Original scientific paper
DOI: /10.5513/JCEA01/20.4.2320
Journal of Central European Agriculture, 2019, 20(4), p.1063-1068

The content of nutrients and fatty acids profile in different oilseeds

Obsah živín a profil mastných kyselín v rôznych druhoch olejnín

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ABSTRACT

The aim of this study was to determine nutrients content of 4 oilseeds (sunflower, soybean, flaxseed and rapessed) and fatty acid profile of oils obtained from the seeds. Dry matter (DM), crude protein (CP), nitrogen free extract (NFE) and fat content of the seeds were determined by standard laboratory methods and procedures. Significant ($P<0.05$) differences in composition of all the analyzed seeds were found. Fatty acid profile analysis was performed using the Agilent 6890 A GC machine. The analyzed oils mainly composed of polyunsaturated fatty acids (PUFA), with the exception of rapeseed oil which primarily contained monounsaturated fatty acids (MUFA). Flaxseed oil has significantly ($P<0.05$) proven to be the richest in PUFA content (76.46%), but on the other hand it contained the least amount of MUFA (13.47%). The saturated fatty acid (SFA) content, except for soybean oil, was below 10%. The most optimal ratio between n-6 and n-3 unsaturated fatty acids (USFA) was found in rapeseed oil (2.22:1). From the fatty acid profile of analyzed oils significant ($P<0.05$) differences in the content of palmitic, stearic, oleic, linoleic, arachidic, eicosenoic, behenic and lignoceric acids were detected.

Keywords: fatty acids, nutrients, oilseeds, pressing, profile, polyunsaturated fatty acids, monounsaturated fatty acids, saturated fatty acid, unsaturated fatty acids

ABSTRAKT

Cieľom práce bolo analyzovať obsah živín rôznych semien olejnín (slnečnicových, sójových, ľanových a repkových) a profil mastných kyselín rastlinných olejov získaných z týchto semien. Analýza obsahu sledovaných živín v semenách olejnín (sušina, dusíkaté látky, bezdusíkaté látky výťažkové a tuk) bola vykonaná prostredníctvom štandardných laboratórnych metód a postupov. Zistili sa preukazné ($P<0.05$) rozdiely v zložení všetkých analyzovaných semien. Analýza profilu mastných kyselín bola vykonaná pomocou zariadenia Agilent 6890 A GC. Analyzované oleje pozostávali hlavne z polynenasýtených mastných kyselín (PUFA), s výnimkou repkového oleja, ktorý obsahoval najmä mononenasýtené mastné kyseliny (MUFA). Ľanový olej bol preukazne ($P<0.05$) najbohatší na obsah PUFA (76.46%), ale na druhej strane obsahoval najmenšie množstvo MUFA (13.47%). Obsah nasýtených mastných kyselín (SFA), s výnimkou sójového oleja,

bol nižší ako 10%. Najoptimálnejší pomer medzi n-6 a n-3 nenasýtenými mastnými kyselinami (USFA) sa zistil v repkovom oleji (2.22:1). V profile mastných kyselín analyzovaných olejov sa zistili preukazné (P<0,05) rozdiely v obsahu kyseliny palmitovej, steárovej, olejovej, linolovej, arachidónovej, eikosaénovej, behénovej a lignocerovej.

Kľúčové slová: mastné kyseliny, mononenasýtené mastné kyseliny, polynenasýtené mastné kyseliny, nasýtené mastné kyseliny, rastlinné oleje

INTRODUCTION

Vegetable oils are obtained from plants that contain enough fat in their seeds, fruits, or other parts to economically advantageous industrial processing (Kučerová et al., 2007). World oilseed production is at the level of 40 million tonnes per year. According to Verhoog (2002) from the countries of the European Union, the major producers of plant oils are France (rape and sunflower), Germany (rape), Spain (sunflower) and Italy (soy). In conditions of Slovakia for plant oil production mainly crops of sunflower and rape are grown. In the past, however, flax was also successfully produced there. Recently, the focus is on available domestic sources of vegetable oils in order to stimulate domestic production and ensure the sustainability of plant and livestock production. Plant oils are from the nutritional point of view appreciated in both, animal and human nutrition for their favorable fatty acid profile. They mainly compose of essential unsaturated fatty acids (Bíro et al., 2016) and therefore are better quality in comparison with animal fats (Lucas, 2000). However, the quality of these oils is also affected by plant species and the technology of their processing. In the last decades, great attention has been given to unsaturated fatty acids because of their beneficial effect on the function of multiple internal organs, protective and antioxidant effects and their potential to replace saturated fats in nutrition (Varga, 2018). Rapeseed oil is typical of high levels of MUFA and α-linolenic acid (McKevith, 2005, Foster et al., 2009). Brát et al. (2010) reported that rapeseed oil is the second richest source of α-linolenic acid compared to other vegetable oils and is well available in our conditions. Sunflower oil is one of the most popular and most often directly consumed oils in the World (Phillips et al., 2005). It's typically rich in oleic acid and linoleic acid content (Morisson et al., 1995) but on the other hand contains very low amount of n-3 PUFA (Foster et al., 2009). Flaxseed oil is a rich source of MUFA and one of the best sources of n-3 essential linoleic acid and α-linolenic acid (McKevith, 2005, Philips et al. 2005, Popa et al. 2012).

MATERIALS AND METHODS

In the experiment the basic nutrients content of 4 oilseeds (sunflower, soybean, flaxseed and rapessed) and fatty acid profile of oils obtained from the seeds was determined. Analyzed crops were grown in University Experimental Farm in Kolíňany in identical agroclimatic conditions. Harvest of seeds was realized at the vegetation stage of full maturity. Seeds were processed in the Laboratory of fats and oils (AgroBio Tech Research Centre of the Slovak University of Agriculture in Nitra). Pressing unit FARMER 10 (Farmet, Czech Republic) was used. Laboratory samples were analysed in the Laboratory of Quality and Nutritive Value of Feeds at the Department of Animal Nutrition at the Slovak Agricultural University. Dry matter (DM), crude protein (CP) as well as nitrogen free extract (NFE) and fat content of the seeds was determined by standard laboratory methods and procedures (EC No 152/2009). For the characteristic of lipid fraction triglycerides were hydrolyzed to glycerol and free fatty acids. Fatty acids were then derivated to methylesters (FAMEs). After preparation FAMEs were separated on the basis of carbon number and level of unsaturation by using gas chromatography fitted with a flame-ionization detector (FID). For the identification column 37 components mixture (Supelco 47885-U) was used. Standard solution was diluted with 10 mL of hexane with 1 mL supplementation of 2 N potassium hydroxide in methanol. Analytic tube was heated 30 seconds at 60 °C in a water bath. After 1 minute 2 mL of 1 N hydrochloric acid was added. The top layer was transferred in an amount 2

mL to autosampler vial with ninhydrin (Na_2SO_4). Injection of samples was performed by injection autosampler Agilent. The content of fatty acids on machine Agilent 6890A GC (Agilent Technologies, USA) as a percentage in crude fat was determined. To calculate basic statistic characteristics, to determine significance of differences and to compare results one-way ANOVA and t-test were performed at $P < 0.05$ level. The SAS statistical package was used (SAS Inc., New York City, USA).

RESULTS AND DISCUSSION

The content of essential nutrients in analyzed oilseeds is shown in Table 1. The dry matter (DM) ranged from 94.32 to 95.88% with significant ($P<0.05$) differences between the samples. Soybean seed contained significantly ($P<0.05$) the highest amount of crude protein (CP) (406.95 g*kg^{-1} of DM). This corresponds with the data published by Candráková (2016). From a nutritional point of view, soybean is considered as an important protein source in animal and human nutrition, because it's characterized by a high content of good quality of CP. In the other analyzed oilseeds the CP content ranged between 140 g*kg^{-1} of DM (sunflower seed) and 216.5 g*kg^{-1} of DM (rapeseed) and these differences were significant ($P<0.05$). This is comparable to the results of Nasiruddin et al. (2012), although these authors report a slightly higher CP content in sunflower seed, which may be affected by several factors, including climatic and agroclimatic conditions (Ernst and Černý, 2016). Significantly ($P<0.05$) the highest content of nitrogen free extract (NFE) was detected in soybean seed (252.75 g*kg^{-1} of DM), while the lowest in sunflower seed (157.15 g*kg^{-1} of DM). In comparison with El-Shemy (2011) and Nadeem et. al (2010) higher amounts were found. Oilseeds are characterized by a high fat content (in the form of oil) that can be used in many different ways. According to Sarwar et al. (2013) oilseeds typically contain 20-40% of fat. Even though soybean doesn't botanically belong to oilseeds, it is characterized by a high fat content around 20% (Gálik et al., 2011 and Gálik et al., 2016). Sunflower and rapeseed contain twice as much fat (around 40%). The seeds of soy, sunflower, rape, but also cotton and groundnut are key sources of fat for global use for nutritional and industrial purposes. Significantly ($P<0.05$) the highest fat content was detected in sunflower seed (504.15 g*kg^{-1} of DM) and the lowest in soybean seed (198.25 g*kg^{-1} of DM). Ernst and Černý (2016) reported, that the fat content of sunflower seed is mostly around 45%. Rapeseed typically has a higher fat content compared to sunflower seed, between 48 and 50% (Malovcová et al., 2016). Depending on the variety, climatic and soil conditions, the fat content of the soybean may be around 15% (Candráková, 2016).

The analyzed oils were characterized by their specific fatty acid profiles (Table 2.). The content of palmitic acid (C16:0) ranged from 4.51% (rapeseed oil) to 10.6% (soybean oil) and these differences were significant ($P<0.05$). Frančáková et al. (2015) and Orsavova et al. (2015) reported slightly higher palmitic acid content in rapeseed oil and according to Jokić et al. (2013) lower amount of this fatty acid in soybean oil was detected.

Table 1. Content of essential nutrients in analyzed seeds (Mean ± SD)

	Sunflower	Soybean	Flaxseed	Rapeseed
Dry matter*	947.25±0.35^a	943.20±0.1^b	948.25±0.15^c	958.80±0.01^d
Crude protein**	140.00±0.3^a	406.95±0.25^b	216.50±1.1^c	186.35±0.45^d
NFE**	157.15±1.85^a	252.75±0.95^b	217.30±0.9^c	170.85±1.65^d
Fat**	504.15±0.45^a	198.25±0.25^b	413.70±2.4^c	466.35±0.05^d

SD: standard deviation, NFE: nitrogen free extract, *in g*kg^{-1}, **in g*kg^{-1} of dry matter. Values followed by different superscripts within a row are significant at the level 0.05

Table 2. Fatty acid profile of analyzed plant oils (% of crude fat ± SD)

	Sunflower oil	Soybean oil	Flaxseed oil	Rapeseed oil
Palmitic acid	5.60±0.0[a]	10.60±0.02[b]	5.98±0.01[c]	4.51±0.0[d]
Palmitoleic acid	ND	ND	ND	0.22±0.0
Margaric acid	ND	0.11±0.0	ND	ND
Heptadecenoic acid	ND	ND	ND	0.10
Stearic acid	3.08±0.0[a]	4.39±0.0[b]	2.87±0.0[c]	1.61±0.0[d]
Oleic acid	22.75±0.0[a]	19.10±0.01[b]	13.34±0.0[c]	61.70±0.02[d]
Linoleic acid	66.70±0.01[a]	56.39±0.04[b]	59.85±0.01[c]	18.26±0.01[d]
α-linoleic acid	ND	7.38±0.03[a]	16.49±0.0[b]	8.09±0.01[c]
Arachidic acid	0.20±0.0[a]	0.36±0.0[b]	0.10±0.0[c]	0.52±0.0[d]
Eicosenoic acid	0.16±0.0[a]	0.17±0.0[b]	0.14±0.0[c]	1.07±0.0[d]
Behenic acid	0.67±0.0[a]	0.37±0.0[b]	0.11±0.0[c]	0.28±0.0[d]
Lignoceric acid	0.22±0.0[a]	0.13±0.0[b]	0.22±0.0[c]	0.14±0.01[d]
DHA	ND	ND	ND	0.13±0.01
PUFA	66.70	63.77	76.46	26.47
MUFA	22.91	19.27	13.47	63.09
SFA	9.78	15.96	9.29	7.06
Ratio Σn3/Σn6	ND	0.13	0.28	0.45
Ratio Σn6/Σn3	ND	7.64	3.60	2.22

SD: standard deviation, ND: not detected, DHA: docosahexaenoic acid, PUFA: polyunsaturated fatty acids, MUFA: monounsaturated fatty acids, SFA: saturated fatty acids. Values followed by different superscripts within a row are significant at the level 0.05

In stearic acid content (C18:0) a range from 1.61% (rapeseed oil) to 4.39% (soybean oil) was detected. This corresponds with results published by Frančáková et al. (2015), Orsavova et al. (2015) and Jokić et al. (2013). Oleic acid (C18:1) along with palmitoleic acid (C16:1) belong to monounsaturated and conditionally essential fatty acids. Both of these acids are very good indicators of thermal stability of vegetable oils, which means that with their increasing content the thermal stability increases as well (Bíro et al., 2016). Among analyzed oils significantly ($P<0.05$) the highest oleic acid content was found in rapeseed oil (61.7%) and sunflower oil (22.75%). In comparision with Orsavova et al. (2015) lower amount of oleic acid in rapeseed oil and sunflower oil was found, however Frančáková et al. (2015) reported even lower content of oleic acid in rapeseed oil. According to McKevith (2005), rapeseed oil is characterized by its high oleic acid content. Komprda (2009) and Keresteš et al. (2011) reported, that linoleic acid (C18:2) and α-linolenic acid (C18:3) are the most important essential fatty acids. These nutritionally greatly studied fatty acids (both in animal and in human nutrition) are typically

highly represented in flaxseed oil. Precisely because of high content of these fatty acids, compared to other common vegetable oils, flaxseed oil is so valuable (Philips et al., 2005 and Popa et al., 2012). Significant ($P<0.05$) differences in the content of linoleic and α-linolenic acid in analyzed oils were detected. The linoleic acid content ranged from 18.26% (rapeseed oil) to 66.7% (sunflower oil). In flaxseed oil the second highest content of linoleic acid (59.85%) was found. The results for linoleic acid content in sunflower and rapeseed oil correspond with McKevith (2005), which claims that sunflower oil may be richer source of this fatty acid than flaxseed oil. Frančáková et al. (2015) reported higher amount of linoleic acid in rapeseed oil and lower amount in flaxseed oil. According to Orsavova et al. (2015) more linoleic acid in sunflower oil was measured. However, in linoleic acid content of flaxseed and soybean oil significantly different values compared to McKevith (2005) were detected. This is likely to be related to the geographical differences between the analyzed oils and the specificity of the hybrid or hybrid line. In the case of α-linolenic acid content the results of McKevith (2005) have been confirmed. In sunflower oil, its content was not detected or was below the used device's detection limit. The highest α-linolenic acid content was found in flaxseed oil (16.49%), which was significantly higher compared to soybean oil (7.38%) and rapeseed oil (8.09%). In comparison with Frančáková et al. (2015) more α-linoleic acid in flaxseed oil and less in rapeseed oil was measured. According to Jokić et al. (2013) higher amount of this fatty acid in soybean oil was detected. α-linolenic acid is very important in nutrition, as this fatty acid belongs to n-3 unsaturated fatty acids whose dietary intake in human nutrition is very low. Significant ($P<0.05$) differences in arachidic acid (C20:0) content of analyzed oils were detected. Its highest content was found in rapeseed oil (0.52%). On the other hand the lowest amount of arachidic acid was determined in flaxseed oil (0.1%), which corresponds with the results published by McKevith (2005), Dubois et al. (2007) and Frančáková et al. (2015). Significantly ($P<0.05$) the highest eicosenoic acid content (C20:1 n9) of 1.07% was detected in rapeseed oil. This is comparable to the results of Frančáková et al. (2015). According to McKevith (2005), behenic acid (C22:0) is in vegetable oils found only in very low amounts, often below the detection limit. An exception is groundnut oil, where the content of this fatty acid may reach 3%. Interestingly, Velíšek and Hajšlová (2009) reported the amount of behenic acid up to 2% in rapeseed oil. In the analyzed oils, the content of behenic acid was between 0.11% (flaxseed oil) and 0.67% (sunflower oil) and these differences were significant ($P<0.05$). A similar range and significant ($P<0.05$) differences were also detected in the content of lignoceric acid (C24:0). An interesting result was found in terms of docosahexaenoic acid content (C22:6 n3) whose dietary intake is mainly monitored in human nutrition. High content of this n-3 unsaturated essential fatty acid is typical for fish oil and sea fishing products. From analyzed samples docosahexaenoic acid was found only in rapeseed oil (0.13%), similar to results of Frančáková et al. (2015). The analyzed oils mainly composed of polyunsaturated fatty acids (PUFA), with the exception of rapeseed oil which primarily contained monounsaturated fatty acids (MUFA). The saturated fatty acid (SFA) content, except for soybean oil, was below 10%. From the nutritional point of view the most optimal ratio between n-6 and n-3 unsaturated fatty acids (USFA) was found in rapeseed oil (2.22:1). Rapeseed oil is often underestimated but high in quality because of high fatty acids content, especially PUFA.

CONCLUSIONS

The aim of this study was to analyze the content of nutrients (DM, CP, NFE, fat content) of 4 oilseeds (sunflower, soybean, flaxseed and rapessed) and fatty acid profile of oils obtained from the seeds. Significant ($P<0.05$) differences in composition of all the analyzed seeds were found. In addition to soybean, which is routinely used in both human and animal nutrition, also flaxseed and rapeseed were characterized by an interesting nutritional composition. Compared to soybean, both had a very good content of CP and a higher fat content. On the other hand, flaxseed and rape seed contained much more fat than soybeans. This moment can be evaluated

positively, mainly because of their potential of being a good source of essential fatty acids. From the fatty acid profile of analyzed oils significant (P<0.05) differences in the content of palmitic, stearic, oleic, linoleic, arachidic, eicosenoic, behenic and lignoceric acids were detected. Flaxseed oil has significantly (P<0.05) proven to be the richest in PUFA content. Rapeseed oil primarily contained MUFA and the highest proportion of SFA was measured in soybean oil. Sunflower and flaxseed oil were characterized by their high linoleic acid content. Next to flaxseed also rapeseed can be considered as a rich source of α-linolenic acid.

ACKNOWLEDGEMENTS

The study was supported by the Grant Agency of the Slovak Ministry of Education, Science, Research and Sport and the Slovak Academy of Sciences (project n. 1/0723/15). This work was co-funded by the European Community project no 26220220180: Building the Research Centre „AgroBioTech".

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