (ISO 6557-2:1984), titratable acidity (ISO 750:1998), total chlorophyll, chlorophyll *a* and *b* (Lichtenthaler, Wellburn 1983), and total carotenoids (Lichtenthaler, Wellburn 1983). The preparation of plant extracts for the determination of total polyphenol content and antioxidant activity was performed using the method proposed by Wojdyło et al. (2007) with some modifications. A sample of 1 g homogenized raw plant material was treated with 80% aqueous methanol (MeOH) to 100 ml volume. The mixtures were placed in an ultrasonic bath at room temperature and sonicated for 30 min (2 × 15 min) and then left for 24 h at room temperature. The extracts were filtered over Whatman No. 1 filter paper. The filtrates were centrifuged at 1500 rpm for 10 minutes. The total polyphenol content was analyzed spectrophotometrically using the Folin-Ciocalteu colorimetric method as described by Wojdyło et al. (2007), and the results were expressed as gallic acid (GAE) mg 100 g^{-1} of fresh weight. The antioxidant activity of Chrysanthemum flowers on DPPH (2,2-diphenyl-1-picrylhydrazyl) radical was determined according to Kumaran and Karunakaran (2007) and Wojdyło et al. (2007). The percentage of DPPH scavenging activity was calculated from the formula $[A_0 - A_1/A_0] \cdot 100$, where A_0 is the absorbance of the control, and A_1 is the absorbance of the extract. The absorbance was read with a spectrophotometer at 517 nm. Each analysis was carried out in triplicate.

Moreover, some of the raw plant material was dried in a through-flow laboratory dryer set at 35°C. Dried flowers (15 g) of each cultivar (separately)

were placed in 1000 ml round-bottomed flasks, each filled with 500 ml of distilled water, and submitted to steam distillation for 3 h using a Clevenger--type apparatus according to the general method recommended by European Pharmacopoeia 7 ed. (2010). The extracted oils were dried over anhydrous sodium sulphate, filtered, weighed and stored in dark in sealed vials placed in a refrigerator until analysis (GC/MS). The distillation process was repeated in triplicate for each cultivar. The essential oil content was determined and expressed as weight of oil per dried material weight (% w/w). The qualitative GC/MS analysis of the isolated oils was carried out on a Hewlett--Packard gas chromatographer (HP 6890), equipped with a HP-5MS capillary column (30 m × 0.25 mm; film thickness 0.25 µm) and coupled with a HP 5973 Mass Selective Detector operated in the electron ionization mode at 70 eV, scanning a mass range of m/z 40-550 at 2.94 scans per second. Helium was used as a carrier gas at a flow rate of 1 ml min^{-1}. Samples of 2 µl (40 mg of oil dissolved in 1.5 ml of methylene chloride) were injected in the split mode at a 5:1 ratio. The injector and the transfer line temp. were set at 280ºC. The ion source temp. was 230ºC. The initial temp. of the column was kept at 40ºC for 5 min, then increased 60ºC at a rate of 30ºC per min, next to 230ºC at a rate of 6ºC per min (kept constant for 10 min), and then increased to the final temp. of 280ºC at a rate of 30ºC per min (kept constant for 30 min). The solvent delay time was 4 minutes. The total running time for a single sample was 76 minutes.

Essential oil constituents were identified by comparison of their calculated retention indices (RI) with those reported in the NIST Chemistry WebBook (http://webbook.nist.gov/chemistry/) and the literature (Adams 2007, Basta et al. 2007). For RI calculation, a mixture of homologous series of *n*-alkanes (C_7-C_{40}, Supelco, Bellefonte, PA, USA) was used under the same chromatographic conditions as for the analysis of the essential oils. Further identification of individual compounds was made by comparison of their mass spectra with those stored in NBS75K and NIST 2002 mass spectral libraries. The relative per cent amounts of the essential oil components were evaluated from the total peak area (TIC) by the apparatus software.

The results of the study were subjected to an analysis of variance, supported by FR-ANALWAR software based on Microsoft Excel. The means were separated by the Tukeys test at $p = 0.05$.

RESULTS AND DISCUSSION

The content of volatile oil in different species of chrysanthemums is variable and depends on the part of plant used as well as the origin of plant material (Mohsenzadeh et al. 2011). In our study, the highest content of essential oil was noted for *C. parthenium* Snowball (1.02%), while the least for *C. arcticum* Schwefelglanz (0.59%) – Table 1. The amount of essential oil

Table 1

Essential oil content in flowers of three *Chrysanthemum* cultivars

Cultivar	Essential oil content (% w/w)
Chrysanthemum arcticum Schwefelglanz	0.59
Chrysanthemum parthenium Aureum	0.82
Chrysanthemum parthenium Snowball	1.02
Mean	0.81
$LSD_{\alpha=0.05}$	0.394

obtained from flowers of *C. parthenium* collected from the Hamedan region (Iran) was 3.61% and from those collected from the Tehran region – 3.39% (Izadi et al. 2010). Interestingly, Shafaghat et al. (2009) found a lower oil content in *C. parthenium* flowers from Ardabil Province (Iran) – 0.8%. Similarly, wild and cultivated plants from Tehran Province (Iran) contained less volatile oil (0.1 and 0.4% of oil, respectively) (Mirjalili et al. 2007). Our results indicate that the content of essential oil in flowers of the investigated *Chrysanthemum* cultivars was higher than the values reported in the cited literature. Only plants from the Hamedan and Tehran regions (Izadi et al. 2010) as well as from Korea (Chang, Kim 2008) had a higher oil content than found in the chrysanthemums we investigated.

The results of GC/MS analysis of *Chrysanthemum* oils are listed in Table 2, where the percentage and retention indices of compounds are given. 82 constituents were identified in the oil from flowers of *C. arcticum* Schwefelglanz, representing 99.15% of the total oil composition. The major components were chrysanthenone (13.98%), *α*-thujone (9.56%), tetradecane (6.90%), camphor (6.20%) and *α*-cadinol (5.70%). Considerable amounts of *β*-bisabolene (3.52%), (Z)-*β*-bisabolene epoxide (2.77%), *α*-bisabolol (2.69%), borneol (2.68%) and bicyclogermacrene (2.37%) were also found. In *C. parthenium* Aureum flower oil, 68 components were identified representing 99.11% of the oil. Camphor was the predominant compound (38.51%), followed by *trans*-chrysanthenyl acetate (25.04%), camphene (6.44%) and bornyl acetate (3.54%). A total of 61 components, which constitute 98.59%, were identified in the essential oil from flowers of *C. parthenium* Snowball. The main compounds were camphor (39.98%), *trans*-chrysanthenyl acetate (22.30%), camphene (7.20%) and bornyl acetate (2.98%). Both *C. parthenium* oils were characterized by a high content of oxygenated monoterpenes (75.15% for Aureum and 73.49% for Snowball) and monoterpene hydrocarbons (13.88 % for Aureum and 13.77% for Snowball) – Table 2. The oil obtained from flowers of *C. arcticum* Schwefelglanz was richer in oxygenated sesquiterpenes (22.10%) and sesquiterpene hydrocarbons (16.16%) in comparison with *C. parthenium* Snowball (5.07% and 2.41%, respectively) and *C. parthenium* Aureum (4.88% and 1.43%, respectively) – Table 2. The fraction of others compounds (mainly saturated and unsaturated hydrocarbons, branched alkanes, fatty acids and

Table 2

Composition of the essential oils from flowers of three *Chrysanthemum cultivars*

No.	Compound	RI	A	B	C
1	2	3	4	5	6
1.	*α*-Tricyclene	920	-*	0.32	0.34
2.	*α*-Pinene	932	0.97	2.78	2.47
3.	Camphene	948	0.50	6.44	7.20
4.	Sabinene	973	1.93	0.14	0.06
5.	*β*-Pinene	976	-	0.82	0.94
6.	Myrcene	991	0.13	0.03	0.04
7.	*α*-Terpinene	1017	0.12	0.12	0.14
8.	*p*-Cymene	1025	0.17	1.36	0.82
9.	Limonene	1029	-	1.19	1.19
10.	Eucalyptol	1031	0.81	-	-
11.	*γ*-Terpinene	1060	0.22	0.59	0.47
12.	cis-Sabinene hydrate	1068	0.10	0.15	0.08
13.	*α*-Terpinolene	1089	0.07	0.09	0.10
14.	Undecane	1100	-	0.13	0.04
15.	Linalool	1103	0.26	0.37	0.38
16.	*α*-Thujone	1110	9.56	0.27	0.29
17.	*β*-Thujone	1117	0.67	0.86	0.57
18.	Chrysanthenone	1126	13.98	0.60	0.83
19.	3-Thujol	1138	0.26	-	-
20.	*trans*-Pinocarveol	1144	0.47	0.45	0.48
21.	Camphor	1152	6.20	38.51	39.98
22.	*cis*-Chrysanthenol	1165	0.11	0.92	0.89
23.	Borneol	1169	2.68	0.82	0.70
24.	Terpinen-4-ol	1179	0.71	0.94	0.92
25.	*α*-Terpineol	1194	0.12	0.22	0.29
26.	1-Dodecene	1196	-	0.12	-
27.	Myrtenol	1199	-	0.46	0.59
28.	Decanal	1205	-	0.24	0.23
29.	*cis*-Verbenone	1213	-	0.33	0.53
30.	(E)-Carveol	1224	-	0.18	0.20
31.	*trans*-Chrysanthenyl acetate	1239	-	25.04	22.30
32.	Hexyl isovalerate	1247	-	0.68	0.66
33.	*cis*-Chrysanthenyl acetate	1265	-	0.28	0.43
34.	Bornyl acetate	1288	0.30	3.54	2.98
35.	*trans*-Pinocarvyl acetate	1294	0.08	-	-
36.	*cis*-Pinocarvyl acetate	1315	-	0.50	0.27
37.	neo-Verbanol acetate	1328	-	0.29	0.22
38.	*γ*-Pyronene	1340	0.03	-	-
39.	*α*-Cubebene	1350	0.12	0.19	0.30
40.	Eugenol	1359	-	0.33	0.46
41.	Nerol acetate	1367	-	0.09	0.10
42.	Capric acid	1374	-	0.39	0.37
43.	*β*-Bourbonene	1389	0.67	0.06	-

cont. Table 2

1	2	3	4	5	6
44.	*β*-Elemene	1395	-	0.09	0.39
45.	Tetradecane	1399	6.90	-	-
46.	Italicene	1403	-	0.40	1.10
47.	*α*-Cedrene	1416	0.38	-	-
48.	*β*-Caryophyllene	1426	0.98	0.36	0.44
49.	*β*-Copaene	1431	0.17	-	-
50.	*β*-Cubebene	1435	0.09	-	-
51.	(Z)-*β*-Santalene	1450	0.35	-	-
52.	(E)-*β*-Farnesene	1462	1.91	0.09	0.07
53.	Undecanoic acid	1467	0.45	0.10	-
54.	*γ*-Gurjunene	1471	0.90	-	-
55.	*β*-Chamigrene	1476	0.16	-	-
56.	*trans*-Chrysanthenyl isovalerate	1481	1.36	-	-
57.	Germacrene D	1487	0.33	-	-
58.	(Z)-*β*-Farnesene	1491	1.03	0.02	-
59.	Viridiflorene	1493	1.45	-	-
60.	Pentadecane	1500	-	0.10	0.07
61.	Bicyclogermacrene	1502	2.37	-	-
62.	*β*-Bisabolene	1515	3.52	0.05	-
63.	*β*-Sesquiphellandrene	1521	0.16	0.12	0.05
64.	*δ*-Cadinene	1528	0.78	-	-
65.	*trans*-Calamenene	1532	0.09	-	-
66.	Cadina-1,4-diene	1539	0.34	-	-
67.	Germacrene B	1556	0.16	-	-
68.	*β*-Calacorene	1561	0.20	0.05	0.06
69.	(E)-Nerolidol	1567	1.56	0.35	0.18
70.	Lauric acid	1576	1.07	-	-
71.	Chrysanthenyl hexanoate	1583	0.61	-	-
72.	Spathulenol	1586	0.54	0.30	0.32
73.	Caryophyllene oxide	1592	1.06	1.24	1.68
74.	Hexadecane	1603	0.63	0.25	0.41
75.	Humulene epoxide II	1613	0.23	0.10	-
76.	1,10-di-epi-Cubenol	1619	0.48	0.24	0.33
77.	Isospathulenol	1635	0.78	-	-
78.	*β*-Eudesmol	1647	0.50	1.05	0.86
79.	*τ*-Cadinol	1654	0.96	-	-
80.	*α*-Cadinol	1667	5.70	-	-
81.	9-Cedranone	1668	1.46	0.89	0.83
82.	*α*-Bisabolol	1681	2.69	0.42	0.58
83.	epi-α-Bisabolol	1689	0.91	-	-
84.	*β*-Sinensal	1694	0.73	-	-
85.	1-Heptadecene	1697	-	0.03	0.23
86.	Heptadecane	1702	1.11	0.20	0.08
87.	Pentadecanal	1717	1.89	-	-
88.	(E,E)-Farnesol	1724	1.00	-	-

cont. Table 2

1	2	3	4	5	6
89.	Methyl myristate	1728	1.59	-	-
90.	(Z)-α-Bisabolene epoxide	1732	2.77	-	-
91.	Bisabolol oxide A	1754	0.53	-	-
92.	Myristic acid	1768	0.20	0.49	0.32
93.	(E)-α-Atlantone	1779	0.20	0.29	0.29
94.	1-Octadecene	1792	0.11	-	-
95.	7-(2,4-Hexadiynylidene)-1,6--dioxaspiro[4.4]nona-2,8-diene	1814	-	0.09	0.10
96.	1-Hexadecanol	1882	-	0.11	0.15
97.	Nonacosane	1902	-	0.46	0.73
98.	Methyl palmitate	1927	0.17	-	-
99.	*m*-Camphorene	1957	0.60	-	-
100.	4-Methylnonadecane	1961	1.47	-	-
101.	Palmitic acid	1973	-	0.19	0.27
102.	Ethyl palmitate	1983	-	0.08	-
103.	Eicosane	2006	0.06	-	-
104.	1-Heneicosene	2095	0.27	-	-
105.	Ethyl linoleate	2156	0.33	-	-
106.	1-Tricosene	2295	0.55	-	-
107.	1-Pentacosene	2494	0.84	-	-
108.	Pentacosane	2503	-	0.11	0.19
109.	1-Heptacosene	2698	0.23	-	-
	Total identified (%)		99.15	99.11	98.59
	Monoterpene hydrocarbons		4.14	13.88	13.77
	Oxygenated monoterpenes		38.28	75.15	73.49
	Sesquiterpene hydrocarbons		16.16	1.43	2.41
	Oxygenated sesquiterpenes		22.10	4.88	5.07
	Diterpenoids		0.60	-	-
	Others compounds		17.87	3.77	3.85

RI – retention indices relative to *n*-alkanes (C_7-C_{40}) on HP-5MS capillary column,
A – *Chrysanthemum arcticum* Schwefelglanz, B – *Chrysanthemum parthenium* Aureum,
C – *Chrysanthemum parthenium* Snowball, * – not detected

their esters) amounted to 17.87% in *C. arcticum* Schwefelglanz, while in *C. parthenium* Aureum and *C. parthenium* Snowball was lower (3.77% and 3.85%, respectively).

The chemical composition of the essential oil of *C. parthenium* has previously been reported (Mirjalili et al. 2007, Haziri et al. 2009, Shafaghat et al. 2009, Stevanovic et al. 2009, Izadi et al. 2010, Sharopov et al. 2015). Based on the origin of plant material, two distinct chemotypes have been identified: one with camphor/chrysanthenyl acetate and the other with camphor/camphene as the main constituents (Sharopov et al. 2015). The comparison of our results with the literature data has shown that *C. parthenium* Aureum and *C. parthenium* Snowball belong to the camphor/*trans*-chrysanthenyl acetate

chemotype. The chemical composition of the essential oil of *C. arcticum* seems to be similar to the essential oil obtained from *C. cinerariifolium* growing in Nepal (Shrestha et al. 2014). Our sample has almost the same major components (chrysanthenone, camphor, α-cadinol). However, no γ-muurolene was detected in the essential oil of arctic daisy in our assays. Moreover, the content of *cis*-chrysanthenol (0.11%) was much lower than given by Shrestha et al. (2014). α-Thujone, which was one of the main constituents of *C. arcticum* essential oil (9.56%), was absent from the oil of *C. cinerariifolium*.

Chemical analysis of raw plant material included determination of the content of bioactive compounds, which are healhful and valued by consumers. The analysis of the results presented in Table 3 showed that flowers of both cultivars of *C. parthenium* were characterised by a significantly higher content of dry matter, titratable acidity, content of total polyphenols as well as the antioxidant activity than flowers of *C. arcticum* Schwefelglanz. There were no significant differences between *Chrysanthemum* cultivars in the con-

Table 3

Content of the main chemical compounds in flowers of the three *Chrysanthemum* cultivars

Compound	*Chrysanthemum arcticum* Schwefelglanz	*Chrysanthemum parthenium* Aureum	*Chrysanthemum parthenium* Snowball	Mean	$LSD_{\alpha=0.05}$
Dry matter (%)	14.72 ± 0.01	22.63 ± 0.25	22.72 ± 0.14	20.02	1.021
L-ascorbic acid (mg 100 g^{-1} f.w.)	21.12 ± 1.06	12.78 ± 0.42	12.54 ± 1.26	15.48	n.s.
Titratable acidity (g citric acid 100 g^{-1} f.w.)	0.392 ± 0.003	0.479 ± 0.001	0.475 ± 0.012	0.448	0.051
Total chlorophyll (μg g^{-1} f.w.)	49.76 ± 8.61	59.57 ± 4.01	75.94 ± 3.98	61.76	n.s.
Chlorophyll *a* (μg g^{-1} f.w.)	32.85 ± 7.82	48.55 ± 3.12	53.52 ± 3.85	44.97	n.s.
Chlorophyll *b* (μg g^{-1} f.w.)	14.75 ± 1.16	5.53 ± 1.50	13.76 ± 0.22	11.34	n.s.
Total carotenoids (μg g^{-1} f.w.)	124.72 ± 6.90	218.34 ± 7.45	100.58 ± 1.35	147.88	41.039
Total polyphenols (mg GAE 100 g^{-1} f.w.)	48.49 ± 1.28	765.89 ± 27.74	982.22 ± 52.56	598.87	144.785
Antioxidant activity (% DPPH)	20.04 ± 3.12	90.26 ± 0.17	92.08 ± 0.07	67.46	6.306

± standard deviation (n = 3), n.s. – not significant

tent of L-ascorbic acid, which on average was 15.48 mg 100 g^{-1} f.w., thus being low in comparison with the data given in the literature for other edible flower species. Grzeszczuk et al. (2016) recorded 241.20 mg of L-ascorbic acid per 100 g of f.w. for *Tagetes tenuifolia* Cav. flowers and Garzón, Wrolstad (2009) determined 71.5 mg 100 g^{-1} f.w. for *Tropaeolum majus* flowers. On the other hand, the chlorophyll content determined in *Chrysanthemum* flowers was higher than in other edible flowers (Grzeszczuk et al. 2016), and this was the result of taking green parts of the flowers for analysis.

The antioxidant activity of pink, yellow and white flowers of *C. morifolium* Ramat. was examined by Yeasmin et al. (2016), who reported that the white flowers had higher antioxidant (% DPPH) activity (93.62%) than pink (92.03%) and yellow (60.83%) ones. According to Fraisse et al. (2011), the total antioxidant capacity (%) of the aerial parts of *C. parthenium* was 7.89%. Our results are in agreement with those obtained by Yeasmin et al. (2016). Both *C. parthenium* cultivars with white flowers showed higher antioxidant activity (Aureum – 90.26%, Snowball – 92.08%) than did *C. arcticum* – 20.06%. The content of total polyphenols in the flowers of both cultivars of *C. parthenium* was very high (Snowball – 982, Aureum – 766 mg 100 g^{-1} f.w.) and higher than assessed by Rop et al. (2012) in the flowers of *C. parthenium* Roya (272 mg 100 g^{-1} f.w.) and *C. frutescens* Silver Leaf (253 mg 100 g^{-1} f.w.). In comparison, flowers of *C. arcticum* Schwefelglanz contained only 48 mg 100 g^{-1} f.w. Park et al. (2015) determined the total carotenoid content in flowers of 23 cultivars of *C. morifolium* Ramat. The highest level of carotenoids (345.56 μg g^{-1} d.w.) was quantified in a chrysanthemum cultivar with yellow petals (II Weol). The *Chrysanthemum* cultivar Fire pink was characterized by the lowest content of carotenoids (19.43 μg g^{-1} d.w.). They also reported that a low (0-50 μg g^{-1} d.w.) and medium (50-100 μg g^{-1} d.w.) levels of carotenoids were found in cultivars with bluish, purplish, whitish or reddish colored petals. Cultivars with yellow or green petals showed the highest levels of carotenoids (more than 100 μg g^{-1} d.w.). It is in agreement with the results of our study. Flowers of *C. parthenium* Aureum (daisy-like flowers with white ray florets and yellow centre disc florets) contained the highest amount of total carotenoids, lower content was determined in flowers of *C. arcticum* Schwefelglanz (long white ray florets and yellow centre disc florets) and the least amount appeared in flowers of *C. parthenium* Snowball (white pompon flowers). Based on the classification proposed by Park et al. (2015), *C. parthenium* Aureum and *C. arcticum* Schwefelglanz can be considered as cultivars with a high level of carotenoids.

CONCLUSIONS

1. Flowers of three *Chrysanthemum* cultivars differed significantly in the content of essential oil, dry matter, total carotenoids, total polyphenols,

titratable acidity and antioxidant activity. Moreover, there were differences in the composition of their essential oil.

2. Camphor, *trans*-chrysanthenyl acetate and camphene were common in both *C. parthenium* essential oils as three major compounds, while in *C. arcticum* chrysanthenone, α-thujone, tetradecane, camphor and *α*-cadinol were the main constituents.

3. The edible flowers of both *C. parthenium* cultivars had the highest content of dry matter, total polyphenols, titratable acidity and antioxidant activity.

4. The highest amount of carotenoids was noted in the flowers of *C. parthenium* Aureum.

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