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The lipid fraction of seeds from *Salvia columbariae* grown in Arizona

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RESEARCH ARTICLE

Abstract

The oil contents and the composition of fatty acids and tocopherols of sixteen samples from *Salvia columbariae* collected in Arizona were investigated. The samples are characterised by high oil content ranging from 19.2 to 36.5 g/100 g with α-linolenic acid as main fatty acid (59.4 to 65.7 g/100 g). The seeds contain linoleic acid (15.9 to 20.9 g/100 g) and oleic acid (8.5 to 10.7 g/100 g) as well as palmitic and stearic acid in remarkable amounts. The 18:3/18:2 ratio could be an interesting chemotaxonomic feature to differentiate *S. columbariae* from other members of the genus *Salvia.* The content of vitamin E active compounds ranged from 82.8 to 536.5 mg/kg, mainly dominated by γ-tocopherol. From the composition of fatty acids and vitamin E active compounds, it can be suggested that seeds and seed oil from *S. columbariae* may constitute high-value products for healthy nutrition.

Keywords: chemotaxonomy, fatty acid composition, nutritional value, *Salvia columbariae*, vitamin E active compounds

1. Introduction

Salvia columbariae is also called golden chia or desert chia. The plant is annually growing mainly in southern parts of America and belongs to the family Lamiaceae. The family is one of the most diverse and widespread plant families in terms of ethnomedicine because of the volatile oil in many species (Coelho de Souze and Elisabetsky, 1998). It comprises about 230 genera with more than 5,000 species and about 900 species belong to the genus *Salvia* (Standley and Williams, 1973).

The seeds from *S. columbariae* are popular with the Chumash, native American people historically living in the central and southern coastal regions of California. It is known that Chumash messengers ate the seeds to maintain their energy when running 30 km and more per day (Adams *et al.*, 2005). The roots of another species, *Salvia miltiorrhiza*, are used in the treatment of stroke (Ji *et al.*, 2000). The preventing compounds are tanshinones, cryptotanshinone and miltionones, which are able to avoid clotting and stabilise blood flow (Chan, 2001; Lei and Chiou, 1986). Adams *et al.* (2005) also found these compounds in *S. columbariae*, with more cryptotanshinone and less tanshinone IIA than in *S. miltiorrhiza*.

Especially the lipid fraction has some importance because it contains the highest energy content of all nutrients. The main part of the lipid fraction comprise of triacylglycerols which contain three fatty acids bond to a glycerol molecule. Additionally to the triacylglycerols the lipid fraction contains also vitamin-E-active compounds, like tocopherols, tocotrienols or 8-plastochromanol, which have some nutritional importance. In nature four different derivatives of tocopherols and tocotrienols (alpha-, beta- gamma- and delta-) can be found, differing in the methylation of the chroman ring. The antioxidant activity increases for tocopherols and tocotrienols in the order alpha to delta at room temperature, whereas the biological activity is inversely proportional to the antioxidant activity (Papas, 1993; Pongracz *et al.*, 1995). Plastochromanol-8 is a related compound that is more effective against oxidation than α-tocopherol (Olejnik *et al.*, 1997).

Knowing more about the fatty acid and tocopherol composition of seed oils can be very useful, because the search for new and sustainable sources for fats and oils is an ongoing story. On the other side it is known that the fatty acid and tocopherol composition have some taxonomic relevance which can help to classify plant genera and species (Aitzetmüller, 1993; Velasco and Goffman, 1999). The high content of α-linolenic acid in seed oil from *S. columbariae* is also interesting from a nutritional point of view because a growing population needs more fats and oils with high contents of omega-3 polyunsaturated fatty acids (Gogus, 2010). In most countries, the consumption of fresh fish has declined over the past 20 years resulting in an undersupply with essential long-chain omega-3-fatty acids. In common used oils, such as rapeseed oil, walnut oil, soybean oil or even linseed oil, higher amounts of shorter-chain omega-3-fatty acids like α-linolenic acid can be found. Thus, such plant oils can help to increase the supply with these important omega-3-fatty acids.

About 600 datasets showing the fatty acid composition of members of the family *Lamiaceae* are available in the internet-based database 'Seed oil fatty acids' (Matthäus, 2012), but only two datasets give some information about the composition of S. *columbariae*, although the seeds are an important constituent of the nutrition of native Americans.

Therefore the aim of the present work was to characterise different samples of seeds from *S. columbariae* from different locations in Arizona to get more information about the fatty acid and tocopherol composition. This helps to evaluate the nutritional value of the seeds regarding the lipid fraction and to get some more information about the taxonomic value of these constituents for the classification of the plant within the genera.

2. Materials and methods

Plant material

Seeds from 16 samples of *Salvia columbariae* were collected in Arizona in 2011 (Table 1). After collection, the seeds were cleaned from dust and foreign matter. They were stored dry at 15 °C until investigation.

Reagents

Petroleum ether (boiling point 40-60 °C) (Merck, Darmstadt, Germany) was of analytical grade (>98% purity) and heptane as well as tert-butyl methyl ether were of HPLC grade (Merck). Tocopherol and tocotrienol standard compounds were purchased from CalBiochem (Darmstadt, Germany).

Oil content

The oil content was determined according to the method ISO 659:2009 (ISO, 2009). Depending on the available material between 0.5000 and 2.0000 g of the seeds were ground in a ball mill (Dangoumau; Prolabo, Paris, France) and extracted with 70 ml petroleum ether in a Twisselmann apparatus (VWR, Darmstadt, Germany) for 6 h. The solvent was removed with a rotary evaporator (Büchi Labortechnik GmbH, Essen, Germany) at 40 °C and 25 Torr. The oil was dried by a stream of nitrogen and stored at -18 °C until use. The repeatability standard deviation s_r was 1.54 g/100 g, according to the standard method validation data.

Fatty acid composition

The gas chromatographic determination (GLC) of fatty acid methyl esters (FAME) followed the ISO draft standard ISO/FDIS 5509:2000 method (ISO, 2000). In brief, one drop of the oil was dissolved in 1 ml of *n*-heptane, 50 µg of sodium methylate was added, and the closed tube was agitated vigorously for 1 min at room temperature. After addition of 100 µl of water, the tube was centrifuged at 4,500×*g* for 10 min and the lower aqueous phase was removed. Then 50 µl of HCl (1 mol/l mixed with methyl orange) was added, the solution was shortly mixed, and the lower aqueous phase was rejected. About 20 mg of sodium hydrogen sulphate (monohydrate, extra pure; Merck) was added, and after centrifugation at 4,500×*g* for 10 min, the top n-heptane phase was transferred to a vial and injected in a Agilent 6890 gas chromatograph with KAS4 Plus and FID detector. Separation took place at a capillary column, CP7420 (100 m long, 0.25 mm ID, film thickness 0.25 µm; Agilent Technologies Deutschland GmbH, Böblingen, Germany).

The temperature programme was as follows: from 150 to 240 °C with 1.5 °C/min, after reaching 240 °C 20 min isotherm. Other settings were: injector: 260 °C, detector: 260 °C; carrier gas: 36 cm/s hydrogen; split ratio: 1:50; detector gas: 30 ml/min hydrogen; 400 ml/min air and 25 ml/min nitrogen, manual injection volume less than 1 µl.

The peak areas were computed by the integration software, and percentages of FAME were obtained as weight percentage by direct internal normalisation.

s_r for the major fatty acids palmitic acid, stearic acid, oleic acid and linoleic acid was 0.09, 0.04, 0.08 and 0.12 g/100 g, respectively, according to the standard method validation data.

Table 1. Origin and oil content (%) of different seeds from *Salvia columbariae*.

Sample number	Origin/location/height	Oil content (%)[1]
1	Arizona, La Paz, East of Highway (Hwy) 95 along the Bill Williams Highway (34.10611932; -11412185669; 275 m)	29.2[bc]
2	Arizona, Yavapai County, Northwest of Rock Springs along the Black Canyon Trail, ca 1-1/2 miles from trailhead and west of Horseshoe Bar (34.0411446; -112.154604; 561 m)	30.5[bc]
3	Arizona, Maricopa, New River, 1114 W Circle Mountain Road (33.885334; -112.087575; 648 m)	33.9[cd]
4	Arizona, Maricopa County, Southeast end of Harquahala Mountains, in desert wash northwest of Eagle Eye Road (33.78185826; -113.24552536; 638 m)	19.2[a]
5	Arizona, Yavapai County, Tonto National Forest, just to the SE of Agua Fria National Monument, on a SSE facing ridge at the junction of Squaw Creek and the North Fork of Squaw Creek (34.08792399; -112.10861206; 633 m)	33.7[cd]
6	Arizona, Maricopa, Tonto National Forest, just north of Spur Cross on Cave Creek trail #4 (33.8871791; -111.951799; 713 m)	30.3[b]
7	Arizona, Maricopa, Route 88, 1.8 miles W of Apache Lake Camp Ground Rd. (33.57426047; -111.25242949; 596 m)	36.5[d]
8	Arizona, Maricopa, Route 88, 1.3 miles W of Burnt Corral Campground Rd.; overlooking Apache Lake to the north and ca. 6 miles W Rosevelt Dam (33.62662677; -111.20494366; 580 m)	35.6[d]
9	Arizona, Gila County, 7.3 mi. S of Hwy 87 on Hwy 188 and 0.4 mi. W of Hwy 188 on pioneer Pass Rd, between Jake's Corner and Punkin Center (33.98208626; -111.31896973; 823 m)	29.4[bc]
10	Arizona, Gila, Hwy 88 between Lake Roosevelt and Globe, just south of jct. Hwy 288 and 88 (33.535027; -110.924335; 1,050 m)	32.3[c]
11	Arizona, Pinal, Ca. 2 miles south of Superior; Apache Leap Trail, east of Hwy 177 and FS Rd 257 (33.266216; -111.086759; 946 m)	30.4[bc]
12	Arizona, Pinal, Hwy 60, between Florence Junction and Superior; ca. 6.5 miles W of Rte 177 (33.24787595; -111.34231567; 557 m)	28.6[bc]
13	Arizona, Yavapai County, Ca. 4 miles NE of Wickenberg along Constellation Rd (34.0003043; -112.66462326; 819 m)	28.5[b]
14	Arizona, Yavapai County, 5.6 miles NE of Maricopa/Yavapai county line along Constellation Rd; ca. 7.5 miles NE of Wickenberg (34.0386196; -112.6208179; 976 m)	27.1[b]
15	Arizona, Maricopa County, 4.4 miles SW of Hwy SR60 on Vulture Mine Rd; SW of Wickenberg (34.0489281; -111.0937311; 1,541 m)	27.9[b]
16	Arizona, Mohave, ca. 7 miles W of Hwy 93 on Hwy 131 (Chicken Springs Rd.) (34.6791775;-113.6959819; 1,036 m)	31.5[c]
	Mean value	30.3

[1] Values bearing different superscript letterss are significantly different ($P<0.05$).

Vitamin E-active compounds

Vitamin E active compounds (tocopherols, tocotrienols and plastochromanol-8) were determined according to the method DGF-F-II 4a (00) (DGF, 2011). In brief, a solution of 250 mg oil in 25 ml heptane was used for high-pressure liquid chromatography (HPLC). The HPLC analysis was conducted using a Merck-Hitachi low pressure gradient system, fitted with a L-6200A pump, a Merck-Hitachi F-2485 fluorescence spectrophotometer (detector wavelengths for excitation 295 nm, for emission 330 nm) and a ChemStation integration system (Agilent Technologies Deutschland GmbH). Twenty microliters of the samples were injected by a Spark Holland Basic Marathon autosampler (Spark Holland B.V., Emmen, the Netherlands) onto a diol phase HPLC column (25 cm × 4.6 mm ID; Merck), used with a flow rate of 1.3 ml/min. The mobile phase used was heptane/tert-butyl methyl ether (99+1, v/v). s_r for the major γ-tocopherol isomer was 7.1 mg/kg according to the standard method validation data.

Statistical analysis

Student's t-test to evaluate the statistical significance for independent and variables interactions was performed with two-tailed t-tests at $P=0.05$. The data were evaluated using a computer programme (Statgraphics, Rockville, MD, USA).

Each method was carried out in triplicate for each sample. The mean values are given in the tables, without the standard deviation, because this value would represent only the deviation of the method and not the variation of the appropriate sample.

3. Results and discussion

Oil content

Sixteen samples from *S. columbariae* were investigated regarding the oil content as well as the composition of fatty acids and tocopherols (Table 1). The seeds from *S. columbariae* are characterised by an oil content ranging from 19.2 g/100 g (sample 4) to 36.5 g/100 g (sample 7) with an average content of 30.3 g/100 g. Besides sample 4, all samples contained at least 27.1 g oil/100 g sample material. The variation of the oil content of the samples is relatively low showing that this characteristic feature of *S. columbariae* is relatively stable. Ayerza and Coates (2007) investigated seeds of *S. columbariae* and found only 21 g oil /100 g in the seeds, remarkable lower than in seeds of *Salvia hispanica* (29.9 g/100 g). This high oil content, comparable or even higher than for soybeans (20 g/100 g) but lower than for rapeseed (40 g/100 g) would justify from an economical point of view the use of seeds from *S. columbariae* for the production of high-quality edible oil.

Fatty acid composition

The fatty acid composition of *S. columbariae* is dominated by a high content of α-linolenic acid which was found in amounts between 59.4 (sample 7) and 65.7 g/100 g (sample 3) with an average content of 62.7 g/100 g (Table 2). Within the genus *Salvia* the content of α-linolenic acid is highest in the specie *S. columbariae* published up to now. Bagci *et al.* (2004) investigated different species of the genus and showed amounts for α-linolenic acid ranging from 0.8% (*Salvia euphratica*) to 55.5% (*Salvia virgata*) with an average amount of 20.2% for 11 species of the genus *Salvia*.

Additionally to α-linolenic acid, the seeds contain between 15.9 (sample 12) and 20.9 g/100 g (sample 7) linoleic acid (average 18.4 g/100 g) and between 8.5 (sample 15) and 10.7 g/100 g (sample 7) oleic acid (average 9.8 g/100 g). The authors of the above mentioned study on the fatty acid composition of different species of the genus *Salvia* suggested to differentiate the samples into three groups (Bagci *et al.*, 2004) with: (1) high in linoleic acid (>50%) and very low in linolenic acid (<10%); (2) high in linolenic acid and low in linoleic acid; and (3) medium in linolenic acid and linoleic. According to this classification, *S. columbariae* belongs together with *Salvia limbata* (28.1% linoleic acid and 40.8% linolenic acid) and *S. virgata* (22.9 and 55.5%) to the second group with a high content of linolenic acid and a low amount of linoleic acid. Additionally to the two species from the publication of Bagci *et al.* (2004), the seed oil fatty acids database contains 24 species of the genus *Salvia* with a content of α-linoleic acid higher than 50% and still 3 species with amounts ranging from 61.8% (*Salvia sclerea*) (Ferlay *et al.*, 1993) to 69.0% (*S. hispanica*) (Taga *et al.*, 1984).

Table 2. Fatty acid composition (g/100 g) of different seeds from *Salvia columbariae*.

Sample number	Palmitic acid (16:0)	Stearic acid (18:0)	Oleic acid (18:1n-9)	*cis*-Vaccenic acid (18:1n-7)	Linoleic acid (18:2n-6)	Arachidic acid (20:0)	γ-Linolenic acid (18:3D6,9,12)	α-Linolenic acid (18:3D9,12,15)	Ratio 18:3/18:2
1	4.9^{d}	2.3^{f}	9.9^{ef}	$1.0b^{c}$	18.6^{f}	0.2	0.3	62.0^{e}	3.3
2	4.6^{bc}	2.1^{d}	10.4^{g}	0.9^{b}	20.8^{j}	0.2	0.3	59.9^{b}	2.9
3	4.6^{bc}	2.0^{c}	9.1^{bc}	1.1^{c}	16.2^{b}	0.2	0.3	65.7^{i}	4.0
4	4.6^{bc}	2.2^{e}	9.6^{d}	0.2^{a}	17.7^{d}	0.2	0.3	62.8^{e}	3.5
5	5.2^{ef}	2.0^{c}	9.0^{b}	1.2^{cd}	20.1^{h}	0.2	0.3	61.3^{c}	3.1
6	4.6^{bc}	2.1^{d}	10.5^{g}	1.0^{bc}	19.9^{h}	0.2	0.4	60.9^{c}	3.1
7	4.7^{c}	2.2	10.7^{h}	1.0^{bc}	20.9^{i}	0.2	0.4	59.4^{a}	2.8
8	5.1^{e}	1.8^{a}	9.8^{e}	1.3^{d}	18.8^{fg}	0.2	0.3	62.3^{d}	3.3
9	4.7^{c}	2.2^{e}	9.8^{e}	1.0^{bc}	17.9^{de}	0.2	0.3	63.3^{f}	3.5
10	4.9^{d}	1.9^{b}	9.2^{c}	1.1^{c}	18.9^{g}	0.2	0.3	62.9^{f}	3.3
11	4.7^{c}	2.1^{d}	9.7^{de}	0.9^{b}	16.6^{c}	0.2	0.4	64.7^{h}	3.9
12	5.0^{de}	2.1^{d}	10.0^{f}	1.0^{bc}	15.9^{a}	0.2	0.3	65.0^{h}	4.1
13	5.0^{de}	2.1^{d}	10.4^{g}	1.0^{bc}	16.6^{c}	0.2	0.3	63.9^{g}	3.8
14	4.5^{b}	2.0^{c}	9.0^{b}	0.9^{b}	18.0^{e}	0.2	0.3	64.3^{gh}	3.6
15	5.2^{ef}	2.1^{d}	8.5^{a}	1.1^{b}	18.9^{g}	0.2	0.3	63.0^{f}	3.3
16	4.1^{a}	2.1^{d}	10.4^{g}	1.0^{bc}	18.8^{fg}	0.2	0.3	61.9^{cd}	3.3
Mean value	4.8	2.1	9.8	1.0	18.4	0.2	0.3	62.7	3.4

Values in the same column bearing different superscript letters are significantly different (P<0.05). If no superscript letters are given within a column there was no statistical significant difference between the samples (P≥0.05).

Another interesting chemotaxonomic feature is the ratio between α-linolenic and linoleic acid, used by Kilic *et al.* (2007) to classify species of *Salvia*. The authors found a good agreement of this characteristic feature with the classification into seven subgroups according to the 'Flora of Turkey' using some botanical features like shapes of leaves or colour of corolla. The 18:3/18:2 ratio was found for the different species to be between 0.01 and 2.64. In the present publication the 18:3/18:2 ratio for *S. columbariae* ranged from 2.9 to 4.1 with an average of 3.4 which is remarkable higher than for most of the other species of the genus *Salvia*.

The total amount of unsaturated fatty acids in the seed oil of *S. columbariae* was in a very narrow range between 90.1 (sample 4) and 91.3 g/100 g (sample 14) with an average content of 90.9 g/100 g. This shows that the total content of unsaturated fatty acids is a very stable characteristic feature for *S. columbariae*. The main saturated fatty acids found in *S. columbariae* seed oil are palmitic and stearic acid with an average content of palmitic acid of 4.8 g/100 g and stearic acid of 2.1 g/100 g. In literature only little information about the fatty acid composition of *S. columbariae* seeds is available, but the results of the present work agree with the data from Hagemann *et al.* (1967) and Ayerza and Coates (2007).

The high content of α-linolenic acid makes seed oil from *S. columbariae* interesting from a nutritional point. α-linolenic acid belongs to the group of omega-3-fatty acids for which a positive effect on coronary heart diseases and inflammatory processes has been shown. Additionally they prevent the platelets in blood from clumping, act vasodilative, reduce blood pressure and improve flow characteristics of blood (Bucher *et al.*, 2001; De Lorgeri and Salen, 2004; Djoussé *et al.*, 2005; Galli and Calder, 2009; Mozaffarian, 2005; Simopoulos, 2008). Especially for inflammatory processes it can be helpful to have higher intake of omega-3-fatty acids. Important for the positive effect on heart and blood vessels is also the ratio between omega-6 and omega-3 fatty acids which is recommended to be between 4:1 and 5:1 (Simopoulos, 2008). In seed oil from *S. columbariae* this ratio is 1:3. Since in western style diets the ratio is 15:1 or even higher the oil can be a good source to shift this ratio to a more favourable value.

Another important point is the low content of saturated fatty acids (7.1 g/100 g) in oil from seeds of *S. columbariae*. Saturated fatty acids are suspected to be responsible for an increased risk for cardiovascular diseases (Mensink *et al.*, 2003; Siri-Tarino *et al.*, 2010). The content of saturated fatty acids in *S. columbariae* seed oil is as low as in rapeseed oil but remarkable lower than for soybean oil (14 g/100 g) or olive oil (14 g/100 g).

Vitamin E active compounds

Vitamin E active compounds can be found in all common used edible vegetable oils in varying amounts. The total content of vitamin E active compounds of *S. columbariae* seed oil was found between 82.8 and 536.5 mg/kg with

Table 3. Composition of the vitamin E active compounds (mg/kg) of different seeds from *Salvia columbariae*.

Sample number	α-tocopherol	α-tocotrienol	γ-tocopherol	Total amount
1	34.9^{d}	15.0^{a}	324.5^{gh}	374.4
2	35.4^{d}	16.1^{a}	258.1^{e}	309.6
3	34.7^{d}	16.7^{a}	240.3^{d}	291.7
4	54.1^{f}	24.7^{b}	4.0^{a}	82.8
5	25.2^{cd}	128.8^{f}	308.3^{g}	462.2
6	41.2^{e}	214.4^{i}	281.0^{ef}	536.5
7	37.9^{e}	192.6^{h}	13.9^{a}	244.4
8	28.3^{d}	149.8^{g}	65.8^{b}	243.9
9	22.3^{bcd}	107.9^{e}	206.5^{c}	336.7
10	20.6^{abc}	99.9^{e}	314.8^{g}	435.3
11	24.2^{cd}	123.1^{f}	237.6^{d}	384.9
12	14.2^{a}	65.1^{c}	379.9^{j}	459.3
13	23.7^{cd}	114.8^{f}	338.6^{hi}	477.1
14	18.2^{abc}	84.5^{d}	344.7^{i}	447.4
15	15.2^{ab}	69.4^{c}	267.6^{e}	352.2
16	22.6^{cd}	109.2^{ef}	292.1^{f}	424.0
Mean value	28.3	95.8	242.4	366.4

Values in the same column bearing different superscript letters are significantly (P<0.05) different.

an average of 424.0 mg/kg (Table 3). Only sample 4 had a total content of vitamin E active compounds below 240 mg/kg. In comparison, the total content of vitamin E active compounds in rapeseed oil ranges between 430 and 2,680 mg/kg and in soybean oil between 600 and 3,370 mg/kg (AOCS, 1996).

In the seed oil only γ-tocopherol as well as α-tocopherol and α-tocotrienol were found. The composition of the vitamin E active compounds was dominated by γ-tocopherol in most of the samples with about 60% (sample 9) to nearly 90% (sample 1), only in sample 4, 7 and 8 either α-tocopherol or α-tocotrienol were predominant.

In contrast to the fatty acid composition the composition of the vitamin E active compounds showed a great variation for the different compounds, 14.2 (sample 12) to 54.1 mg/kg (sample 4) for α-tocopherol, 15.0 (sample 1) to 214.4 mg/kg (sample 6) for α-tocotrienol and 4.0 (sample 4) to 379.9 mg/kg (sample 12) for γ-tocopherol. That shows that the content and composition of vitamin E active compounds is not a very stable characteristic feature for the seed oil of *S. columbariae*. One reason for this finding could be the climatic conditions at the different locations where the seeds were collected. The variation also could be a result of plant specific characteristics.

Only few results about the composition of vitamin E active compounds of members of the genus *Salvia* are available in the literature. Results from Bagci *et al.* (2007) showed that also in other *Salvia* species α-tocopherol, α-tocotrienol and γ-tocopherol are the predominant vitamin E active compounds in varying compositions with γ-tocopherol as the most abundant vitamin E active compound in most of the seed oils. They also found for different species of the genus *Salvia* that the total content of tocopherols was much higher compared to the total content of tocotrienols. Because of the great variation of the content and the composition of vitamin E active compounds in seeds of *S. columbariae* the use of this feature as chemotaxonomic marker is not possible.

From epidemiologic studies it has be concluded that vitamin E active compounds may protect against cardiovascular diseases. One suggestion was that vitamin E active compounds inhibit the oxidation of low-density lipoprotein which may be responsible for the formation of atherosclerotic plaque, one reason for myocardial infarction and cardiovascular death (Stephens *et al.*, 1996). γ-tocopherol came more and more into the focus of interest since different *in vitro* and animal studies showed that not only α-tocopherol has some anti-inflammatory and antioxidant properties (Jiang *et al.*, 2000, 2002). Dietrich *et al.* (2006) stated that a possible protective effect of γ-tocopherol on cardiovascular diseases cannot be dismissed. From this it can be concluded that the high content of γ-tocopherol in seed oil of *S. columbariae* is a remarkable positive feature of the oil with respect to health aspects.

4. Conclusions

Seeds from *S. columbariae* have high oil content with an interesting fatty acid composition dominated by α-linolenic acid. Within the investigated and published data on species of the genus *Salvia*, the highest amount of α-linolenic acid has been found in *S. columbariae*. This high content of α-linolenic acid and the resulting high value for the 18:3/18:2 ratio could be used as a chemotaxonomic feature of this species. Additionally the seeds are characterised by a low content of saturated fatty acids and a moderate content of vitamin E active compounds dominated by γ-tocopherol in most samples. Since the vitamin E active compounds show a great variation regarding the content and the composition, the use of this parameter as chemotaxonomic feature is not possible. With regard to the search for sources of healthy oils, seed oil from *S. columbariae* may constitute high-value products for a healthy nutrition.

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