Journal of Elementology ISSN 1644-2296

Sinkovič L., Kolmanič A. 2021.
Elemental composition and nutritional characteristics of Cucurbita pepo subsp. *pepo seeds, oil cake and pumpkin oil.*
J. Elem., 26(1): 97-107. DOI: 10.5601/jelem.2020.25.4.2072

RECEIVED: 23 October 2020
ACCEPTED: 8 December 2020

ORIGINAL PAPER

ELEMENTAL COMPOSITION AND NUTRITIONAL CHARACTERISTICS OF *CUCURBITA PEPO* SUBSP. *PEPO* SEEDS, OIL CAKE AND PUMPKIN OIL*

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Abstract

The objectives of the present study were to investigate multi-elemental and nutritional characteristics of dry pumpkin seeds, oil cake and pumpkin oil from different cultivars of oil seed pumpkin (*Cucurbita pepo* subsp. *pepo* var. *styriaca*, Cucurbitaceae). Two traditional oil seed pumpkin cultivars (Slovenska golica, Gleisdorfer Ölkürbis) and three hybrid cultivars (GL Maximal, GL Rustical, GL Opal) were studied. Dry pumpkin seeds were processed in an industrial scale oil mill into pumpkin seed oils whereby leaving oil cake as a by-product. Multi-elemental composition, dry matter, crude proteins and fats were analysed in pumpkin seeds and oil cake from all cultivars. A total of fourteen elements (P, K, Mg, S, Na, Ca, Fe, Zn, Mn, Cu, Mo, Cr, Co, V) were determined. Crude proteins in pumpkin seeds and oil cake ranged within 38.3-39.5% and 65.3-68.9%, while crude fats made up 47.1-49.8% and 8.7-10.3%, respectively. The highest protein content in seeds was found for GL Maximal, and in oil cake for GL Opal. Content of most elements in oil cake was twice as high as in seeds. The oil yield when processing pumpkin seeds into pumpkin oil was 39.7-41.5%. The highest relative fatty acid content in pumpkin oil was achieved by linoleic (C18:2; 46.1%), followed by oleic (C18:1; 34.2%) and stearic acid (C16:0; 12.3%). Differences in fatty acid oil composition were observed. Traditional cultivars had a higher content of oleic and lower content of linoleic acid than hybrid cultivars. Among all the cultivars, Gleisdorfer Ölkürbis had the highest oleic acid content, while GL Maximal was the richest in linoleic acid. The content of the analysed compounds in oil cakes suggest that these can be a valuable source of protein and minerals for the food processing industry.

Keywords: oil seed pumpkins; oil cakes; proteins; fats; fatty acid; elements.

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* The research was part of the reserch programme Agrobiodiversity (P4-0072) financially suported by the Slovenian research agency (ARRS), Ljubljana, Slovenia.

INTRODUCTION

Oil seed pumpkins (*Cucurbita pepo* subsp. *pepo* var. *styriaca*, Cucurbitaceae) have a long tradition of production in Slovenia, especially in the north-eastern Slovenian regions Štajerska and Prekmurje. As their name suggests, they are mostly grown for the purpose of oil processing. Dry seeds are usually roasted, ground and pressed into pumpkin oil (i.e. hot oil extraction), although cold oil extraction processes are also known. The final product from the hot or cold processing of pumpkin seeds is pumpkin oil, while oil cake is a by-product. The oil seed pressed cake is mostly used as animal fodder in Slovenia, although it could represent a raw material for some novel foods such as biscuits or spreads (Radočaj et al. 2012, Jukić et al. 2019).

Pumpkin oil has been gaining importance over the last years owing to its dietary and culinary properties. The pumpkin oil called "Štajersko prekmursko bučno olje" has been approved by the Commission of the European Union as a protected geographical indication (PGI) food in 2004. It is produced from pumpkin seeds of the highest quality, which undergo supervision during the production process carried out by a traditional method. Oil itself undergoes a mechanical process using heat, without any supplements.

The inclusion of oil seed pumpkins in Slovenian farming where crop rotation is dominated by cereal crops is a very welcome diversification. Oil seed pumpkins are mostly cultivated as a main crop. Pumpkin seeds are usually sown in early May and the fruits, i.e. pumpkins, reach full physiological maturity in late August or early September. The area intended for the production of oil pumpkins has fluctuated slightly in recent years, but there has been a noticeable trend of increase and the cropped area has been between 4,000 and 5,000 ha in recent years with an average seed yield of 800 kg ha^{-1} (Stat 2020). There are several reasons for the expansion of oil pumpkins production, including the appearance of new cultivars/hybrids with higher seed yied and the introduction of mechanical harvesting. This changed the technique of harvesting of whole pumpkins to only obtaining the pumpkin seeds. While years ago, oil seed pumpkins were harvested by hand and transported whole from the field, today the harvest is mostly carried out in the field with modern machines.

The characteristics of *Cucurbita pepo* subsp. *pepo* var. *styriaca*, in Slovenia named Slovenska golica, which is a phylogenetically young member of the *Cucurbita* genus, are dark green seeds with stunted outer hulls and visible protochlorophyll (Fruhwirth, Hermetter 2007, Butinar et al. 2011). In these so-called naked seeds, the amounts of lignin and cellulose in the hypodermis, sclerenchyma and parenchyma tissues of the seed coat are reduced (Loy 2000, Loy 2004). Further selection and breeding efforts, made in order to enhance positive characteristics like yield, seed, and oil content or to introduce the resistance to field pests and viruses, generated several new cultivars and hybrids, among which the Gleisdorfer type is the

most widespread (Teppner 2000). The oil content of pumpkin seeds usually varies from 40% to 50%, depending on the genotype and cultivation technology. Pumpkin seeds are dried to the remaining water content of 5-7% immediately after harvest (Fruhwirth, Hermetter 2007). Pumpkin oil pressed from roasted seeds has a unique chemical composition characterised by fatty acids, vitamins, minerals, phytosterols, pigments, aromatic compounds and phenolics (Butinar et al. 2011). Traditional pumpkin seed oil is produced by pressing pumpkin seeds which were roasted at 110-130°C for 30-60 minutes. Such oil, according to Codex Alimentarius, belongs to the virgin oil category.

The main plant lipids are the saturated fatty acids (SFAs) palmitic (C16:0) and stearic (C18:0) acids, the monounsaturated fatty acid (MUFA) oleic acid (C18:1; *n*-9) and the polyunsaturated fatty acids (PUFAs) linoleic (C18:2; *n*-6) and linolenic (C18:3; *n*-3) acids (Singh et al. 2005). Pumpkin seed oils are typical highly unsaturated oils with predominant oleic and linoleic fatty acids (Stevenson et al. 2007), whereby their ratio depends on the cultivar, climate, cultivation conditions and the degree of ripeness of oil seed pumpkins (Nawirska-Olszańska et al. 2013). The high content of linoleic acid is an important nutritional aspect of pumpkin seed oil, since it represents an essential fatty acid, which the human body cannot synthesize from other food components. Linoleic acid is involved in the formation of cellular membranes, vitamin D and various hormones (Fruhwirth, Hermetter 2007). Pumpkin seed oils are known for its pleasing fatty acid structure with around 20% of SFAs, 30-40% of MUFAs and 40-50% of PUFAs.

Pumpkin seeds, oil cake and oil have many effects beneficial to health, showing anti-diabetic, anti-carcinogenic and anti-microbial potential (Stevenson et al. 2007, Xanthopoulou et al. 2009, Yadav et al. 2010, Vaštag et al. 2011). The main by-product of pumpkin oil extraction is oil cake, which is mostly used as animal fodder. Oil cake, however, could be a rich source of nutritious compounds, such as phenolics, proteins, vitamins and minerals (Peričin et al. 2009, Vaštag et al. 2011).

To the best of our knowledge, the elemental composition and nutritional characteristics of dry pumpkin seeds, oil cake and pumpkin oil obtained from diferent oil pumpkin cultivars has not been researched yet. The aim of this study was to investigate the multi-elemental and nutritional characteristics (protein, fat, fatty acids) of seeds, cake and oil from traditional and hybrid cultivars.

MATERIAL AND METHODS

Five commercial cultivars of oil seed pumpkins (Cucurbita pepo subsp. pepo var. styriaca) were studied, two traditional (Slovenska golica, Gleisdorfer Ölkürbis) and three hybrid cultivars (GL Maximal, GL Rustical, GL Opal),

which are the most popular cultivars for cultivation and processing in Slovenia and neighbouring countries. Slovenska golica (Slovene origin) and Gleisdorfer Ölkürbis (Austrian origin) are early types with high oil content (45-46%). All hybrid cultivars, GL Opal (early), GL Maximal (medium) and GL Rustical (late), are of Austrian origin and have very high oil content (0.5-2% higher than Gleisdorfer Ölkürbis).

The field experiment was conducted on a production scale (0.5 ha for each cultivar) according to the established cultivation technology at the location Središče ob Dravi, Ormož, Slovenia (46°23′24″ N, 16°16′20″ E; 183 m above sea level). After mechanical harvest, pumpkin seeds were washed and dried with hot air to reduce the water content below 7%. During pumpkin oil industrial pressing, an average sample of 136 kg of dried pumpkin seeds from each cultivar was pressed after roasting in an oil mill located at north-eastern Slovenia (Jeruzalem SAT). Seeds were roasted at 107-111°C for 30 min, ground and then pressed to obtain oil. The heating process was carried out in a wood burning stove. Here, the oil yield (%) was calculated from the pressed amount of the oil of each sample. After the pressing procedure, the fresh pumpkin oil from each of the five cultivars was left, according to the standard procedure, resting in tanks (INOX) for two weeks, before the samples for fatty acid analysis were taken. Representative samples of oil cake were taken immediately after the pressing and homogenised for further analyses.

Dry pumpkin seeds and oil cake were analysed for dry matter, crude proteins, crude fats and elemental composition. Dry matter (%) was determined by heating the samples at 103°C for 4 h (EC 152/2009 App. III A). Crude proteins were analysed using method ISO 5983:2, using factor 6,25; and crude fats were analysed with petroleum ether extraction (152/2009 App. III H). For multi-elemental analysis, inductively coupled plasma mass spectrometry (ICP-MS) was used. Prior to sample analysis on Agilent 7900 ICP-MS, microwave digestion and dilution were performed. The accuracy of results and analytical procedures was checked with certified reference material NIST SRM 1573a Tomato leaves.

The fatty acid composition of pumpkin seed oils was determined using gas chromatography (GC) of fatty acid methyl esters (FAMEs). In the analytical procedure, NaOH and BF_3 in methanol were used for transesterification (IUPAC method 2.301) and heptadecanoic acid (Sigma H 3500) was used as the internal standard for quantification of fatty acids (IUPAC method 2.302). The solution of FAMEs was quantified on a GC (Agilent 6890N, USA) with a flame ionization detector. Separation was carried out on a column SPB PUFA (30 m×0.25 mm×0.2 µm; SUPELCO). Identification of fatty acids was carried out using a reference standard mixture of methyl esters of higher fatty acids (Lipid standard Sigma 189-19). The following fatty acids were detected: C14:0, C16:0, C16:1, C18:0, C18:1, C18:2, C18:3, C20:0, C20:1, C22:0, C22:1 (*n*-11), C22:1 (*n*-9), C24:0 and C24:1. The amounts of each fatty

acid were calculated from the areas of the internal standard (heptadecanoic acid, C17:0) and are expressed as % of total fatty acids content. Several nutritional data were calculated, i.e. total SFAs, total MUFAs, total PUFAs, PUFA/SFA ratio, *n*-3, *n*-6 and *n*-6/*n*-3 ratio. The atherogenicity index (AI), thrombogenicity index (TI) and health index (HI) were calculated from the equations proposed by Ulbricht and Southgate (1991):

$$AI=[(4\times C14:0)+C16:0]/(MUFA+PUFA);$$

$$TI=(C14:0+C16:0+C18:0)/[0.5\times MUFA+0.5\times n\text{-}6+3\times n\text{-}3+(n\text{-}3/n\text{-}6)];$$

$$HI=(MUFA+PUFA)/SFA.$$

Analyses of Student's *t*-test for independent sample comparisons (α=0.05) were used to test the significance of difference between the groups of traditional and hybrid oil seed pumpkin cultivars. The data also underwent analysis of variance (ANOVA) using the general linear model (α=0.05). The variables included in the model were the replications (n=3) as random effects, and cultivars (n=5) as fixed effects. If ANOVA indicated statistical differences, the Tukey's *post hoc* tests was run for multiple comparisons. Statgraphics Centurion XVI statistical analysis program was used.

RESULTS AND DISCUSSION

Nutritional characteristics of dry pumpkin seeds and oil cakes of different traditional and hybrid oil seed pumpkin cultivars are summarised in Table 1. Dry pumpkin seeds contained on average 38.7% of crude proteins in traditional and 38.9% in hybrid cultivars. Among the studied cultivars, dry seeds of GL Maximal contained the highest amount of crude proteins (39.5%). Crude fat content was higher in the hybrid cultivars than in the traditional ones, 49.0% and 47.2%, respectively. Significantly higher crude fats were found in dry seeds of cultivar GL Rustical (49.8%). Previous reports on *Cucurbita pepo* subsp. *pepo* var. *styriaca* seeds grown in Iran showed lower content of crude proteins and fats, 25.4% and 41.6%, respectively (Gohari Ardabili et al. 2011). The results of hot oil extraction during dry pumpkin seed processing into pumpkin oil were comparable for traditional and hybrid cultivars, where the oil yield reached 39.7-41.5% and remaining oil seed cake was a by-product. Among the different cultivars, the highest oil yield was obtained from Gleisdorfer Ölkürbis and the lowest one – from Slovenska golica (Table 1).

The oil cake contained 65.7% of crude proteins in traditional and 68.5% in hybrid cultivars. The content of crude fats was higher in oil cake from traditional cultivars than from hybrid ones, 9.7% and 8.7%, respectively. Among the tested cultivars, significantly higher crude protein content in oil cake was found in cultivar GL Opal (68.9%), while that of crude fats – in cultivar Gleisdorfer Ölkürbis (10.3%). The composition of oil seed cake is depen-

Table 1

Nutritional characteristics and multi-elemantal composition of pumpkin seeds and oil cake of five oil seed pumpkin cultivars (*Cucurbita pepo* subsp. *pepo* var. *styriaca*, Cucurbitaceae)

Pumpkin oil type	Traditional cultivar			Hybrid cultivar			
Cultivar name	Slovenska golica	Gleisdorfer ölkürbis	mean	GL maximal	GL rustikal	GL opal	mean
Dry pumpkin seeds							
Dry matter (%)	94.9^{c}	96.2^{e}	95.6	93.7^{b}	93.3^{a}	95.7^{d}	94.2
Cude protein (%)	38.5^{b}	38.8^{c}	38.7	39.5^{e}	38.3^{a}	39.0^{d}	38.9
Crude fat (%)	47.2^{a}	47.1^{a}	**47.2**	48.7^{c}	49.8^{d}	48.4^{b}	**49.0**
P (g kg^{-1})	11.47^{e}	11.03^{c}	**11.25**	10.54^{b}	10.11^{a}	11.12^{d}	**10.59**
K (g kg^{-1})	8.63^{d}	8.58^{d}	**8.61**	7.76^{b}	7.31^{a}	7.85^{c}	**7.64**
Mg (g kg^{-1})	4.89^{d}	4.76^{c}	4.83	4.69^{b}	4.54^{a}	5.03^{e}	4.75
S (g kg^{-1})	3.22^{b}	3.31^{c}	3.27	3.39^{e}	3.03^{a}	3.36^{d}	3.26
Na (g kg^{-1})	0.014^{c}	0.012^{b}	0.013	0.010^{a}	0.011^{a}	0.010^{a}	**0.010**
Ca (g kg^{-1})	0.59^{c}	0.54^{b}	0.57	0.50^{a}	0.66^{d}	0.59^{c}	0.58
Fe (mg kg^{-1})	84.57^{d}	88.30^{e}	**86.44**	78.16^{a}	82.44^{c}	79.91^{b}	**80.17**
Zn (mg kg^{-1})	76.21^{e}	72.40^{c}	74.31	66.82^{a}	74.94^{d}	69.41^{b}	70.39
Mn (mg kg^{-1})	39.72^{d}	39.01^{c}	**39.37**	34.90^{a}	38.01^{b}	37.87^{b}	**36.93**
Cu (mg kg^{-1})	13.93^{d}	13.38^{c}	13.66	13.27^{b}	13.17^{a}	13.90^{d}	13.45
Mo (mg kg^{-1})	1.60^{a}	1.69^{c}	1.65	1.98^{e}	1.62^{b}	1.71^{d}	1.77
Oil cakes							
Dry matter (%)	97.7	96.4	97.1	97.0	97.7	96.6	97.1
Cude protein (%)	66.1^{b}	65.3^{a}	**65.7**	68.5^{d}	68.0^{c}	68.9^{e}	**68.5**
Crude fat (%)	9.0^{c}	10.3^{e}	9.7	9.4^{d}	8.7^{b}	7.9^{a}	8.7
P (g kg^{-1})	20.22^{e}	19.14^{d}	**19.68**	18.63^{b}	18.53^{a}	18.77^{c}	**18.64**
K (g kg^{-1})	15.76^{d}	15.06^{c}	**15.41**	13.67^{a}	13.86^{b}	13.76^{ab}	**13.76**
Mg (g kg^{-1})	8.65^{d}	8.19^{b}	8.42	8.17^{b}	8.12^{a}	8.39^{c}	8.23
S (g kg^{-1})	5.75^{e}	5.45^{b}	5.60	5.73^{d}	5.42^{a}	5.54^{c}	5.56
Na (g kg^{-1})	4.06^{a}	4.02^{a}	**4.04**	4.49^{b}	5.08^{c}	5.02^{c}	**4.86**
Ca (g kg^{-1})	1.26^{d}	1.15^{a}	1.21	1.18^{b}	1.41^{e}	1.24^{c}	1.28
Fe (mg kg^{-1})	199.4^{b}	196.3^{b}	197.9	244.2^{c}	176.0^{a}	176.4^{a}	198.9
Zn (mg kg^{-1})	139.3^{d}	130.1^{c}	134.7	121.9^{a}	139.2^{d}	127.0^{b}	129.4
Mn (mg kg^{-1})	72.55^{d}	69.03^{c}	**70.79**	62.92^{a}	69.15^{c}	67.38^{b}	**66.48**
Cu (mg kg^{-1})	24.55^{c}	23.07^{a}	23.81	23.14^{a}	23.14^{a}	23.81^{b}	23.36
Mo (mg kg^{-1})	2.74^{a}	2.78^{a}	2.76	3.57^{c}	4.93^{d}	2.99^{b}	3.83
Oil yield (calculated from pressing procedure of 136 kg of dry pumpkin seeds)							
Oil yield (%)	41.5^{d}	39.7^{a}	40.6	41.2^{c}	40.4^{b}	40.4^{b}	40.7

Bold mean values within columns show significant difference between the groups of traditional and hybrid cultivars ($P \leq 0.05$; *t*-test). Different letters in a row show significant differences between cultivars ($P \leq 0.05$; Tukey HSD test).

dent on the method of extraction, i.e. hot or cold oil extraction. Jukić et al. (2019) reported lower crude protein (52.2%) and much higher crude fat content (30.4%) in oil cake obtained by cold oil extraction.

Multi-elemental composition of dry pumpkin seeds and oil cake is presented in Table 1. A total of fourteen elements were obtained in dry pumpkin seed and oil cake samples, which were divided into three groups: the macronutrients (>1 g kg^{-1} DW) Na, Mg, P, S, K and Ca (Table 1); the micronutrients (>1 mg kg^{-1} DW) Mn, Fe, Cu, Zn and Mo (Table 1); and the trace elements V, Cr and Co. The order of the elements by an average abundance, as determined by ICP-MS, is P > K > Mg > S > Na > Ca > Fe > Zn > Mn > Cu > Mo > Cr > Co > V. Overall, oil cake had higher content of both macro- and micronutrients. The average content of most elements was approximately twofold higher in oil cake than in dry pumpkin seeds. The biggest difference was observed for the micronutrient Fe (2.4×). On the other hand, the differences between traditional and hybrid cultivars were not so clear. Similar results on the content of macro- (Ca, Mg, K, and Na) and micronutrients (Fe, Mn, Cu, and Zn) in seeds of oil pumpkin cultivars were presented by Danilcenko et al (2011).

Fatty acid composition of pumpkin oil from different traditional and hybrid oil seed pumpkin cultivars is given in Table 2. Fourteen fatty acids were

Table 2

Fatty acid composition (% of total) of five oil seed pumpkin cultivar oils

Pumpkin oil type	Traditional cultivar			Hybrid cultivar			
Cultivar name	Slovenska golica	Gleisdorfer ölkürbis	mean	GL maximal	GL rustikal	GL opal	mean
C14:0	0.10^{a}	0.10^{a}	**0.10**	0.11^{b}	0.11^{b}	0.12^{b}	**0.11**
C16:0	11.98^{a}	12.03^{b}	**12.01**	12.62^{d}	12.59^{d}	12.26^{c}	**12.49**
C16:1	0.15	0.15	0.15	0.15	0.16	0.16	0.16
C18:0	5.61^{a}	5.78^{c}	5.70	5.70^{b}	5.95^{d}	5.93^{d}	5.86
C18:1	36.75^{c}	37.16^{d}	**36.95**	31.48^{a}	31.75^{a}	33.89^{b}	**32.37**
C18:2	44.05^{b}	43.45^{a}	**43.75**	48.57^{e}	48.09^{d}	46.39^{c}	**47.68**
C18:3	0.19^{d}	0.18^{c}	**0.19**	0.16^{b}	0.16^{b}	0.15^{a}	**0.16**
C20:0	0.40^{b}	0.41^{c}	0.41	0.39^{a}	0.40^{b}	0.41^{c}	0.40
C20:1	0.113^{c}	0.107^{c}	**0.10**	0.093^{b}	0.087^{a}	0.093^{b}	**0.09**
C22:0	0.138^{c}	0.127^{b}	**0.13**	0.116^{a}	0.117^{a}	0.123^{ab}	**0.12**
C22:1	0.08^{b}	0.07^{a}	0.07	0.11^{c}	0.11^{c}	0.08^{b}	0.10
C22:1	0.09^{b}	0.08^{a}	0.09	0.13^{c}	0.13^{c}	0.09^{b}	0.12
C24:0	0.09	0.08	0.09	0.09	0.08	0.08	0.08
C24:1	0.10^{a}	0.10^{a}	0.10	0.11^{b}	0.12^{c}	0.14^{d}	0.12

Bold mean values within columns show significant difference between the groups of traditional and hybrid cultivars ($P \leq 0.05$; *t*-test). Different letters in a row show significant differences between cultivars ($P \leq 0.05$; Tukey HSD test).

determined: myristic (C14:0), palmitic (C16:0), palmitoleic (C16:1), stearic (C18:0), oleic (C18:1; *n*-9), linoleic (C18:2; *n*-6), α-linolenic (C18:3; *n*-3), arachidic (C20:0), gondoic (C20:1; *n*-9), behenic (C22:0), cis-cetoleic (C22:1; *n*-11), erucic (C22:1; *n*-9), lignoceric (C24:0) and nervonic (C24:1; *n*-9). There were variations in the fatty acid content of the pumpkin oils in relation to the traditional and hybrid cultivars. Significant differences among cultivars were found for most of the fatty acids, except palmitoleic (C16:1) and lignoceric (C24:0) ones. The most abundant fatty acids were polyunsaturated linoleic acid (C18:2) and monounsaturated oleic acid (C18:1), 43-49% and 31-37%, respectively. Saturated palmitic (C16:0) and stearic (C18:0) acids were less abundant, <13% and <6%, respectively. Among the different pumpkin types, significantly higher average content of oleic acid (C18:1) was detected in the traditional (37%) compared to hybrid cultivars (32%). On the other hand, significantly higher average content of linoleic acid (C18:2) was detected in the hybrid (48%) compared to traditional cultivars (44%). When comparing different cultivars, the highest content of linoleic acid was observed for cultivar Slovenska golica (36.75%) while oleic acid for GL Maximal (48.57%). Similar results on the content of palmitic (10-12%) and stearic acids (4-6%) were found by Tańska et al. (2020) in their recent study on new hybrids of Stirian oil pumpkins grown in Poland. For oleic acid fatty acid, they reported lower values (20-33%), while for the linoleic and α-linolenic higher, 51-63% and 0.6-0.9%, respectively, than in our study. Potočnik et al. (2016) reported that oleic acid has the highest abundance in oil samples from Slovenia compared to those from Austria or Croatia, whereas the content of linoleic acid is the lowest in pumpkin oil from Slovenia.

Nutritional information on pumpkin oils from traditional and hybrid oil seed pumpkin cultivars is summarised in Table 3. SFAs ranged from 18 to 19%, MUFAs from 32 to 38% and PUFAs from 44 to 49%. Among the different pumpkin oil types, higher content of MUFAs was found in traditional (37.39%) than in hybrid cultivars (32.86%), contrary to the higher of PUFAs, which was higher in hybrid (47.84%) than in traditional cultivars (43.94%). When comparing different cultivars, the highest MUFAs were found in Gleisdorfer Ölkürbis (37.59%) and the highest PUFAs in GL Rustical (48.25%). These results are in agreement with previous studies on pumpkin seed oil, which revealed that the content of PUFAs is considerably higher than the content of MUFAs or SFAs (Fruhwirth, Hermetter 2007). Linolenic acid was the only representative of the *n*-3 and linoleic acid was the only representative of the *n*-6 fatty acids in analysed pumpkin oils. The *n*-3 and *n*-6 PUFAs are essential for normal human growth and development, and appear to be important for the prevention of several diseases (Kuhnt et al. 2012). The average PUFA/SFA ratio was 2.4 for the traditional cultivars and 2.5 for the hybrid cultivars, while the *n*-6/*n*-3 ratio showed higher differences between the traditional cultivars and hybrid cultivars, 232 and 298, respectively. According to the Department of Health and Social Security, diets that feature a PUFA/SFA value greater than 0.45 are considered healthy

Table 3

Nutritional data of five oil seed pumpkin cultivar oils

Pumpkin oil type	Traditional cultivar			Hybrid cultivar			
Cultivar name	Slovenska golica	Gleisdorfer ölkürbis	mean	GL maximal	GL rustikal	GL opal	mean
SFA	18.33^{a}	18.54^{b}	**18.43**	19.03^{d}	19.24^{e}	18.92^{c}	**19.06**
MUFA	37.20^{c}	37.59^{d}	**37.39**	31.97^{a}	32.25^{a}	34.38^{b}	**32.86**
PUFA	44.24^{b}	43.64^{a}	**43.94**	48.73^{e}	48.25^{d}	46.54^{c}	**47.84**
PUFA/SFA	2.41^{b}	2.35^{a}	2.38	2.56^{e}	2.51^{c}	2.46^{d}	2.51
n-3	0.19^{c}	0.18^{c}	0.19	0.16^{b}	0.16^{b}	0.15^{a}	0.16
n-6	44.05^{b}	43.45^{a}	**43.75**	48.57^{e}	48.09^{d}	46.39^{c}	**47.68**
n-6/*n*-3	227.6^{a}	237.5^{b}	**232.6**	296.1^{c}	301.4^{c}	309.3^{d}	**302.3**
AI	0.15^{a}	0.15^{a}	0.15	0.16^{b}	0.16^{b}	0.16^{b}	0.16
TI	0.43^{a}	0.44^{a}	0.43	0.45^{b}	0.46^{c}	0.45^{b}	0.45
HI	4.44^{e}	4.38^{d}	**4.41**	4.24^{b}	4.18^{a}	4.28^{c}	**4.23**

SFA – saturated fatty acid; MUFA – monounsaturated fatty acid; PUFA – polyunsaturated fatty acid; *n*-3 – omega-3 fatty acids; *n*-6 – omega-6 fatty acids; AI – atherogenic index; TI – thrombogenic index; HI – health index. Bold mean values within columns show significant difference between the groups of traditional and hybrid cultivars ($P \leq 0.05$; *t*-test). Different letters in a row show significant differences between cultivars ($P \leq 0.05$; Tukey HSD test).

to human nutrition. Based on both the scientific evidence and conceptual limitations, there is no compelling scientific rationale for the recommendation of a specific ratio of *n*-6/*n*-3 fatty acids.

CONCLUSIONS

In conclusion, the study is the first overview of elemental composition and nutritional characteristics of dry pumpkin seeds and oil cakes, and nutritional and fatty acid composition of pumpkin oils obtained from different oil pumpkin cultivars, traditional and hybrid ones. Dry pumpkin seeds contained 39% of proteins and 48% fats. The oil cake obtained after traditional oil pressing had a high protetin content (over 65%), which means it could be valuable raw material for novel foods. The content of most macro- and micronutrients was twice as high in oil cake as in pumpkin seeds. The content of MUFAs was higher in traditional cultivars than in hybrid ones, while that of PUFAs was higher in hybrid than in traditional cultivars. The results can contribute to the selection of pumpkin cultivars in order to produce more valuable pumpkin seed products and oil cake as a by-product of seed pressing for oil for further processing.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Alenka Levart (Animal Science Department, Biotechnical Faculty, University of Ljubljana, Slovenia) for her valuable help in fatty acids analysis, and to the company Jeruzalem SAT (Oljarna-Mešalnica Središče d.o.o.) for pressing the pumpkin oils.

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