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MINERAL PROFILE ANALYSIS OF OILSEEDS AND THEIR BY-PRODUCTS AS FEEDING SOURCES FOR ANIMAL NUTRITION

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ABSTRACT

The aim of this study was to determine the dry matter (DM) and crude ash content, as well as the mineral content of oilseeds and their by-products, cakes. Four samples of oilseeds (sunflower, soybean, flaxseed and rapessed) were analysed as seeds and cakes. Analyzed crops were grown at the University Experimental Farm in Kolíňany. Cakes were obtained by using FARMER 10 pressing unit. Dry matter and crude ash were determined by standard laboratory methods and procedures. Mineral nutrient profile analysis was performed by using the High Resolution Continuum Source Atomic Absorption Spec trometer contrAA 700 for calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn). To analyze phosphorus (P) content, 6400 Spectrophotometer was used. Significant differences ($P < 0.05$) in DM and crude ash content, as well as in mineral composition of analyzed seeds and cakes, were found. The most represented macroelements were K (soybean seed and soybean cake over 20 $g.kg^{-1}$ of DM) and P (rapeseed cake 12.23 $g.kg^{-1}$ of DM and sunflower cake 11.42 $g.kg^{-1}$ of DM). On the other hand, Na was present in the analyzed samples the least, mostly below 1 $g.kg^{-1}$ of DM. From microelements, the highest values were observed for Fe (with the maximum for rapeseed cake 107.94 $mg.kg^{-1}$ of DM and soybean cake 88.97 $mg.kg^{-1}$ of DM) and Zn (with the maximum for sunflower cake 58.94 $mg.kg^{-1}$ of DM and rapeseed cake 52.38 $mg.kg^{-1}$ of DM). Rapeseed and rapeseed cake have significantly ($P < 0.05$) proven to be the richest in Mn content (32.96 $mg.kg^{-1}$ of DM and 54.07 $mg.kg^{-1}$ of DM, respectively), but on the other hand they contained the least amount of Cu (6.82 $mg.kg^{-1}$ of DM and 8.90 $mg.kg^{-1}$ of DM, respectively).

Key words: oilseeds; oliseed cakes; mineral content; macroelemnets; microelements

INTRODUCTION

Oilseeds are considered an important source of many nutrients and minerals in both human and animal nutrition (Das *et al.*, 2017). Despite their high energy value and high protein content, oilseeds in feed industry are used only marginally, because they often contain antinutrients, which negatively affect the quality of animal products or animal health (Zeman *et al.*, 2006). Due to their high fat content they are mainly used for oil production (Gunstone, 2002). In animal nutrition only by-products from the production of vegetable or technical oils, such as extracted meals or cakes, are used with great importance. Ramachandran *et al.* (2007) and Gálik *et al.* (2016) reported that in recent decades there has been an increasing interest in the use of organic by-products of industrial processing as feed ingredients for economic and environmental reasons.

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In terms of mineral content oilseeds are considered as deficient, which means that they are nutritional sources of only a small range of minerals. From macroelements they are mostly rich in phosphorus, much like grain cereals. From microelements, oilseeds (including soy) can be a very good source of iron and zinc. Other microelements are typically found only in trace amounts (Gálik *et al.*, 2016). The mineral content of oilseeds is influenced by a number of factors, such as species, soil and climatic conditions, as well as agrotechnics and breeding (Gálik *et al.*, 2016).

MATERIAL AND METHODS

In the experiment, dry matter (DM) and crude ash content, as well as minerals content of oilseeds and their cakes were determined. Four samples of oilseeds (sunflower, soybean, flaxseed and rapeseed) in triplicate were analysed as seeds and cakes. Analyzed crops were grown in University Experimental Farm in Kolíňany under identical agroclimatic conditions. Harvest of seeds was realized at the 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). FARMER 10 pressing unit (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. DM and crude ash were determined by standard laboratory methods and procedures (EC No 152/2009). The contents of mineral nutrients were determined by High Resolution Continuum Source Atomic Absorption Spectrometer contrAA 700 (ANALYTIK JENA) (Ca, Mg, Na, K, Zn, Cu, Fe, Mn) and 6400 Spectrophotometer (P). The determination of individual element content was based on the absorptions measured at the following wavelengths: Ca content was detected at 422.7 nm, P at 666 nm, Mg at 285.2 nm, Na at 589.0 nm, K at 766.5 nm, Zn at 213.9 nm, Cu at 324.7 nm, Fe at 248.3 nm and Mn at 279.5 nm. To calculate basic statistic characteristics, to determine significance of differences and to compare results a 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

Dry matter and Crude ash

In analyzed seeds the DM content ranged from 94.32 to 95.88 % (Table 1.), however, differences were significant ($P < 0.05$). The lowest DM content was observed for soybean. Ítavo *et al.* (2015) reported higher value for DM in soybean seed (981.2 $g.kg^{-1}$) in comparision to our data. The highest DM content was observed in rapeseed, though it was lower than reported by Rymer and Short (2003).

The crude ash content of feed materials is often wrongly mistaken for mineral content. In terms of quality, safety and availability of nutrients in nutrition, however, a lower content of crude ash in nutrient sources is desired (Gálik *et al.*, 2016). As shown in Table 1., among seeds, significantly lowest crude ash content ($P < 0.05$) was detected in sunflower seed and rapeseeds. Chung *et al.* (2009) reported higher, whilst Nadeem *et al.* (2010) – lower crude ash content in whole sunflower seeds. In comparision with Ewing *et al.* (1997), Santos *et al.* (2009) and Carré *et al.* (2016) a lower content of crude ash in rapeseed was found. Significantly highest crude ash content ($P < 0.05$) was revealed in soybean seeds. This corresponds to the results

Table 1. Dry matter ($g.kg^{-1}$) and crude ash ($g.kg^{-1}$ of DM) content of analyzed oilseeds

	Sunflower seed	Soybean seed	Flaxseed	Rapeseed
	Mean ± SD (n = 2)			
Dry matter	947.25 ± 0.35^{a}	943.20 ± 0.10^{b}	948.25 ± 0.15^{c}	958.80 ± 0.01^{d}
Crude ash	36.20 ± 0.20^{a}	53.40 ± 1.20^{b}	39.80 ± 0.20^{c}	36.10 ± 0.20^{a}

SD: standard deviation. Values followed by different letters within a row are significant at the level 0.05.

published by Rymer and Short (2003), whilst lower content of crude ash in soybean seed was reported by Ciabotti *et al.* (2016) and higher – by Goes *et al.* (2010). Differences in crude ash content compared to the literature sources may be due to topographic and climatic factors.

Table 2. demonstrates that the DM content of cakes differed only slightly compared to the DM content of seeds. The lowest DM content was determined in rapeseed cake and the highest DM content was observed in soybean cake. Leming and Lember (2005) found lower DM content in rapeseed cake (917 $g.kg^{-1}$). Analysed DM content in soybean cake was higher than reported by Geremew *et al.* (2015). These discrepancies in DM content may in general result from differences in moisture absorption between spieces due to genetic variations, processing and storage of samples. The analyzed differences in DM content of cakes were significant ($P < 0.05$).

Compared to seeds, the crude ash content of cakes was higher with a maximum for rapeseed cake and the minimum for flaxseed cake. According to Geremew *et al.* (2015), lower content of ash in flaxseed cake was found. Significant differences ($P < 0.05$) in the ash content of all the analyzed cakes were observed (Table 2.).

Macroelements

The mineral content of oilseeds is influenced by several factors such as species, soil and climatic conditions, as well as agro-technology and breeding (Gálik *et al*., 2016). The content of macroelements in analyzed seeds is shown in Table 3. In the content of macroelements (Ca, P, Mg, Na and K), significant differences ($P < 0.05$) between the analyzed seeds were observed. Significantly highest Ca content ($P < 0.05$) was detected in rapeseed (3.56 $g.kg^{-1}$ of DM), which corresponds to the results published by McKevith (2005). On the other hand, sunflower seed contained significantly ($P < 0.05$) lowest amount of Ca (2.32 $g.kg^{-1}$ of DM). According to McKevith (2005) in terms of Ca content, sesame seeds (an average of 7 $g.kg^{-1}$ of DM), rapeseeds (4 $g.kg^{-1}$ of DM) and flaxseeds (2 $g.kg^{-1}$ of DM) can be considered as the most qualitative. On the contrary, groundnut and soybean seeds are deficient in calcium content. In the case of P content, we found quantitatively higher values compared to Ca. Significantly highest ($P < 0.05$) amount of P was detected in flaxseed (8.55 $g.kg^{-1}$ of DM) and the lowest in rapeseed (5.53 $g.kg^{-1}$ of DM). Morris (2007) reported lower amount of P in flaxseed (6.22 $g.kg^{-1}$ of DM). From oilseeds, the most P rich are cotton seeds, rapeseeds, sesame and flax seeds (McKevith, 2005). Very similar levels of Ca and P in oilseeds were also reported by Petrikovič *et al*. (2000), as well as Gálik *et al*. (2016). In terms of Ca and P content, oilseeds in diets are considered primarily a nutritional source of P. In Mg content, we observed significant differences ($P < 0.05$) between sunflower, soybean and rapeseeds. Compared to other seeds, the significantly ($P < 0.05$) highest Mg content was found in flaxseed (3.44 $g.kg^{-1}$ of DM). A slightly higher average Mg content for flaxseed was reported by Petrikovič *et. al.* (2000) and Morris (2007). Mg content detected for soybean seed was significantly ($P < 0.05$) lowest. Na is considered as an important cation in animal nutrition, which retains water in the body (Gálik *et al*., 2011). Its content is generally low in oilseeds and must be nutritionally supplied from other sources (Bíro *et al*. 2014). In analyzed seeds the content of Na ranged from 0.17 $g.kg^{-1}$ of DM (sunflower seed) to 0.43 $g.kg^{-1}$ of DM (flaxseed), and these differences were significant ($P < 0.05$). In comparition with Morris (2007), higher amount of Na in flaxseed was found. K is antagonistic to Na and promotes

Table 2. Dry matter ($g.kg^{-1}$) and crude ash ($g.kg^{-1}$ of DM) content of analyzed cakes

	Sunflower cake	Soybean cake	Flaxseed cake	Rapeseed cake
	Mean ± SD (n = 2)			
Dry matter	947.60 ± 0.30^{a}	950.35 ± 0.05^{b}	946.55 ± 0.25^{c}	945.00 ± 0.20^{d}
Crude ash	54.10 ± 0.30^{a}	56.10 ± 0.10^{b}	51.00 ± 0.10^{c}	61.90 ± 0.30^{d}

SD: standard deviation. Values followed by different letters within a row are significant at the level 0.05.

Table 3. Content of macroelements in analyzed oilseeds (g.kg^{-1} of DM)

	Sunflower seed	Soybean seed	Flaxseed	Rapeseed
	Mean ± SD (n = 2)			
Ca	2.32 ± 0.06^{a}	2.56 ± 0.10^{b}	2.95 ± 0.01^{c}	3.56 ± 0.05^{d}
P	6.91 ± 0.08^{a}	7.03 ± 0.00^{a}	8.55 ± 0.00^{b}	5.53 ± 0.08^{c}
Mg	3.35 ± 0.10^{a}	2.09 ± 0.01^{b}	3.44 ± 0.03^{a}	2.26 ± 0.06^{c}
Na	0.17 ± 0.00^{a}	0.22 ± 0.00^{b}	0.43 ± 0.04^{c}	0.18 ± 0.00^{d}
K	8.69 ± 0.10^{a}	20.23 ± 0.37^{b}	9.52 ± 0.09^{c}	8.00 ± 0.36^{d}

SD: standard deviation. Values followed by different letters within a row are significant at the level 0.05.

the release of water from the body (Gálik *et al*., 2011). The highest content of K was detected in soybean seed (20.23 g.kg^{-1} of DM). According to Van Eys *et al*. (2004) and Aletor *et al*. (2010) higher amount of K in soybean seed was observed. On the contrary, the lowest amount of K was detected in rapeseed (8.0 g.kg^{-1} of DM). Differences in K content of soybean and rapeseed were significant ($P < 0.05$).

The content of macroelements in cakes is shown in Table 4. Between the analyzed cakes, significant differences ($P < 0.05$) in the content of Ca and P were found. In comparison with seeds, quantitatively higher values were observed, with the highest levels of Ca and P detected for rapeseed cake. According to Leming and Lember (2005) lower contents of Ca and P in rapeseed cake were found. The Mg content in cakes ranged from 2.09 g.kg^{-1} of DM (soybean cake) to 4.41 g.kg^{-1} of DM (flaxseed cake). Just as in analyzed seeds, only traces of Na in cakes were found. The highest amount of K was observed in soybean cake (20.47 g.kg^{-1} of DM) and the lowest in flaxseed cake (12.41 g.kg^{-1} of DM).

Microelements

Recently, only a limited number of papers has been published on the content of microelements in oilseeds and by-products derived from their industrial processing. Table 5. lists the content of selected microelements in analyzed seeds. The highest Cu content was found by a laboratory analysis in sunflower seed (21.25 mg.kg^{-1} of DM) and the lowest in rapeseed (6.82 mg.kg^{-1} of DM). These results correspond with the work of Petrikovič *et al*. (2000), although in the case of sunflower seed, the authors report an average Cu content only 10.9 mg.kg^{-1} of DM. Mainly flax and sunflower seeds are characterized by a higher Fe content, typically over 100 mg.kg^{-1} of DM (Petrikovič *et al*., 2000). However, Morris (2007) provides half of this amount of Fe in flaxseeds. In analyzed oilseeds the Fe content was between 38.30 mg.kg^{-1} of DM (sunflower seed) and 72.85 mg.kg^{-1} of DM (rapeseed). Nadeem *et al*. (2010) detected higher Fe content in sunflower seeds (68.61 mg.kg^{-1} of DM). However, in another work McKevith (2005) reported a very similar Fe content in flaxseed,

Table 4. Content of macroelements in analyzed cakes (g.kg^{-1} of DM)

	Sunflower cake	Soybean cake	Flaxseed cake	Rapeseed cake
	Mean ± SD (n = 2)			
Ca	3.28 ± 0.00^{a}	3.49 ± 0.00^{b}	3.61 ± 0.06^{c}	6.63 ± 0.07^{d}
P	11.42 ± 0.16^{a}	6.08 ± 0.00^{b}	9.52 ± 0.32^{c}	12.23 ± 0.00^{d}
Mg	4.22 ± 0.04^{a}	2.09 ± 0.10^{c}	4.41 ± 0.01^{b}	4.08 ± 0.35^{ab}
Na	0.29 ± 0.00^{a}	0.23 ± 0.00^{b}	0.34 ± 0.00^{c}	0.18 ± 0.00^{d}
K	13.82 ± 0.60^{a}	20.47 ± 0.00^{b}	12.41 ± 0.23^{a}	13.81 ± 0.07^{a}

SD: standard deviation. Values followed by different letters within a row are significant at the level 0.05.

Table 5. Content of microelements in analyzed oilseeds (mg.kg^{-1} of DM)

	Sunflower seed	Soybean seed	Flaxseed	Rapeseed
	Mean ± SD (n = 2)			
Cu	21.25^a ± 1.23^a	13.15 ± 0.15^b	14.24 ± 0.00^c	6.82 ± 0.00^d
Fe	38.30 ± 2.83^a	71.83 ± 0.09^b	59.53 ± 0.01^c	72.85 ± 0.96^d
Mn	15.56 ± 0.07^a	25.82 ± 0.53^b	10.91 ± 0.22^c	32.96 ± 0.00^d
Zn	47.30 ± 0.20^a	48.13 ± 0.44^b	45.19 ± 1.41^a	35.20 ± 0.07^c

SD: standard deviation. Values followed by different letters within a row are significant at the level 0.05.

rapeseed, soybean and sunflower seeds compared to our results. These findings point out that this issue is not covered by a sufficient number of relevant studies and works that would be available. In Mn content also a wide range from 10.91 mg.kg^{-1} of DM (flaxseed) to 32.96 mg.kg^{-1} of DM (rapeseed) was detected. In comparision with the work of Nadeem *et al*. (2010), lower amount of Mn in sunflower seed was observed. The last analyzed microelement in oilseeds was Zn, a microelement, whose importance in nutrition is mainly related to the immunization of animals (Gálik *et al*., 2011). According to Petrikovič *et al*. (2000) a higher content of Zn occurs mainly in flaxseed and rapeseeds. However, according to McKevith (2005), Zn in flaxseed is found in a lower amount, the higher content is typical for sunflower seed and only trace amounts of Zn occur in soybean seed and rapeseed. In the analyzed seeds, Zn was present in a range from 35.20 mg.kg^{-1} of DM (rapeseed) to 48.13 mg.kg^{-1} of DM (soybean seed). Anuonye *et al*. (2010) reported Zn content in soybean seed between 30 and 50 mg.kg^{-1} of DM. With the exception of the Zn content, all differences in the microelements content between the seeds were significant ($P < 0.05$).

Table 6. shows the content of selected microelements in analyzed cakes. Similarly to seeds, in addition to Zn content, significant differences were found ($P < 0.05$). The significantly ($P < 0.05$) highest content of Cu was obtained in sunflower cake, the significantly ($P < 0.05$) highest content of Fe and Mn was detected in rapeseed cake. The highest content of Zn was found in sunflower cake.

CONCLUSION

The aim of this study was to determine DM and crude ash content as well as mineral profile of four oilseeds (sunflower, soybean, flaxseed and rapessed) and their cakes. Significant ($P < 0.05$) differences in the composition of analyzed seeds and cakes, as well as in their mineral content were found. Compared with other studies of various authors

Table 6. Content of microelemnets in analyzed cakes (mg.kg^{-1} of DM)

	Sunflower cake	Soybean cake	Flaxseed cake	Rapeseed cake
	Mean ± SD (n = 2)			
Cu	31.98 ± 0.01^a	14.68 ± 0.52^b	17.75 ± 0.74^c	8.90 ± 0.00^d
Fe	58.78 ± 1.47^a	88.97 ± 0.68^b	78.60 ± 0.03^c	107.94 ± 1.46^d
Mn	21.05 ± 0.53^a	25.62 ± 0.37^b	13.73 ± 0.30^c	54.07 ± 0.13^d
Zn	58.94 ± 0.65^a	44.77 ± 0.67^b	48.60 ± 0.62^a	52.38 ± 0.58^c

SD: standard deviation. Values followed by different letters within a row are significant at the level 0.05.

these differences are probably related to the variety and environment in which the crops are grown. The experimental results show that oilseeds and by-products from oil production can be a good source of K and P, Fe and Zn but are deficient in Na and Cu content. The wide range in microelement content in analyzed samples points out that this issue is not covered by a sufficient number of relevant studies and works that would be available. In this way, further research in the future is needed.

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