Determination and quantification of volatile compounds in fruits of selected elderberry cultivars grown in Czech Republic

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Summary

The aim of this work was to identify and quantify the volatile aroma compounds in fruits of several elderberry cultivars and to find a cultivar with the highest content of them. Wild elder and sixteen cultivars of elderberries were analysed. Aroma compounds were extracted by solid phase microextraction, identified by gas chromatography-mass spectrometry and quantified by gas chromatography. In total, 102 volatile compounds were identified in all elderberry samples, among them 38 alcohols, 16 aldehydes, 10 ketones, 19 esters, 4 heterocycles, 6 hydrocarbons and 9 acids. Alcohols, aldehydes and esters were the most abundant, while significantly ($P < 0.05$) lower contents of heterocycles and hydrocarbons were found. Based on the literature, 36 compounds known as significant components of elderberry aroma, were chosen as markers of differences among cultivars. Owing to the highest total content of the selected compounds, cultivars Korsör (77.89 ± 3.57) $mg \cdot kg^{-1}$, Pregarten (43.20 ± 7.14) $mg \cdot kg^{-1}$ and Samdal (67.85 ± 8.22) $mg \cdot kg^{-1}$ were recommended for practical use.

Keywords

elderberry; aroma compounds; solid-phase microextraction; gas chromatography; gas chromatography-mass spectrometry

Black elder (*Sambucus nigra* L.) is a plant with miscellaneous use due to its therapeutic effects in medicine, for its aroma and taste in the kitchen. It grows wild in several countries of Europe. Wild elderberry fruits and flowers are used mainly for the home-made production of marmalades, juices, syrups, teas, liqueurs and wines. Fruits are known by high contents of anthocyanin pigments and they are used for industrial production of natural colorants for various types of food products [1]. Czech food industry uses mainly imported frozen elderberries as a fruit component of yoghurts. However, elderberry contains many health-promoting substances [2–4], so its consumption is highly advisable. Novel food products based on elderberry, with a high antioxidative potential, could enrich the Czech consumer market.

Current research focuses on cultivated varieties, which offer higher yields, higher contents of valuable compounds, lower content of toxic sambunigrin, better sensory properties and other advantages compared to the wild plant. Elderberry is cultivated in some European countries, e.g. Austria, Denmark, Germany, Hungary. Several cultivars are grown in Slovakia in a small extent. The production of cultivated elderberries in Czech Republic is only at the beginning. No new varieties were bred in Czech region, but various foreign cultivars are tested for breeding here. The information about them is very scarce.

Successful commercialization of elderberry fruits depends on their sensory properties, in particular good taste and aroma, which are strongly associated with the content of volatile aroma-active substances [5]. The aroma of elderberry flowers [6–10] and fruits of elderberries [5, 11–13] were characterized by several authors, albeit not many articles were published. More than 100 volatiles were identified. Using GC-olfactometry, Jensen et al. [12] divided the aroma compounds

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of elderberries into six odour classes: elderberry, flowery, fruity, grassy, agrestic and miscellaneous. Most of other authors adhered to this classification and came to similar conclusions [5, 13].

The aim of this work was to identify and quantify the volatile aroma compounds in fruits of several elderberry cultivars tentatively grown in Czech Republic. The volatile compounds identified were then compared in order to recommend the cultivars that would be suitable for growing in the Czech region on a large scale and would be suitable for following practical use. Aroma compounds were assessed by gas chromatography with flame ionization detector (GC-FID) and gas chromatography-mass spectrometry (GC-MS). Solid phase microextraction (SPME) as a modern sample preparation technique, saving preparation time, solvent needs and disposal costs, was used for their extraction. In headspace mode, the method is in particular suitable for the extraction of volatile and semi-volatile organic compounds [14] and was used by many authors to analyse volatile aroma compounds of food samples (reviewed by Kataoka et al. [14]), including various fruits such as raspberries, apricots, plums, pineapples and others [15–23].

MATERIALS AND METHODS

Samples

Wild elder and sixteen cultivars of elderberries (grown by Research and Breeding Institute of Pomology, Holovousy, Czech Republic) were used for analysis: Albida, Allesö, Aurea, Bohatka, Dana, Haschberg, Korsör, Mammut, Pregarten, Riese aus Voßloch, Sambo, Sampo, Sambu, Samdal, Samyl and Weihenstephan.

The berries were picked in September 2011, frozen immediately after picking and stored in a freezer before processing. For analysis, 1 g of the de-frozen sample was mashed and placed into a vial for SPME extraction of aroma compounds. Three samples of every cultivar was taken, every sample was analysed three times ($n = 9$).

SPME-GC and SPME-GC-MS conditions

Volatile compounds in the elderberry samples were extracted by SPME, identified by GC-MS (based on mass spectra) and quantified using standards by GC-FID. The SPME conditions were: SPME fibre CAR/PDMS 85 μm (Supelco, Bellefonte, Pennsylvania, USA). Sample volume 1 ml, extraction temperature 35 °C, equilibrium time 30 min, extraction time 20 min, desorption temperature 250 °C, desorption time 5 min.

Gas chromatograph TRACE GC (ThermoQuest, Milan, Italy) was used, with a capillary column DB-WAX 30 m × 0.32 mm × 0.5 μm (J&W Scientific, Folsom, California, USA). GC conditions: injector 250 °C, splitless desorption 5 min, carrier gas N_2 0.9 ml·min^{-1}, FID at 220 °C, H_2 35 ml·min^{-1}, air 350 ml·min^{-1}, make up N_2 30 ml·min^{-1}. The oven temperature was 40 °C for 1 min, 40–200 °C at 5 °C·min^{-1}, 200 °C for 7 min.

GC-MS analyses were done by a gas chromatograph HP 6890 with MS detector 5973 N and Mass Spectral Library NIST 98 (Agilent, Santa Clara, California, USA). Capillary column ZB-5Sil MS 30 m × 0.25 mm × 0.25 μm (Phenomenex, Torrance, California, USA) was used, with carrier gas He 0.9 ml·min^{-1} and the oven temperature 50–250 °C at 3 °C·min^{-1}. Other GC conditions were the same as stated above. MS was operated in electron ionization (EI) mode at 70 eV with a scan range of m/z from 30 to 370.

A mixture of 20 standards was used for method validation. The intra-day repeatability was verified by repeated extraction ($n = 5$) of the mixture (relative standard deviation < 10%). The detection limit (*LOD*) and quantification limit (*LOQ*) were estimated by successive dilution of standards to achieve the lowest signal registered by the detector (*LOD*, $S/N = 3$; *LOQ*, $S/N = 10$). The detection limits varied in a range of 0.001–0.50 μg·ml^{-1}. Linearity was tested within the range of 0.001–200 μg·ml^{-1}, for ethanol and propan-2-ol in the range of 0.50–2 000 μg·ml^{-1}); based on linear regression analysis, correlation coefficients were all greater than 0.99.

Statistical evaluation

The results were treated using MS Excel 2010 (Microsoft, Redmond, Washington, USA) and were expressed as mean ± standard deviation ($n = 9$). Parametric one way analysis of variance and subsequently Duncan test was used for statistical evaluation of the results using Unistat version 5.5 (Unistat, London, United Kingdom).

RESULTS AND DISCUSSION

Identification of volatile aroma compounds in elderberries

In total, 102 volatile compounds were identified in all elderberry samples, among them:

- 38 alcohols: methanol, ethanol, propan-1-ol, propan-2-ol, butan-1-ol, pentan-1-ol, hexan-1-ol, heptan-1-ol, octan-1-ol, heptan-2-ol, benzyl alcohol, 2-phenylethyl alcohol,

1-penten-3-ol, (*E*)-2-hexen-1-ol, (*E*)-3-hexen-1-ol, (*Z*)-3-hexen-1-ol, 1-octen-3-ol, (*E*)-2-octenol, 2-methylpropan-1-ol, 2-methylbutan-1-ol, 3-methylbutan-1-ol, 4-methylpentan-1-ol, 4-methylhexan-2-ol, 2-ethylhexanol, butane-2,3-diol, butane-1,3-diol, linalool, hotrienol, nerol, citronellol, geraniol, borneol, menthol, α-terpineol, β-terpineol, hydroxycitronellol, eucalyptol, terpinen-4-ol;
- 16 aldehydes: ethanal, pentanal, hexanal, heptanal, octanal, nonanal, benzaldehyde, phenylacetaldehyde, 2-methylpropanal, 3-methylbutanal, 2-methylbutanal, (*E*)-2-heptenal, (*E*)-2-octenal, (*E*)-2-hexenal, geranial, citral;
- 10 ketones: butan-2-one, propan-2-one, pentan-2-one, hexan-2-one, heptan-2-one, octan-2-one, nonan-2-one, 3-hydroxybutan-2-one, camphor, β-damascenone;
- 19 esters: methyl acetate, ethyl acetate, propyl acetate, butyl acetate, hexyl acetate, octyl acetate, (*Z*)-3-hexenyl acetate, phenylethyl acetate, methyl butyrate, ethyl butyrate, butyl butyrate, butyl propanoate, ethyl valerate, methyl hexanoate, ethyl hexanoate, ethyl octanoate, ethyl decanoate, methyl benzoate, ethyl benzoate;
- 4 heterocycles: (*Z*)-linalool oxide, (*E*)-linalool oxide, (*Z*)-rose oxide, nerol oxide;
- 6 hydrocarbons: (*Z*)-β-ocimene, limonene, α-terpinene, γ-terpinene, *o*-cymene, β-phellandrene; and
- 9 acids: acetic, propanoic, butanoic, hexanoic, octanoic, decanoic, 2-methylpropanoic, 3-methylbutanoic, 2-hydroxypropanoic acids.

Most of the compounds identified were previously detected in elderberries [5, 13].

As mentioned before, JENSEN et al. [12] divided the most important aroma compounds of the elderberries into six odour classes.

The characteristic elderberry odour is related to dihydroedulan, β-damascenone and ethyl-9-decenoate.

In the flowery group, (*Z*)- and (*E*)-rose oxide, nerol oxide, nonanal and hotrienol contribute significantly to elder flowery notes, whereas e.g. linalool, α-terpineol, benzyl alcohol, 2-phenylethyl alcohol and phenylacetaldehyde contribute to flowery notes [5, 12, 13].

The fruity odour of elderberry appears to be related to alcohols, aldehydes and esters of lower carboxylic acids and lower alcohols: in particular 2-methylpropan-1-ol, 2- and 3-methylbutan-1-ol, pentan-1-ol, pentanal, heptanal, octanal and methyl- and ethyl benzoate.

The grassy group is composed of aliphatic aldehydes and alcohols with typical odours of green grass: hexanal, hexan-1-ol, heptan-1-ol, octan-1-ol, (*E*)-2-hexen-1-al, (*Z*)-3-hexen-1-ol, (*E*)-3-hexen-1-ol, (*E*)-2-hexen-1-ol and (*E*)-2-octen-1-al [5, 13].

1-octen-3-one and 1-octen-3-ol with mushroom note and 3-hydroxybutan-2-one with creamy, buttery note belong to the agrestic group.

Benzaldehyde with its candy, sweet note could be placed to miscellaneous group, also lower carboxylic acids and ketones with creamy, oily or buttery odour.

Based on the olfactory evaluation compounds with characteristic elderberry odour are the most important, followed by fruity and flowery groups. The volatiles in the grassy group are important for the freshness of the elderberry [12].

On the basis of comparison to the literature (e.g. JENSEN et al. [12]; KAACK et al. [5]; KAACK [13]), compounds (*Z*)-3-hexen-1-ol, (*E*)-3-hexen-1-ol, (*E*)-2-hexen-1-ol, pentan-1-ol, hexan-1-ol, octan-1-ol, 2-phenylethyl alcohol, benzyl alcohol, 1-octen-3-ol, 2-methylbutan-1-ol, 3-methylbutan-1-ol, linalool, geraniol, α-terpineol, hotrienol, benzaldehyde, phenylacetaldehyde, pentanal, hexanal, heptanal, octanal, nonanal, (*E*)-2-hexenal, (*E*)-2-octenal, methyl acetate, ethyl acetate, butyl acetate, ethyl butyrate, ethyl octanoate, ethyl decanoate, (*Z*)-linalool oxide, (*Z*)-rose oxide, nerol oxide, (*Z*)-β-ocimene, β-damascenone and limonene were chosen as probably the most important components of the aroma of our samples, whose changes could express differences between cultivars. In particular these compounds were further monitored in samples of elderberry (Tab. 1A, 1B, 1C, 1D).

Comparison of volatile aroma compounds in elderberry cultivars

The volatile compounds of the samples were then compared in order to recommend the best cultivar with respect to the expected aroma properties. The comparison of the selected aroma compounds identified in cultivars is given in Tab. 1A, 1B, 1C, 1D, the comparison of the total content of compounds identified and the chemical groups of compounds is given in Tab. 2. The contents of the aroma compounds are expressed as micrograms (or milligrams) per kilogram of the sample. Differences among cultivars in the total content and chemical groups of aroma compounds, as well as in the case of single compounds, were observed in accordance with other authors [5, 7, 12, 13].

As can be seen from Tab. 2, the total content of aroma compounds was the significantly ($P < 0.05$)

Tab. 1A. Contents of selected aroma compounds in elderberry cultivars.

Aroma compounds [μg·kg^{-1}]	Cultivar of elderberries			
	Albida	Allesö	Aurea	Bohatka
Alcohols				
2-Methylbutan-1-ol	587.67 ± 6.21^{a}	495.82 ± 106.88^{ac}	182.79 ± 7.09^{a}	7475.17 ± 609.56^{bg}
3-Methylbutan-1-ol	317.11 ± 2.08^{a}	nd	nd	523.24 ± 3.35^{b}
Pentan-1-ol	173.79 ± 1.84^{a}	57.62 ± 14.74^{b}	385.74 ± 17.79^{c}	151.90 ± 17.23^{ad}
Hexan-1-ol	751.27 ± 12.59^{a}	194.46 ± 8.27^{b}	435.86 ± 9.43^{c}	454.70 ± 24.47^{c}
(*E*)-2-hexen-1-ol	21.38 ± 0.57^{a}	nd	1.32 ± 0.02^{b}	nd
(*E*)-3-hexen-1-ol	nd	nd	10.53 ± 0.04^{a}	nd
(*Z*)-3-hexen-1-ol	61.49 ± 9.21^{a}	231.24 ± 26.00^{b}	115.51 ± 6.18^{cd}	77.94 ± 15.35^{a}
Octan-1-ol	193.07 ± 0.82^{a}	nd	nd	59.07 ± 0.15^{b}
1-Octen-3-ol	213.77 ± 9.03^{a}	nd	nd	160.47 ± 9.13^{b}
Benzyl alcohol	1.02 ± 0.01^{a}	nd	nd	2.02 ± 0.01^{b}
Phenylethyl alcohol	1.23 ± 0.01^{a}	nd	2.89 ± 0.07^{b}	nd
Linalool	2.79 ± 0.03^{a}	nd	1.18 ± 0.01^{a}	21.72 ± 0.73^{b}
Geraniol	1.05 ± 0.04^{a}	4.89 ± 0.08^{b}	nd	4.02 ± 0.10^{c}
α-Terpineol	213.56 ± 0.57^{a}	nd	nd	2699.56 ± 20.57^{b}
Hotrienol	4.09 ± 0.08^{a}	5.78 ± 0.12^{b}	nd	6.03 ± 0.99^{bcd}
Aldehydes				
Pentanal	176.71 ± 2.63^{a}	nd	nd	39.71 ± 5.43^{b}
Hexanal	67.55 ± 2.24^{a}	nd	nd	19.05 ± 2.54^{b}
(*E*)-2-hexenal	386.21 ± 5.52^{a}	72.29 ± 28.78^{b}	479.00 ± 106.83^{a}	155.21 ± 8.17^{c}
Heptanal	10.51 ± 0.08^{a}	nd	nd	6.61 ± 0.03^{b}
Octanal	3.09 ± 0.02^{a}	nd	nd	nd
(*E*)-2-octenal	1.05 ± 0.76^{a}	nd	nd	1.03 ± 0.04^{a}
Nonanal	5.16 ± 0.01^{a}	nd	nd	1.06 ± 0.01^{b}
Benzaldehyde	61.54 ± 3.76^{a}	57.95 ± 5.74^{a}	nd	16.92 ± 2.62^{b}
Phenylacetaldehyde	104.78 ± 9.88^{a}	nd	nd	108.68 ± 1.82^{a}
Ketones				
β-Damascenone	518.25 ± 56.19^{a}	429.39 ± 34.88^{ab}	400.12 ± 44.47^{b}	465.12 ± 62.44^{ab}
Esters				
Methyl acetate	253.56 ± 14.53^{a}	2717.87 ± 870.85^{be}	776.91 ± 64.87^{c}	4863.50 ± 370.49d
Ethyl acetate	42.27 ± 3.14^{a}	348.85 ± 29.98^{b}	349.05 ± 43.79^{b}	3397.35 ± 54.99c
Ethyl butyrate	3.02 ± 0.17^{a}	2.04 ± 0.75^{b}	nd	nd
Butyl acetate	369.13 ± 6.90^{a}	315.02 ± 30.00^{a}	521.09 ± 64.61^{b}	6.13 ± 0.90f
Ethyl octanoate	nd	3.14 ± 0.12^{a}	nd	nd
Ethyl decanoate	nd	5.02 ± 1.00^{a}	3.56 ± 0.08^{b}	1.02 ± 0.17c
Heterocycles				
(*Z*)-rose oxide	2.14 ± 0.06^{a}	1.68 ± 0.44^{a}	8.34 ± 0.95b	3.35 ± 0.01c
(*Z*)-linalool oxide	4.02 ± 0.12^{a}	nd	1.44 ± 0.04b	4.13 ± 0.70a
Nerol oxide	3.13 ± 0.90^{a}	5.09 ± 0.61^{bd}	4.12 ± 0.44b	nd
Hydrocarbons				
(*Z*)-β-ocimene	nd	7.87 ± 0.85^{ae}	3.68 ± 0.44b	5.85 ± 0.04c
Limonene	3.56 ± 0.02^{a}	8.85 ± 0.98^{bf}	nd	2.42 ± 0.21c

The results are expressed as mean ± standard deviation (n = 9). Different superscript letters in the same row indicate significant statistical differences ($P < 0.05$). nd – not detected.

Tab. 1B. Contents of selected aroma compounds in elderberry cultivars.

Aroma compounds [$\mu g \cdot kg^{-1}$]	Cultivar of elderberries			
	Dana	Haschberg	Korsör	Mammut
Alcohols				
2-Methylbutan-1-ol	199.79 ± 5.09a	533.98 ± 34.39 ^{ae}	3 699.03 ± 11.77 ^{df}	3 306.06 ± 96.92 ^{cef}
3-Methylbutan-1-ol	248.44 ± 6.32a	414.06 ± 5.16 ^{c}	nd	9.12 ± 1.36 ^{d}
Pentan-1-ol	148.63 ± 12.74 ^{ad}	32.70 ± 2.02 ^{b}	119.65 ± 19.25 ^{dg}	179.63 ± 29.78 ^{a}
Hexan-1-ol	328.41 ± 8.27 ^{d}	383.77 ± 18.83 ^{de}	471.71 ± 53.18 ^{ce}	230.37 ± 2.51 ^{b}
(*E*)-2-hexen-1-ol	11.24 ± 0.51 ^{c}	6.47 ± 0.33 ^{d}	1.44 ± 0.13 ^{b}	nd
(*E*)-3-hexen-1-ol	8.21 ± 0.04 ^{a}	nd	19.82 ± 0.79 ^{b}	nd
(*Z*)-3-hexen-1-ol	101.46 ± 7.24 ^{d}	170.56 ± 10.41 ^{e}	275.83 ± 15.08 ^{b}	34.91 ± 1.59 ^{f}
Octan-1-ol	5.02 ± 0.31 ^{c}	142.88 ± 6.25 ^{d}	nd	nd
1-Octen-3-ol	12.72 ± 1.24 ^{c}	198.77 ± 11.67 ^{a}	nd	nd
Benzyl alcohol	5.03 ± 0.23 ^{c}	2.06 ± 0.43 ^{b}	nd	nd
Phenylethyl alcohol	1.26 ± 0.02 ^{a}	3.64 ± 0.64 ^{b}	nd	7.10 ± 1.03 ^{c}
Linalool	13.12 ± 1.53 ^{c}	nd	1.65 ± 0.10 ^{a}	nd
Geraniol	2.35 ± 0.45 ^{d}	nd	7.21 ± 1.47 ^{e}	2.65 ± 0.54 ^{df}
α-Terpineol	104.29 ± 3.57 ^{c}	161.79 ± 2.06 ^{d}	nd	nd
Hotrienol	5.88 ± 0.47 ^{bd}	2.76 ± 0.03 ^{e}	nd	nd
Aldehydes				
Pentanal	nd	13.08 ± 1.96 ^{c}	nd	6.34 ± 1.08 ^{d}
Hexanal	14.49 ± 1.46 ^{b}	2.15 ± 0.06 ^{c}	7.91 ± 0.07 ^{d}	nd
(*E*)-2-hexenal	49.08 ± 6.74 ^{b}	115.35 ± 1.40 ^{d}	nd	nd
Heptanal	9.21 ± 0.06 ^{c}	4.87 ± 0.03 ^{d}	nd	nd
Octanal	nd	2.09 ± 0.01 ^{b}	nd	nd
(*E*)-2-octenal	nd	nd	nd	nd
Nonanal	nd	5.17 ± 0.01 ^{a}	12.84 ± 0.78 ^{c}	nd
Benzaldehyde	4.12 ± 0.47 ^{c}	19.88 ± 1.69 ^{b}	nd	nd
Phenylacetaldehyde	5.33 ± 0.05 ^{b}	143.78 ± 5.38 ^{c}	nd	nd
Ketones				
β-Damascenone	31.75 ± 6.08 ^{c}	394.62 ± 4.23 ^{b}	240.83 ± 53.23 ^{d}	471.92 ± 1.38 ^{a}
Esters				
Methyl acetate	86.51 ± 3.86a	787.20 ± 21.02 ^{c}	3796.46 ± 161.69 ^{e}	2 792.17 ± 355.56 ^{b}
Ethyl acetate	394.35 ± 14.45b	348.20 ± 75.27 ^{b}	69 229.85 ± 370.00 ^{d}	1 489.90 ± 271.26 ^{c}
Ethyl butyrate	nd	nd	nd	nd
Butyl acetate	nd	nd	nd	nd
Ethyl octanoate	15.02 ± 1.00b	nd	nd	nd
Ethyl decanoate	5.47 ± 0.78a	nd	nd	nd
Heterocycles				
(*Z*)-rose oxide	6.46 ± 0.69d	2.00 ± 0.23 ^{a}	nd	4.24 ± 0.17 ^{e}
(*Z*)-linalool oxide	9.85 ± 0.09c	nd	7.79 ± 0.94 ^{d}	13.11 ± 0.90 ^{e}
Nerol oxide	2.62 ± 0.21a	nd	nd	nd
Hydrocarbons				
(*Z*)-β-ocimene	1.79 ± 0.09d	nd	nd	7.79 ± 0.94 ^{a}
Limonene	2.44 ± 0.32c	nd	6.78 ± 0.84 ^{be}	nd

The results are expressed as mean ± standard deviation (n = 9). Different superscript letters in the same row indicate significant statistical differences (P < 0.05). nd – not detected.

Tab. 1C. Contents of selected aroma compounds in elderberry cultivars.

Aroma compounds [μg·kg^{-1}]	Cultivar of elderberries				
	Pregarten	Riese aus Voβloch	Sambo	Sampo	Sambu
Alcohols					
2-Methylbutan-1-ol	3520.24 ± 1166.10 ^{df}	10071.90 ± 51.66 ^{g}	5576.26 ± 534.42 ^{bf}	32.62 ± 3.45 ^{a}	24.62 ± 1.40 ^{a}
3-Methylbutan-1-ol	402.14 ± 4.14 ^{c}	nd	nd	244.04 ± 13.27 ^{a}	4.87 ± 0.47 ^{d}
Pentan-1-ol	160.40 ± 41.19 ^{ad}	42.23 ± 9.17 ^{b}	120.41 ± 24.29 ^{dg}	536.94 ± 36.57 ^{e}	381.60 ± 97.17 ^{c}
Hexan-1-ol	236.92 ± 36.04 ^{b}	261.20 ± 4.32 ^{bd}	602.15 ± 7.55 ^{f}	104.69 ± 7.31 ^{g}	74.62 ± 1.40 ^{g}
(*E*)-2-hexen-1-ol	5.07 ± 0.06 ^{e}	2.57 ± 0.35 ^{b}	nd	nd	4.11 ± 0.24 ^{e}
(*E*)-3-hexen-1-ol	nd	25.22 ± 7.33 ^{b}	9.69 ± 0.48 ^{a}	11.75 ± 0.71 ^{a}	nd
(*Z*)-3-hexen-1-ol	55.97 ± 9.36 ^{a}	686.83 ± 47.44 ^{g}	133.01 ± 17.53 ^{hc}	62.40 ± 2.13 ^{a}	31.70 ± 9.72 ^{f}
Octan-1-ol	87.14 ± 2.83 ^{e}	nd	nd	121.40 ± 3.48 ^{df}	nd
1-Octen-3-ol	146.60 ± 5.27 ^{b}	nd	nd	393.94 ± 16.57 ^{d}	nd
Benzyl alcohol	nd	670.60 ± 35.11 ^{d}	nd	nd	nd
Phenylethyl alcohol	2.12 ± 0.51 ^{d}	nd	3.01 ± 0.43 ^{bd}	nd	nd
Linalool	9.75 ± 0.07 ^{c}	nd	nd	21.75 ± 0.71 ^{b}	nd
Geraniol	1.22 ± 0.03 ^{a}	1.48 ± 0.11 ^{a}	nd	nd	3.70 ± 0.72 ^{cf}
α-Terpineol	70.85 ± 2.36 ^{e}	nd	nd	264.89 ± 5.41 ^{f}	nd
Hotrienol	7.11 ± 0.89 ^{d}	4.57 ± 1.03 ^{ac}	nd	8.08 ± 1.36 ^{d}	nd
Aldehydes					
Pentanal	33.12 ± 2.08 ^{b}	nd	nd	81.72 ± 0.37 ^{e}	41.52 ± 2.37 ^{b}
Hexanal	81.33 ± 4.31 ^{e}	nd	nd	26.49 ± 0.74 ^{f}	nd
(*E*)-2-hexenal	24.06 ± 2.28 ^{e}	nd	nd	21.52 ± 0.13 ^{e}	nd
Heptanal	3.58 ± 0.89 ^{e}	nd	nd	7.15 ± 0.11 ^{f}	nd
Octanal	2.77 ± 0.86 ^{ab}	nd	nd	nd	nd
(*E*)-2-octenal	1.01 ± 0.03 ^{a}	nd	nd	1.02 ± 0.02 ^{a}	nd
Nonanal	1.38 ± 0.03 ^{d}	nd	nd	2.05 ± 0.21 ^{e}	nd
Benzaldehyde	12.75 ± 3.33 ^{b}	185.63 ± 30.21 ^{d}	17.94 ± 5.25 ^{b}	2.14 ± 0.02 ^{c}	nd
Phenylacetaldehyde	104.86 ± 3.46 ^{a}	nd	nd	152.14 ± 1.32 ^{c}	nd
Ketones					
β-Damascenone	282.41 ± 49.24 ^{d}	510.38 ± 44.82 ^{a}	nd	541.48 ± 74.92 ^{ae}	517.06 ± 44.82 ^{a}
Esters					
Methyl acetate	2738.63 ± 145.33 ^{b}	1031.04 ± 6.97 ^{c}	3239.29 ± 870.85 ^{be}	nd	9.49 ± 0.64 ^{f}
Ethyl acetate	33824.24 ± 239.17 ^{e}	2380.32 ± 437.86 ^{c}	147.80 ± 3.17 ^{b}	21.04 ± 0.03 ^{a}	nd
Ethyl butyrate	nd	nd	nd	nd	nd
Butyl acetate	1387.79 ± 48.94 ^{c}	nd	nd	169.15 ± 3.45 ^{d}	164.99 ± 3.45 ^{d}
Ethyl octanoate	nd	4.86 ± 0.47 ^{c}	nd	1.24 ± 0.02 ^{d}	4.74 ± 0.49 ^{c}
Ethyl decanoate	1.45 ± 0.01 ^{d}	nd	nd	1.08 ± 0.03 ^{c}	nd
Heterocycles					
(*Z*)-rose oxide	2.63 ± 0.03 ^{a}	6.70 ± 0.62 ^{bd}	nd	2.68 ± 0.16 ^{a}	2.93 ± 0.02 ^{ac}
(*Z*)-linalool oxide	nd	9.19 ± 0.85 ^{cd}	nd	2.32 ± 0.86 ^{b}	1.60 ± 0.31 ^{b}
Nerol oxide	1.15 ± 0.45 ^{c}	7.80 ± 1.17 ^{d}	6.15 ± 0.45 ^{d}	3.79 ± 0.94 ^{ab}	1.15 ± 0.22 ^{c}
Hydrocarbons					
(*Z*)-β-ocimene	1.04 ± 0.97 ^{d}	nd	1.44 ± 0.02 ^{d}	nd	9.92 ± 0.24 ^{e}
Limonene	2.32 ± 0.86 ^{c}	4.79 ± 0.54 ^{d}	6.08 ± 0.03 ^{e}	nd	nd

The results are expressed as mean ± standard deviation (n = 9). Different superscript letters in the same row indicate significant statistical differences (P < 0.05). nd – not detected.

Tab. 1D. Contents of selected aroma compounds in elderberry cultivars.

Aroma compounds [µg·kg^{-1}]	Cultivar of elderberries			
	Samdal	Samyl	Weihenstephan	Wild elder
Alcohols				
2-Methylbutan-1-ol	5220.53 ± 1348.57^{bf}	64.44 ± 3.81^{a}	101.16 ± 9.14^{a}	nd
3-Methylbutan-1-ol	nd	287.54 ± 23.47^{a}	260.16 ± 4.12^{a}	nd
Pentan-1-ol	33.40 ± 1.18^{b}	721.07 ± 60.96^{f}	28.79 ± 0.28^{b}	96.75 ± 8.22^{g}
Hexan-1-ol	457.29 ± 141.13^{cf}	181.37 ± 9.51^{b}	212.12 ± 36.04^{b}	161.25 ± 26.04^{b}
(*E*)-2-hexen-1-ol	nd	nd	nd	nd
(*E*)-3-hexen-1-ol	16.12 ± 4.07^{ab}	259.84 ± 17.12^{c}	nd	nd
(*Z*)-3-hexen-1-ol	153.97 ± 44.22^{cde}	406.40 ± 34.23^{i}	169.63 ± 26.04^{eh}	33.65 ± 5.13^{f}
Octan-1-ol	nd	98.04 ± 3.53^{ef}	39.23 ± 2.47^{b}	nd
1-Octen-3-ol	nd	141.65 ± 5.53^{be}	121.13 ± 6.14^{e}	nd
Benzyl alcohol	nd	nd	2.18 ± 0.29^{b}	nd
Phenylethyl alcohol	nd	2.07 ± 0.37^{d}	nd	nd
Linalool	nd	128.89 ± 5.22^{d}	22.53 ± 6.01^{b}	nd
Geraniol	5.02 ± 0.45^{b}	nd	3.45 ± 0.28^{f}	nd
α-Terpineol	nd	236.97 ± 4.37^{g}	380.05 ± 2.64^{h}	nd
Hotrienol	nd	2.56 ± 0.47^{e}	6.87 ± 1.37^{bd}	nd
Aldehydes				
Pentanal	nd	18.11 ± 2.56^{f}	19.05 ± 0.26^{f}	38.17 ± 2.16^{b}
Hexanal	nd	31.58 ± 1.36^{g}	14.30 ± 1.78^{b}	nd
(*E*)-2-hexenal	nd	22.68 ± 1.27^{e}	110.82 ± 9.14^{d}	111.47 ± 8.22^{d}
Heptanal	nd	7.17 ± 1.22^{bf}	3.13 ± 0.18^{e}	nd
Octanal	nd	nd	1.05 ± 0.08^{c}	4.97 ± 0.03^{d}
(*E*)-2-octenal	nd	2483.48 ± 171.16^{b}	nd	nd
Nonanal	nd	8.32 ± 1.26^{f}	5.01 ± 0.02^{a}	nd
Benzaldehyde	14.63 ± 0.87^{b}	15.69 ± 2.62^{b}	17.20 ± 3.67^{b}	90.42 ± 4.16^{e}
Phenylacetaldehyde	nd	68.13 ± 2.82^{d}	110.02 ± 4.58^{a}	nd
Ketones				
β-Damascenone	414.04 ± 113.83^{ab}	647.95 ± 97.40^{e}	329.73 ± 91.94^{bd}	329.04 ± 110.33^{bd}
Esters				
Methyl acetate	4448.73 ± 1404.30^{de}	18.25 ± 0.70^{a}	98.96 ± 4.84^{a}	597.24 ± 14.53^{c}
Ethyl acetate	57082.61 ± 1368.42^{f}	12.93 ± 4.02^{a}	31.44 ± 4.82^{a}	116.93 ± 4.11^{b}
Ethyl butyrate	nd	1.15 ± 0.22^{c}	nd	nd
Butyl acetate	nd	992.92 ± 27.24^{e}	180.24 ± 4.78^{d}	nd
Ethyl octanoate	nd	nd	nd	nd
Ethyl decanoate	nd	1.25 ± 0.23^{c}	1.65 ± 0.08^{d}	nd
Heterocycles				
(*Z*)-rose oxide	3.92 ± 0.24^{e}	6.29 ± 0.67^{d}	2.44 ± 0.82^{ac}	nd
(*Z*)-linalool oxide	nd	4.92 ± 0.24^{a}	7.20 ± 0.67^{d}	8.32 ± 0.12^{cd}
Nerol oxide	1.21 ± 0.20^{c}	nd	1.02 ± 0.58^{c}	3.04 ± 0.33^{a}
Hydrocarbons				
(*Z*)-β-ocimene	7.85 ± 1.06^{ae}	1.55 ± 0.25^{d}	9.32 ± 0.12^{e}	nd
Limonene	2.24 ± 0.61^{c}	9.92 ± 0.24^{f}	3.04 ± 0.33^{a}	7.32 ± 0.12^{b}

The results are expressed as mean ± standard deviation (n = 9). Different superscript letters in the same row indicate significant statistical differences ($P < 0.05$). nd – not detected.

Tab. 2. Contents of chemical groups of compounds in elderberry cultivars.

Elderberry cultivar	Aroma compounds							
	Alcohols [mg·kg^{-1}]	Aldehydes [mg·kg^{-1}]	Ketones [mg·kg^{-1}]	Esters [mg·kg^{-1}]	Acids [mg·kg^{-1}]	Heterocycles [μg·kg^{-1}]	Hydrocarbons [μg·kg^{-1}]	Total [mg·kg^{-1}]
Albida	$3\,854.56 \pm 204.63^{aA}$	5.15 ± 0.54^{aB}	1.08 ± 0.11^{aC}	0.66 ± 0.02^{aC}	14.38 ± 4.38^{adD}	9.03 ± 0.06^{aE}	3.56 ± 0.02^{aE}	$3\,876.69 \pm 204.67^{a}$
Allesö	$1\,006.63 \pm 120.65^{bjA}$	38.66 ± 3.12^{bB}	1.15 ± 0.18^{aC}	3.38 ± 0.20^{bC}	1.21 ± 0.08^{beC}	6.77 ± 0.44^{bD}	16.72 ± 0.80^{bD}	$1\,048.08 \pm 122.86^{b}$
Aurea	82.26 ± 2.14^{cA}	52.81 ± 5.31^{cfB}	0.71 ± 0.02^{bC}	1.66 ± 0.57^{cC}	2.03 ± 0.05^{bC}	13.9 ± 0.44^{cD}	3.68 ± 0.44^{adD}	136.04 ± 5.75^{c}
Bohatka	561.28 ± 47.24^{dA}	11.00 ± 1.64^{dB}	2.04 ± 0.56^{cfC}	8.26 ± 0.43^{dB}	1.76 ± 0.03^{bC}	7.48 ± 0.60^{bD}	8.27 ± 0.10^{cD}	585.67 ± 47.64^{d}
Dana	1.19 ± 0.02^{eA}	0.08 ± 0.01^{eB}	0.03 ± 0.01^{dC}	0.51 ± 0.03^{agD}	13.08 ± 0.45^{aE}	18.93 ± 0.20^{dC}	4.23 ± 0.13^{dF}	14.82 ± 0.02^{e}
Haschberg	71.43 ± 1.14^{cA}	60.15 ± 6.95^{fA}	1.08 ± 0.02^{aB}	1.14 ± 0.60^{acB}	2.38 ± 0.15^{bB}	2.06 ± 0.23^{eC}	nd	136.15 ± 7.07^{c}
Korsör	271.67 ± 27.27^{fA}	9.24 ± 0.02^{gB}	0.61 ± 0.02^{eC}	73.08 ± 0.53^{eD}	3.47 ± 0.28^{cE}	7.79 ± 0.94^{bfF}	6.78 ± 0.84^{eF}	358.04 ± 29.13^{f}
Mammut	$1\,112.29 \pm 83.66^{bgjA}$	26.08 ± 7.98^{hiB}	2.04 ± 0.58^{cfC}	4.28 ± 0.63^{bC}	3.79 ± 0.02^{cC}	17.35 ± 0.50^{gD}	7.79 ± 0.94^{ceD}	$1\,146.60 \pm 84.24^{b}$
Pregarten	$1\,197.00 \pm 29.22^{gA}$	40.24 ± 14.89^{bcfB}	1.48 ± 0.14^{cC}	36.58 ± 0.39^{fB}	17.38 ± 3.32^{dD}	3.78 ± 0.14^{hE}	3.36 ± 0.82^{adE}	$1\,294.05 \pm 36.02^{g}$
Riese aus Voßloch	823.27 ± 41.07^{hA}	18.60 ± 2.87^{hB}	1.75 ± 0.05^{fC}	3.45 ± 0.45^{bC}	3.14 ± 0.54^{cC}	23.69 ± 0.95^{iD}	4.79 ± 0.54^{dD}	849.03 ± 41.49^{h}
Sambo	713.15 ± 55.08^{iA}	5.47 ± 0.63^{aB}	0.45 ± 0.04^{gC}	3.41 ± 1.87^{bBD}	1.35 ± 0.24^{beD}	6.15 ± 0.45^{bkE}	7.52 ± 0.02^{eE}	721.17 ± 55.31^{i}
Sampo	$1\,043.40 \pm 108.30^{bjA}$	2.29 ± 0.10^{jB}	0.86 ± 0.12^{hC}	0.16 ± 0.01^{gC}	3.81 ± 0.03^{cB}	8.79 ± 0.86^{afD}	nd	$1\,051.08 \pm 108.31^{b}$
Sambu	$1\,044.33 \pm 118.87^{bjA}$	3.18 ± 0.43^{jB}	0.71 ± 0.02^{bC}	0.17 ± 0.01^{gC}	1.29 ± 0.04^{beC}	5.68 ± 0.22^{jkD}	9.92 ± 0.24^{fD}	$1\,047.57 \pm 118.89^{b}$
Samdal	680.52 ± 47.11^{iA}	9.11 ± 0.88^{dgB}	1.89 ± 0.04^{cfC}	61.53 ± 2.77^{hD}	1.30 ± 0.84^{eC}	5.13 ± 0.21^{jE}	10.09 ± 0.90^{fE}	754.21 ± 46.15^{i}
Samyl	$1\,182.31 \pm 108.56^{bgA}$	6.55 ± 0.70^{aB}	1.10 ± 0.06^{aC}	1.03 ± 0.03^{cC}	12.89 ± 0.71^{aD}	11.21 ± 0.32^{lE}	11.47 ± 0.23^{gE}	$1\,204.74 \pm 108.73^{bg}$
Weihenstephan	$1\,009.23 \pm 48.44^{jA}$	28.69 ± 5.29^{iB}	0.71 ± 0.08^{beC}	0.13 ± 0.04^{gC}	4.17 ± 2.08^{bcD}	10.66 ± 0.62^{lE}	12.36 ± 0.24^{hE}	$1\,041.83 \pm 48.77^{b}$
Wild elder	$2\,392.32 \pm 95.67^{kA}$	44.27 ± 6.22^{bcB}	0.72 ± 0.07^{bC}	0.71 ± 0.02^{aC}	2.25 ± 0.23^{bD}	11.36 ± 0.12^{lE}	7.32 ± 0.12^{eE}	$2\,437.48 \pm 96.14^{j}$

The results are expressed as mean ± standard deviation (n = 9). Different superscript letters in the same column (capital letter in the same row) indicate significant statistical differences (P < 0.05). nd – not detected.

highest in Albida cultivar and in wild elder, while the lowest in Aurea, Bohatka, Dana, Haschberg and Korsör cultivars.

Alcohols contributed the most to the aroma profile of all cultivars concerning the quantity (except Dana cultivar); they mostly created about 60–95% of the total content of aroma compounds. Albida cultivar and wild elder contained the significantly (P < 0.05) highest content of alcohols, which was in particular caused by quite high contents (> 10 mg·kg^{-1}) of methanol, ethanol, propan-2-ol and 2-methylpropan-1-ol. Although present in higher contents, these compounds are not considered as typical and important for characteristic elder aroma [12]. Aurea, Bohatka, Dana, Haschberg and Korsör cultivars had the lowest (P < 0.05) contents of alcohols.

Aldehydes were the second most abundant group of compounds; they contributed significantly (P < 0.05) to the aroma profile of Aurea and Haschberg cultivars. The high content of aldehydes was also found in cultivars Allesö, Pregarten and Weihenstephan, and in wild elder. This fact was caused by a particularly high content (> 20 mg·kg^{-1}) of ethanal, which is, however, also not considered as important for the elder aroma [12, 13].

Esters were the third important group, in particular in Korsör, Samdal and Pregarten cultivars. The contents of methyl- and ethyl acetate, and moreover butyl acetate in the case of Pregarten cultivar, were the highest (> 1 mg·kg^{-1}). Many esters were identified in various elder samples so far and they are known as important components of the elderberry aroma, contributing more precisely to its fruity note [5, 12, 13].

From the quantitative point of view, acids contributed particularly to the aroma profile of

Dana cultivar, because a surprisingly low content of alcohols was found in this cultivar. Further, Albida, Pregarten and Samyl cultivars contained higher contents of acids, in particular acetic acid (> 10 mg·kg^{-1}). This compound is also not considered as important for the elder aroma [12, 13].

Significantly (P < 0.05) lower contents of ketones, heterocycles and hydrocarbons, compared to the above mentioned groups, were found in all cultivars (Tab. 2). Bohatka, Mammut, Riese aus Voßloch and Samdal cultivars had the highest contents of ketones, in particular propan-2-one (> 0.2 mg·kg^{-1}), which is not important for the elder aroma, and β-damascenone (> 0.4 mg·kg^{-1}), which is related to the characteristic elderberry odour [5, 12, 13]. (Z)-β-ocimene and limonene were the most abundant hydrocarbons, present in a range 1–10 μg·kg^{-1}, except Haschberg and Sampo cultivars, where no hydrocarbons were identified. These two compounds were also identified by several authors as important in elderberries [5]. (Z)-rose oxide, (Z)-linalool oxide and nerol oxide were the most abundant heterocycles, present in a range 1–14 μg·kg^{-1}. (Z)-rose oxide and nerol oxide are considered to contribute to elder aroma with elder flower notes [5, 12, 13].

The most surprising finding was that wild elder had the second highest content of aroma compounds, which was similar to Kaack [9], who compared extracts from wild and cultivated elder flowers. Wild elderberries have markedly bitter, sour and astringent taste and a mild, not intense aroma. They are cultivated to reach, among others, better taste and aroma. Therefore, a much richer and more varied aroma profile could be expected in the cultivated types. However, we should take into consideration that several volatile compounds identified were present in relatively high contents but probably are not so necessary for the typical aroma of elderberries. On the other hand, compounds that are known as significant components of the elderberry aroma, were found in very low contents. This is in accordance with the well established concept of aroma value of the compound, which is calculated by dividing the content of the compound in a food by its odour threshold (e.g. acquired from the literature). Compounds with higher aroma values (lower threshold values) are considered as contributing to the aroma [24]. The higher total content of volatile aroma compounds does not necessary mean a more intense aroma of the sample.

Concerning single selected aroma compounds (Tab. 1), only pentan-1-ol, hexan-1-ol and (Z)-3-hexen-1-ol were present in all cultivars.

β-damascenone as a contributor to the typical elderberry aroma [5, 13] was identified in all cultivars except Sambo. Dihydroedulan and ethyl-9-decenoate, also known as components of the elderberry aroma [5, 13], were not present in our samples.

In the group of compounds with elder flower note [12], (Z)-rose oxide, nerol oxide, nonanal, hotrienol and (Z)-linalool were compared, and their contents in various cultivars were found to be in the range about 5–10 μg·kg^{-1}.

From the flowery group [12], (Z)-β-ocimene, geraniol, benzyl alcohol and 2-phenylethyl alcohol were present in contents 1–8 μg·kg^{-1}, with the exception of Riese aus Voβloch cultivar, which contained a significantly (P < 0.05) high amount of benzyl alcohol (670.60 ± 35.11) μg·kg^{-1}. Linalool was present at contents 5–15 μg·kg^{-1}, except for Samyl cultivar (128.89 ± 5.22) μg·kg^{-1}. Phenylacetaldehyde (100–120 μg·kg^{-1}) and α-terpineol (200–300 μg·kg^{-1}) were the most abundant in this group, in particular cultivar Bohatka contained a significantly (P < 0.05) high amount of α-terpineol (2.69 ± 0.02) mg·kg^{-1}.

Esters are mainly responsible for the fruity note of elderberry [12]. Several esters were followed (Tab. 1), methyl acetate (1–4 mg·kg^{-1}) and ethyl acetate, in particular in Korsör (69.23 ± 0.37) mg·kg^{-1}, Pregarten (33.82 ± 0.24) mg·kg^{-1} and Samdal (57.08 ± 1.37) mg·kg^{-1} cultivars, were the most important. Several aldehydes from this group were identified, heptanal and octanal (3–8 μg·kg^{-1}) and pentanal (20–40 μg·kg^{-1}) with significantly high (P < 0.05) content in Albida (176.71 ± 2.63) μg·kg^{-1}. Pentan-1-ol (100–400 μg·kg^{-1}), 3-methylbutan-1-ol (200–500 μg·kg^{-1}) and 2-methylbutan-1-ol (100–3 000 μg·kg^{-1}) with significantly (P < 0.05) high content in cultivars Bohatka (7.48 ± 0.61) mg·kg^{-1} and Riese aus Voβloch (10.07 ± 0.05) mg·kg^{-1}, were the most important alcohols in this group.

Regarding the important aldehydes from grassy group [12], hexanal was present mainly in cultivars Albida (67.55 ± 2.24) μg·kg^{-1} and Pregarten (81.33 ± 4.31) μg·kg^{-1}; (E)-2-hexen-1-al in cultivars Albida (386.21 ± 5.52) μg·kg^{-1} and Aurea (479.00 ± 106.83) μg·kg^{-1}. The important alcohols from grassy group [12] hexan-1-ol, octan-1-ol and (Z)-3-hexen-1-ol were present in the range about 100–500 μg·kg^{-1}, (E)-3-hexen-1-ol in particular in Samyl cultivar (259.84 ± 17.12) μg·kg^{-1}.

The last two groups of compounds are probably not necessary for the typical aroma of elderberry [5, 12, 13]. 1-octen-3-ol belonging to the agrestic group was present in contents about 150–400 μg·kg^{-1}, 1-octen-3-one, albeit known as

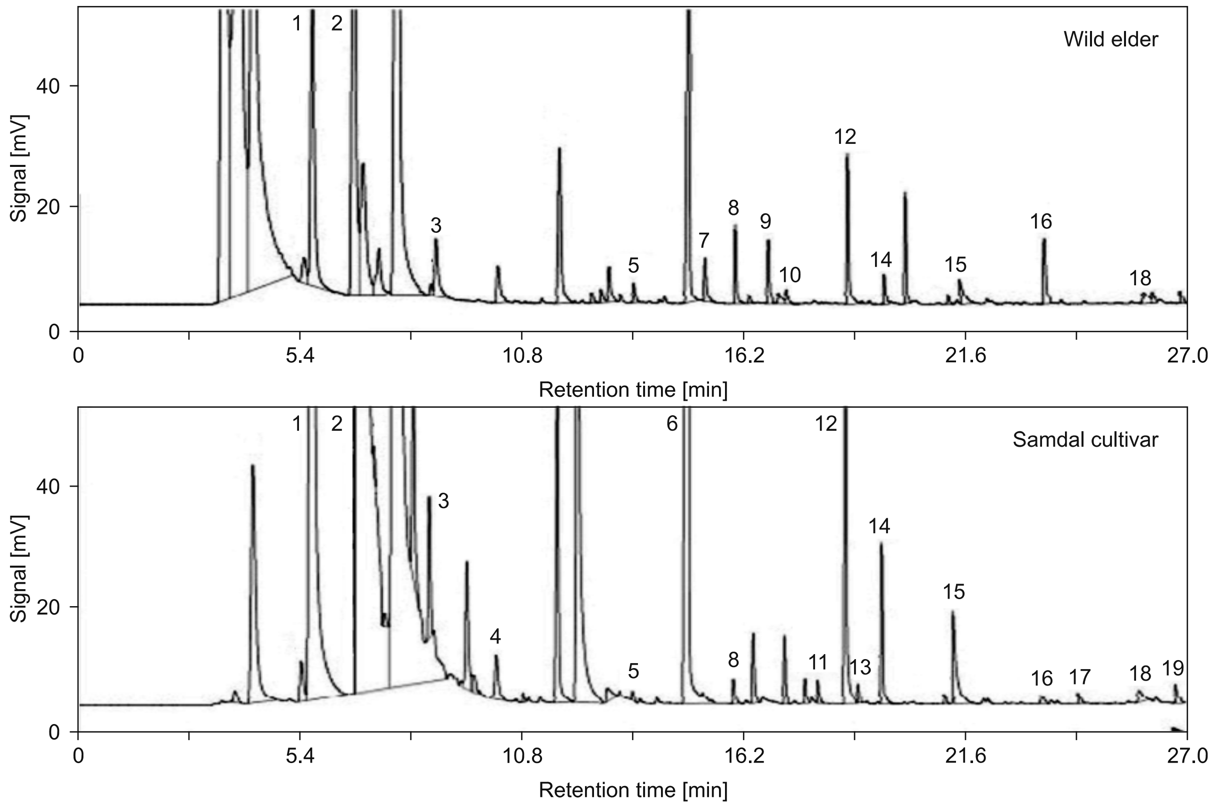

Fig. 1. Chromatograms of selected aroma compounds in wild elder (upper) and Samdal cultivar (lower).

Peak designation: 1 – methyl acetate, 2 – ethyl acetate, 3 – pentanal, 4 – ethyl butyrate, 5 – limonene, 6 – 2-methylbutan-1-ol, 7 – (*E*)-2-hexenal, 8 – pentan-1-ol, 9 – octanal, 10 – (*Z*)-linalool oxide, 11 – (*Z*)-rose oxide, 12 – hexan-1-ol, 13 – (*E*)-3-hexen-1-ol, 14 – (*Z*)-3-hexen-1-ol, 15 – nerol oxide, 16 – benzaldehyde, 17 – geraniol, 18 – β-damascenone, 19 – (*Z*)-β-ocimene.

the member of this group [5, 12], was not identified in our samples. Benzaldehyde, placed to miscellaneous group [12], was present in contents about 20–50 $\mu g \cdot kg^{-1}$, except for the cultivar Riese aus Voβloch (185.63 ± 30.21) $\mu g \cdot kg^{-1}$.

Taking into consideration the highest total content of the selected compounds, which are known to be involved in the aroma of elderberry [5, 12, 13], we could recommend Korsör (77.89 ± 3.57) $mg \cdot kg^{-1}$, Pregarten (43.20 ± 7.14) $mg \cdot kg^{-1}$ and Samdal (67.85 ± 8.22) $mg \cdot kg^{-1}$ cultivars for possible practical use.

For illustration, the chromatogram of compounds identified in Samdal cultivar is presented in Fig. 1, compared to a chromatogram of wild elderberry. Although the total content of volatile compounds in wild elder was high (Tab. 2), a lower number of selected compounds was present in lower quantities, with the lowest ($P < 0.05$) total content (1.59 ± 0.03) $mg \cdot kg^{-1}$ of them.

CONCLUSION

Although several articles about aroma profile of elder berries have been published up to now, this work is focused on selected cultivars intended to be grown in Czech Republic. One-hundred-and-two volatile compounds were identified; alcohols, aldehydes and esters being the most abundant. Thirty-six from the identified compounds were followed as possible components of the aroma. Taking into consideration the highest contents of these compounds, three promising cultivars (Korsör, Pregarten and Samdal) from the sixteen tested were recommended for growing on a large scale.

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