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Fatty acids composition of fruits of selected Central European sedges, *Carex* L. (Cyperaceae)

By **Anna Bogucka-Kocka[a] and Magdalena Janyszek[b*]**

[a] Department of Pharmaceutical Botany, Medical University, Lublin, Poland,
[b] Department of Botany, Poznan University of Life Sciences Poznań, Poland
(*Corresponding author:carexmag@au.poznan.pl)

RESUMEN

Composición de ácidos grasos de frutos de juncos (*Carex* L., Cyperaceae) seleccionados de Europa Central.

Los ácidos grasos de frutos de 13 especies de juncos (*Carex* L., Cyperaceae) fueron analizados. El contenido de aceite en los frutos de juncos estudiados vario desde un 3.73 a un 46.52%. En los aceites de los frutos estudiados fueron identificados 14 ácidos grasos diferentes. Los principales ácidos grasos insaturados fueron los ácidos linoleico, α-linolenico, oleico, n-7 palmitoleico, n-9 palmitoleico, octadecenoico y eicosanoico. Los siguientes ácidos grasos fueron encontrados en mayor cantidad: ácido linoleico, ácido oleico, ácido α-linolenico, y ácido palmítico. Basado en la composición de ácidos grasos, las especies estudiadas pueden ser divididas en dos grupos. El primer grupo (*C. flava, C. pseudocyperus*, *C. riparia, C. leporina*) es una muy buena fuente de ácido linoleico. El segundo grupo, que incluye las especies restantes, es una buena fuente de ácido α-linolenico. Los contenidos más altos de ácido oleico fueron observados en *C. vulpine.* El material estudiado ha mostrado una baja concentración de ácidos grasos saturados, de entre los cuales el ácido palmítico fue el principal. El análisis de los resultados nos permite considerar que los frutos de las especies de plantas estudiadas se caracterizan por su alto contenido en ácidos grasos insaturados.

PALABRAS CLAVE: Carex – Composición de ácidos grasos – Fruto – Junco – Nueces.

SUMMARY

Fatty acids composition of fruits of selected Central European sedges (*Carex* L. Cyperaceae).

Fatty acids in the fruits of 13 sedge species (*Carex* L., Cyperaceae) were analyzed. The oil contents in the fruits of the studied sedges ranged from 3.73 and 46.52%. In the studied fruit oils 14 different fatty acids were identified. The main unsaturated fatty acids were: linoleic, α-linolenic, oleic, oleopalmitic n-7; oleopalmitic n-9, octadecenic, and eicosenoic acids. The following acids were found in the greatest quantities: linoleic, oleic, α-linolenic and palmitic acids. Based on the fatty acid composition, studied taxa can be divided in two groups. The first group (*C. flava, C. pseudocyperus*, *C. riparia, C. leporina*) is a very good source of linoleic acid. The second group, including the remaining species, is a good source of α-linolenic acid. The highest oleic acid contents were observed in *C. vulpina*. The studied material has shown a low concentration of saturated fatty acids, among which palmitic acid was the main one. Results of the analyses allow for the inclusion of the studied species among plants whose fruits are characterized by a high content of unsaturated fatty acids.

KEY-WORDS: Carex – Fatty acid composition – Fruit – Nut – Sedge.

1. INTRODUCTION

Sedges (*Carex* L., Cyperaceae) represent one of the most common vascular plant groups in the world. They occur in very different habitat conditions, both in wet and moist locations such as peat bogs, fens, meadows and pasture communities as well as their peripheries. They also exist in dry and extremely dry habitats which include among others xerothermic and psammophilous grasslands. Many of these habitats constitute or may potentially constitute areas of agricultural use, for example as pastures for cattle. In spite of the fact that such diversified habitat types are dominated by the representatives of one genus and in spite of the high biocenotic importance of sedges, the practical utilization of these plants is not great. Only in some regions of the world, few species are used as fodder, or they are sown in meadow grass mixtures (i.e. Ingvason, 1969; Herman, 1970; Fox, 1991). However the results of an increasing number of studies on the chemical composition of sedges indicate high nutritive values. They include among others macro and microelements (e.g. Catling *et al*., 1994; Grzelak *et al*., 2005; Janyszek *et al*., 2005), flavonoids (Kukkonen, 1971; Manhrt, 1986), oligostilbenes (Suzuki *et al*., 1987; Kawabata *et al*., 1989; Hegnauer, 1986; Kurihara *et al*., 1990; Kawabata *et al*., 1991; Kurihara *et al*., 1991) alkaloids (Hegnauer, 1986), phenolic acids (Li, 1974; Bogucka-Kocka and Krzaczek, 2004), essential oils and saponins (Hegnauer, 1963).

Substances which also have a great importance in nutrition are fatty acids contained in the seed oils of many plant species which have been used since a long time ago in food and pharmaceutical industries as well as in the cosmetic industry. The unsaturated fatty acids are particularly valuable. They are indispensable for a correct metabolism, but,

unfortunately, animals are not able to synthethize them by themselves. Plant species which possess abundant amounts of this type of fatty acids include e.g.: *Olea europaea* L., *Helianthus annuus* L., *Zea mays* L., *Oenothera biennis* L., *Arachis hypogaea* L., *Juglans regia* L., *Linum usitatissimum* L. and *Brassica napus* L.

The analysis of fatty acids in the representatives of the *Carex* genus is not frequent. The few existing studies carried out in the generative organs of sedge nutlets were performed on only about a dozen species (Earle and Jones, 1962; Jones and Earle, 1966; Barclay and Earle, 1974; Egorova, 1999; Ahmad and Ansari, 1987) and only the percent of oil content was reported. Additionally, in the case of fruits, most of the earlier methods of analyses were based on hot extraction, which have currently been replaced by cold extraction. The use of the latter method protects fatty acids against oxygenation. On the other hand, other works dealing with this topic referred to fatty acids occurring in leaf structures and not producing any oil fractions (e.g. Ayaz and Olgun, 2000).

The main aim of the present work was the quantitative and qualitative analyses of the fatty acids occurring in the oil from fruits (nuts) of selected *Carex* species and the determination of selected species as a potential source of IUFA.

2. MATERIALS AND METHODS

2.1. Plant material

The study was conducted on representatives of 13 species of sedges which are comparatively widespread and relatively common in the Central European Netherlands. Representatives of the following species were studied: from the *Vignea* subgenus: *Carex paniculata* L., *C. appropinquata* Schum., *C. diandra* Schrank.; *C. vulpina* L., *C. otrubae* Podp.; *C. contigua* Hoppe. From the *Carex* subgenus: *C. leporina* L., *C. rostrata* Stokes; *C. pseudocyperus* L.; *C. flava* L; *C. acuta* L., *C. nigra* Reich, *C. elata* All. Systematics and nomenclature of the species have been accorded to Egorova (1999).

For each species, ripe utricles were collected from three different populations growing in the same types of phytocenoses. Plant material was sampled from natural sites from characteristic and most typical habitats and phytocenotic conditions for the given species (e.g. Janyszek *et al*., 2008; Janyszek and Jagodzinski, 2009). The specimens came from the territory of Poland. Plant material has been deposited in the Herbarium of Botany Department (POZNB) of Poznań University of Life Sciences (Poland).

The utricles were dried in natural conditions. After drying, the fruits were removed from the utricles. The nuts (fruits of the *Carex*), constituting the study material, were analyzed. Nuts were weighed, packed, kept in a cool dry room, and later ground into powder form with an electrical mill.

2.2. Extraction of oil

Fatty acids were obtained by cold hexane extraction from disintegrated fruits. Fatty acid fractions were taken using cold hexane. Disintegrated raw material was flooded with a 5-fold amount of hexane and it was macerated for 24 hr at room temperature in the dark. After that time the samples were filtered and again they were flooded with an adequate amount of solvent. This procedure was repeated three times. Then, the extract was pooled, hexane was removed (vacuum rotary evaporation, 35 °C), and the extract was filled into glass ampoules and vacuum packed. These samples were stored at −20 °C until the time of analysis. Each analysis for each species was performed in three replicates which with 3 collected utricle populations for each taxon made 9 independent tests. Averaged values are reported (Tables 1, 2).

Fatty acid occurrences were determined in the analyzed samples by HR-GC methods. After standard methylation, fatty acid methyl esters were analyzed by a GC Agilent 6890 gas chromatograph equipped with a column RTX 2330 Restek 100 m, calibre 0.25 mm, temperature of injector port 240 °C, in column 175 °C, in detector port 250 °C, carrier gas – helium 11/1 min., injection of split 1 µl/cm^3. Content percentage was estimated by internal normalization.

2.3. Statistical Analysis

The obtained results of the qualitative and quantitative fatty acid fractions were subject to cluster analysis by Ward's method using Statistica 6.0. The analyzed variables included standardized concentrations of the particular fatty acids. Mutual similarities of the particular species are presented in the dendrogram (Fig. 1).

3. RESULTS AND DISCUSSION

In the examined seed oil samples the occurrence of 14 fatty acids was confirmed (Tables 1, 2). In the studied *Carex* oils monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids predominated. In all studied species, linoleic, oleic, α-linolenic (UNSAT) and palmitic acids (SAT) were found in the greatest quantities. From the point of view of nutrition physiology, the most important for a correct metabolism in the animal organism are PUFA. From this group of acids, linoleic and α-linolenic acids were identified in the analyzed fruits. Both acids occur in significant amounts in the fruits of all analyzed taxa. Linoleic acid occurs in all studied species and it is the predominant compound in the majority of them. This acid is present in the greatest quantities (above 60%) in *C. flava* (74.23%), *C. pseudocyperus* (72.61%), *C. rostrata* (67.54%), and *C. leporina* (64.87%) (Tables 1, 2). These species differ regarding the concentration of linoleic acid as compared with the other studied taxa. The concentration of this compound is also higher than

Table 1
Percentage contents of fatty acids obtained from fruits of *Carex* L. from the *Carex* subgenus

Fatty acid*	C. rostrata	C. pseudocyperus	C. flava	C .acuta	C. nigra	C. elata
C14:0*	0.26 ± 0.033	0.15 ± 0.020	0.27 ± 0.101	0.71 ± 0.049	0.25 ± 0.023	0.44 ± 0.081
C16:0	5.43 ± 0.174	3.11 ± 0.086	4.75 ± 0.111	6.56 ± 0.119	6.07 ± 0.051	7.76 ± 0.089
C16:1;Δ^9	0	0.08 ± 0.015	0	0.17 ± 0.050	0.09 ± 0.001	0.28 ± 0.028
C16:1;Δ^7	0.20 ± 0.031	0.03 ± 0.010	0.03 ± 0.002	0.20 ± 0.070	0	0.29 ± 0.019
C18:0	1.34 ± 0.040	0.90 ± 0.021	3.23 ± 0.121	2.70 ± 0.055	2.26 ± 0.053	3.31 ± 0.014
C18:1;Δ^9	14.64 ± 0.273	18.19 ± 0.326	11.50 ± 0.434	15.79 ± 0.913	17.13 ± 0.511	15.90 ± 0.546
C18:1;Δ^7	0.40 ± 0.050	0.40 ± 0.051	0.30 ± 0.062	0.37 ± 0.041	0.42 ± 0.050	0.39 ± 0.012
C18:2;$\Delta^9.\Delta^{12}$	67.54 ± 1.036	72.61 ± 1.598	74.23 ± 1.878	49.30 ± 1.032	46.34 ± 0.381	34.65 ± 0.768
C20:0	1.20 ± 0.091	0.27 ± 0.023	0.80 ± 0.091	1.55 ± 0.080	0.76 ± 0.024	1.24 ± 0.123
C18:3; $\Delta^9.\Delta^{12}.\Delta^{15}$	2.18 ± 0.113	0.51 ± 0.023	1.65 ± 0.082	14.06 ± 0.324	24.56 ± 0.611	32.49 ± 0.560
C20:1;Δ^3	0.22 ± 0.021	0.32 ± 0.098	0.33 ± 0.060	0.70 ± 0.092	0.25 ± 0.021	0.25 ± 0.050
C22:0	0.31 ± 0.039	0.19 ± 0.027	0.96 ± 0.022	1.41 ± 0.060	0	0
C22:1;Δ^{13}	0.04 ± 0.015	0.04 ± 0.030	0.06 ± 0.008	0.65 ± 0.060	0.51 ± 0.022	0.57 ± 0.024
C24:0	0.13 ± 0.060	0.19 ± 0.021	0.25 ± 0.033	0.61 ± 0.032	0	0.38 ± 0.012
SFA	8.67 ± 0.072	4.81 ± 0.033	9.96 ± 0.080	13.54 ± 0.066	9.34 ± 0.038	13.11 ± 0.064
MUFA	15.5 ± 0.078	19.06 ± 0.088	12.22 ± 0.113	17.88 ± 0.204	18.4 ± 0.121	17.68 ± 0.113
PUFA	69.72 ± 0.575	73.12 ± 0.811	75.88 ± 0.950	66.36 ± 0.678	70.9 ± 0.496	67.14 ± 0.664
MUFA+PUFA	85.22 ± 0.220	92.18 ± 0.269	88.1 ± 0.361	84.24 ± 0.323	89.3 ± 0.228	84.82 ± 0.251
SAT/UNSAT	0.1	0.04	0.11	0.16	0.1	0.15
C18:1;Δ^9/ C18:2;$\Delta^9.\Delta^{12}$	0.21	0.25	0.15	0.36	0.4	0,46
Mass of samples (g)	25.3	59.75	14.95	15.95	4.5	4,4
Quantity of oil (g)	3.17	2.23	2.14	1.72	1.58	1,75
Percentage contents of oil	12.53	3.73	14.31	10.78	35.11	39.97

*C14:0 Myristic acid; C16:0 Palmitic acid; C16:1 Δ^9- Oleopalmitic acid; C16:1 Δ^7- Oleopalmitic acid; C18:0 Stearic acid; C18:1 Δ^9 -Oleic acid; C18:1 Δ^7- Octadecenic acid; C18:2 $\Delta^9.\Delta^{12}$- Linoleic acid; C20:0 Arachidic acid; C18:3 $\Delta^9.\Delta^{12}.\Delta^{15}$- α-linolenic acid; C20:1 Δ^3 - Eicosenic acid; C22:0 Behenic acid; C22:1 Δ^{13} - Erucic acid; C24:0 Lignoceric acid; SFA saturated fatty acids; MUFA monounsaturated fatty acids; PUFA polyunsaturated fatty acids; SAT/UNSAT saturated/unsaturated fatty acids.

in *Olea europaea* (about 12%) (Dubois *et al*., 2007) and it is comparable with the content observed in the *Oenothera* genus (Krzaczek *et al*., 1995).

The α-linolenic acid, found in the fruits of all studied species, is a predominant component of the fatty acid fraction in *C. elata* (32.44%) and in *C. otrubae* (31.93%). The lowest amounts were observed in *C. pseudocyperus* (0.51%). For comparison purposes, in the fruits of *Olea europaea*, only 0.6% of this acid was found (Dubois *et al*., 2007) (i.e. about 50 times lower content than in *C. elata* and *C. otrubae*).

Among the isolated and identified MUFA, oleic acid was the most abundant. It is found in all the studied taxa ranging from 11.5% in *C. flava* to 42.5% in *C. vulpina*. The presence of other unsaturated acids was found (oleopalmitic n-9, oleopalmitic n-7, octadecenic and eicosenoic), but these acids occur in significantly smaller amounts. In the studied species there was also a small amount of erucic acid, whose concentration is generally lower in species belonging to the *Carex* subgenus (Tables 1, 2).

The highest percent value of unsaturated fatty acids is observed in *C. pseudocyperus* (92.18%). The remaining species have lower concentration of these acids (62.98%-89.3%) (Tables 1, 2).

As commented, *C. pseudocyperus* has a high content of unsaturated fatty acids (particularly linoleic acid – 72.61%), but is also characterized by the lowest level of α-linolenic acid (0.51%). Such a situation also refers to other species. The dominating unsaturated fatty acids divide the analyzed group into two subgroups. The first one, with 4 species (*C. flava, C. pseudocyperus, C. riparia* and *C. leporina*), is a good source of linoleic acid and the second subgroup, including the remaining species, is a good source of α-linolenic acid. Also for oleic acid, *C. vulpina* can be regarded as the best raw material.

A greater content of linoleic acid characterizes the species from the *Carex* subgenus, and α-linolenic and oleic acids from the *Vignea* subgenus.

Our analyses have also shown the presence of saturated acids in the studied samples, where palmitic acid is the predominant one. The remaining saturated fatty acids, which were not found in all the studied species, occur in comparatively low concentrations (usually not exceeding 2%) (Tables 1, 2).

Our results agree with those reported for other sedge species: *C. carsei, C. solandri, C. fedia, C. flava, C. pendula* and *C. dioica* (Lotti and Averna, 1969; Morice, 1977; Ahmad and Ansari, 1987). The especially visible similarity concerning the saturated acids group is the domination linoleic acid and a significant differentiation of the α-linolenic acid

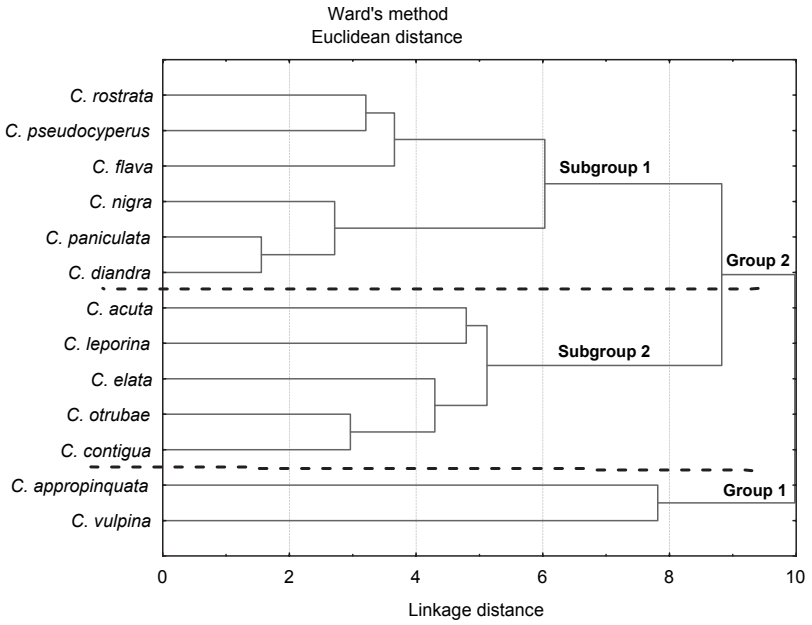

Figure 1.
Dendrogram of cluster analysis of fatty acid compositions of 13 species of *Carex* based on all identifying fatty acids. The clustering was made using Ward's method of agglomeration with Euclidean distance.

concentration in sedges. The results of our study and the literature data show that the studied sedges can be divided into two distinct groups: one with a concentration of α-linolenic acid oscillating within the limits from ten-plus to several tens percent and another, varying from slightly more than 0 to almost 2.2 percent. The confirmed feature concerning the group of saturated acids is the domination of the palmitic acid and the concentrations of the remaining saturated acids, which were similar to those presented in the literature data. Most likely, one can believe that such a composition of fatty acids and their mutual proportions are characteristic of the representatives of the *Carex* genus.

Similar studies on the fruits of *Cyperus esculentus* (Cyperaceae) have been carried out by Kapseu *et. al* (1997). The fruits of *C. esculentus* are characterized by definitely worse parameters of the fatty acid composition than the studied *Carex* species. In addition, in *C. esculentus,* a distinct domination of saturated fatty acids was found, particularly stearic acid.

The percentages of fatty oil fractions in the fruits of studied sedges are varying. The lowest content was observed in *C. pseudocyperus* (3.73%) and the highest in *C. leporina* (46.52%) (Tables 1, 2). In the remaining species these values oscillated within two intervals. The first interval (10-15% oil content) agrees with the one reported by earlier authors (Earle and Jones, 1962; Jones and Earle, 1966; Morice, 1977; Ahmad and Ansari, 1987) on other sedge species or organs (Ayaz and Olgun, 2000). The importance of the species from the Cyperaceae family as a significant source of oil is confirmed by athe results of studies made on *Cyperus esculentus* tubers by Eteshola and Oraedu (1996). According to these authors the tubers can contain up to 27% oil.

A dendrogram was obtained after the analysis of similarity based on the profile of fatty acid composition. The obtained dendrogram (Fig. 1) shows a division of the *Carex* species into two groups: the first one included *C. appropinquata* and *C. vulpina*, distinguished by the highest level of palmitic acid, but having no close habitat connections; the second group, including the remaining species, can be additionally divided into two subgroups. The species belonging to the first of the subgroups is characterized by a higher level of linoleic acid and a lower level of α-linolenic acid than the taxa from second one. This subgroup includes only species from very moist or medium moist habitats. It refers particularly to the agglomeration of *C. rostrata, C. pseudocyperus, C. flava* and *C. nigra,* and the agglomeration of *C. paniculata* and *C. diandra.* In both cases, the listed species grow in very similar habitat conditions. A majority of the species in the described subgroup includes representatives from the *Carex* subgenus. The second of the determined subgroups, except for *C. acuta*, contains species growing in more dry habitats. In this subgroup, all taxa, except for *C. acuta* and *C. elata* belong to the *Vignea* subgenus.

Based on our results, the fruits of the studied species of the genus *Carex* can be considered as plant raw material with a relatively high content of unsaturated fatty acids, both polyunsaturated such as linoleic and α-linolenic and monounsaturated such oleic acids. Comparing the obtained results to data referring to other species of plants widely applied in prophylaxis and therapy, we can infer that oil from sedge nutlets is a very good source of PUFA.

Table 2
Percentage contents of fatty acids obtained from fruits of *Carex* L. from the *Vignea* subgenus

Fatty acid	C. paniculata	C. appropinquata	C. diandra	C. vulpina	C. otrubae	C. contigua	C. leporina
C14:0	0.12 ± 0.010	2.11 ± 0.100	0.28 ± 0.010	0.18 ± 0.020	0.26 ± 0.030	0.14 ± 0.030	0.62 ± 0.003
C16:0	7.42 ± 1.032	20.63 ± 0.199	9.83 ± 0.098	15.08 ± 0.099	6.68 ± 0.760	6.07 ± 0.065	8.20 ± 0.100
C16:1;Δ^9	0.05 ± 0.001	0.05 ± 0.002	0.07 ± 0.001	0.20 ± 0.007	0.23 ± 0.024	0.06 ± 0.002	0.20 ± 0.045
C16:1;Δ^7	0.07 ± 0.002	0.28 ± 0.008	0.06 ± 0.001	0.25 ± 0.007	0.18 ± 0.002	0.20 ± 0.010	0.13 ± 0.033
C18:0	3.22 ± 0.098	2.74 ± 0.099	3.64 ± 0.043	1.49 ± 0.010	1.98 ± 0.020	1.77 ± 0.049	1.87 ± 0.040
C18:1;Δ^9	20.51 ± 1.001	14.02 ± 0.800	19.83 ± 0.989	42.50 ± 0.998	20.37 ± 0.101	19.13 ± 0.890	12.33 ±0.099
C18:1;Δ^7	0.67 ± 0.122	0	0.54 ± 0.154	0	0.81 ± 0.009	0.97 ± 0.010	0.64 ± 0.079
C18:2;$\Delta^9.\Delta^{12}$	48.79 ± 2.000	33.50 ± 0.099	45.39 ± 0.760	33.61 ± 1.002	28.89 ± 0.350	39.64 ± 0.450	64.87 ± 0.980
C20:0	0.50 ± 0.009	0.32 ± 0.003	0.55 ± 0.050	0.29 ± 0.007	1.12 ± 0.033	0.75 ± 0.009	0.77 ± 0.009
C18:3; $\Delta^9.\Delta^{12}.\Delta^{15}$	16.04 ± 0.670	13.39 ± 0.100	17.09 ± 0.323	1.08 ± 0.009	31.93 ± 0.100	26.19 ± 0.340	3.23 ± 0.003
C20:1;Δ^3	0.27 ± 0.010	0.14 ± 0.009	0.20 ± 0.001	0.74 ± 0.007	0.32 ± 0.020	0.27 ± 0.060	0.28 ± 0.003
C22:0	0.44 ± 0.070	0	0	0	1.01 ± 0.009	0.46 ± 0.034	0.07 ± 0.001
C22:1;Δ^{13}	0.19 ± 0.023	1.60 ± 0.087	0.41 ± 0.021	0.20 ± 0.004	0.16 ± 0.009	0.38 ± 0.020	1.12 ± 0.024
C24:0	0.31 ± 0.008	0.94 ± 0.005	0.18 ± 0.009	0.23 ± 0.001	0.70 ± 0. 012	0.36 ± 0.008	0.68 ± 0.009
SFA	12.01 ± 0.205	26.74 ± 0.081	14.48 ± 0.042	17.27 ± 0.027	11.75 ± 0.144	9.95 ± 0.033	12.21 ± 0.027
MUFA	21.76 ± 0.193	16.09 ± 0.181	21.29 ± 0.194	44.12 ± 0.205	22.07 ± 0.028	21.01 ± 0.165	14.7 ± 0.047
PUFA	64.83 ± 1.335	46.89 ± 0.100	62.48 ± 0.542	34.69 ± 0.505	60.82 ± 0.225	65.83 ± .395	68.1 ± 0.492
MUFA+PUFA	86.59 ± 0.479	62.98 ± 0.215	83.77 ± 0.281	78.81 ± 0.291	82.89 ± 0.077	86.84 ± 0.223	82.27 ± 0.158
SAT/UNSAT	0.13	0.42	0.17	0.21	0.14	0.11	0.14
C18:1;Δ^9/ C18:2;$\Delta^9.\Delta^{12}$	0.42	0.41	0.43	1.26	0.7	0.48	0.19
Mass of samples (g)	17.46	3.6	10.3	3.6	9.6	9.2	2.3
Quantity of oil (g)	1.64	1.1	3.58	1.6	1.52	1.37	1.07
Percentage contents of oil	9.39	30.55	34.75	44.44	15.83	14.89	46.52

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