https://doi.org/10.17221/159/2022-CJFS

The effects of heat treatment on the quality of fat in flaxseeds and chia seeds

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Citation: Brestenský M., Nitrayová S., Patráš P. (2023): The effects of heat treatment on the quality of fat in flaxseeds and chia seeds. Czech J. Food Sci., 41: 21–28.

Abstract: Flaxseeds (*Linum usitatissimum* L.) (FS) and chia seeds (*Salvia hispanica* L.) (ChS) contain fatty acids (FA) with beneficial health effect for the human body. Some people often use them as part of boiled or baked dishes. Therefore, the aim of this study was to observe the effect of FS and ChS heat treatments at 40 °C and 150 °C for 20 min on the content of fat, FA, atherogenicity index (AI) and thrombogenicity index (TI), and total antioxidant activity (TAA) in comparison with heat treatments at 20 °C. The content of fat in FS was higher in comparison with ChS ($P < 0.05$). Similarly, the content of alpha-linolenic acid, oleic acid, polyunsaturated FA, and monounsaturated FA was greater ($P < 0.05$) in FS when compared with ChS. However, n6 : n3 ratio [n6 – omega 6 polyunsaturated FA (PUFA), with first double bound on 6th carbon; n3 – omega 3 PUFA, with first double bound on 3rd carbon], AI and TI were lower ($P < 0.05$) in FS in comparison with ChS. The TAA in FS was 37% lower ($P < 0.05$) compared to ChS, moreover TAA in FS decreased ($P < 0.05$) at 150 °C in comparison with 20 °C and 40 °C. No effect of different heat treatments was observed on the content of FA or AI and TI in FS and ChS.

Keywords: α-linolenic acid; antioxidant activity; fatty acids; linoleic acid, temperature

Flaxseeds (*Linum usitatissimum* L.) and chia seeds (*Salvia hispanica* L.) are sources of nutritional compounds important in nutrition. It is well known that both seeds are sources of polyunsaturated fatty acids (PUFA), fibre, protein and antioxidants, and their consumption has a positive effect on human health (Bowen et al. 2016; Opyd et al. 2018). The quality of fat is also characterized by the atherogenicity index (AI) and thrombogenicity index (TI) (Razmaitė et al. 2021).

The seeds are consumed either raw or processed under high temperature (Zettel and Hitzmann 2018). However, the heat treatment of food may have a negative effect on the nutritional value of products (Moussa et al. 2014) and therefore, the question has been raised

Supported by the Operational program Integrated Infrastructure, Demand-driven research for the sustainable and innovative food, Drive4SIFood (Project No. 313011V336) co-financed by the European Regional Development Fund.

https://doi.org/10.17221/159/2022-CJFS

whether the heat treatment adversely affects the content of fatty acids (FA) either in flax or chia seeds.

Both flax and chia seeds contain polyphenols which are characterized by antioxidant activities and therefore, these compounds may have a protective effect against negative external conditions (Nykter et al. 2006). Therefore, the nutritional value of seeds during thermal processing could be protected by these compounds. The results of studies which compared the effect of heat treatment on the content of fatty acids (FA) in flaxseeds are controversial. In some studies, the content of FA in flaxseeds was adversely affected by high temperature (Ganorkar and Jain 2014; Moknatjou et al. 2015), however, in the others it was not (Epaminondas et al. 2011). The studies aimed at the effect of heat treatment on the content of FA in chia seeds are scarce (Imran et al. 2016; Ghafoor et al. 2018).

Therefore, the aim of the present study was to compare the effect of heat treatment at different temperatures on the content of fat, FA, AI, TI and total antioxidant activity (TAA) in flaxseeds and chia seeds. The comparisons of both plant seeds were also performed.

MATERIAL AND METHODS

Samples and experimental design. The study was performed using brown flaxseed (*Linum usitatissinum* L.) and chia seeds (*Salvia hispanica* L.). Tested samples of seeds of each plant were of the same batch. Samples were obtained by purchasing from a regular market store. There were 3 treatments, with 4 replicates per each treatment and per seeds of each tested plant. A total of 1 500 g either flax or chia seeds were milled. After that, from the batch of the milled sample, 3 treatments with a total of 12 replicates per tested seeds were formulated. The weight of each replicate was 125 g. Treatments were as follows: treatment at ambient temperature of 20 °C, treatments with thermal processing at 40 °C and 150 °C for 20 min. The samples of the treatment at 20 °C were stored in a room with a controlled environment. The heat treatment was performed in a combi oven at dry heat, with a controlled temperature environment. After the heat treatment, the samples were cooled at room temperature and the chemical analyses were performed.

Chemical analyses and calculations. In the samples of tested seeds, the content of dry matter (DM), fat, FA and TAA were analysed. The TAA was analysed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method – radical scavenging activity. The content of DM and fat was determined according to Association of Official Agricultural Chemists [AOAC (1990): Official Methods of Analysis of the Association of Official Analytical Chemists. 15th ed. Arlington, AOAC Intl.].

The radical scavenging activity of samples was measured using DPPH according to the procedures described by Sánchez-Moreno et al. (1998). An amount of 1 mL of extract was added to 4 mL of DPPH solution (0.025 g DPPH in 100 mL ethanol). The absorbance of the reaction mixture was determined using the spectrophotometer (6405 UV/Vis; Jenway, England) at 515 nm. The radical scavenging activity of the samples was expressed as Trolox equivalent antioxidant capacity (mg TEAC·g^{-1} extract) (TEAC – trolox-equivalent antioxidant capacity). Dry matter content was determined gravimetrically. The samples were dried using a laboratory BMT Venticell 707 oven at 103 ± 2 °C for 24 h. After then the samples were cooled in a desiccator and 5 g of the samples were put back into the dryer and dried at 103 ± 2 °C for 4 hours until the given temperature was reached.

The fat content was determined by Soxhlet extraction method after extraction of 3 g of the homogenized sample with petroleum ether in a SER148 Soxhlet extractor (Velp Scientifica, Italy) for 6 h. The solvent was added to the boiling flask, the volume of which was 1.5 times larger than the volume of the extractor. After the extraction was finished and the solvent was distilled off, the flask with the fat was dried and the fat content was determined by weighing. The content of FA was analysed after extraction of the samples with petroleum ether and subsequent esterification with an esterifying agent, such as methyl esters of FA, by gas chromatography using a GC 6890N gas chromatograph (Agilent Technologies, USA). The content of fat and FA was expressed either as g·kg^{-1} of DM or as g·(100 g)$^{-1}$ of fat.

Atherogenicity index (AI) and thrombogenicity index (TI) were calculated according to Ulbricht and Southgate (1991) and Senso et al. (2007).

Statistical analysis. Statistical analyses of experimental data were performed using one-way ANOVA of Statgraphic Plus (Software package, version 3.1; Statistical Graphic Corp. 1997, USA). The effect of heat treatment and the effect of different plant seeds on the examined data was observed. When a significant value for the treatment effect ($P < 0.05$) was obtained, the differences between means were assessed using Fisher's LSD procedure. The presented data are means of the values obtained in the experiment using individual replicates. For a comparison of flaxseeds and chia seeds, the values of all treatments within the flax or chia were

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polled together. Each replicate was considered an experimental unit.

RESULTS AND DISCUSSION

Fat and fatty acid content. The fat content in flaxseed was 21% higher ($P < 0.05$) in comparison with chia seeds (Table 1). Similar results were also reported in other studies (Nitrayová et al. 2014; Kaur et al. 2018). The major FA in flax and chia are palmitic, stearic, oleic acid, linoleic acid (LA) and α-linolenic acid (ALA). The content of other FA in both seeds is represented to a minor extent (Table 1). This is in agreement with the results published by Matthäus and Özcan (2017) and Ghafoor et al. (2018). The greatest difference between the tested seeds was observed in arachidic acid, whose content was 80% greater in chia seed in comparison with flaxseed ($P < 0.05$). However, the content of oleic acid in flaxseed (65.51 g·kg^{-1} DM) was 65% greater ($P < 0.05$) when compared with chia seed (23.06 g·kg^{-1} DM). Similarly, the content of ALA was 25% greater ($P < 0.05$) in flaxseed than in chia seed. The content of other FA in the seeds varied between 21% and 41% ($P < 0.05$). There were no differences observed in the content of saturated fatty acids (SFA) between the seeds. However, the content of monounsaturated fatty acids (MUFA) and PUFA was 64% and 17% higher, respectively, ($P < 0.05$) in flaxseed than in chia seeds.

Both ALA and LA are essential because the human body is not able to synthesize them and therefore, their

Table 1. The content of studied parameters in tested flaxseed and chia seed (means of all treatments ± SD; $n = 12$)

Item	Unit of measurement	Tested seed	
		flaxseed	chia seed
Dry matter	%	96.92 ± 1.02^{a}	95.51 ± 1.12^{b}
Fat	g·kg^{-1} DM	427.64 ± 3.70^{a}	336.69 ± 20.20^{b}
Caprylic acid	g·kg^{-1} DM	0.43 ± 0.02	0.51 ± 0.41
Capric acid	g·kg^{-1} DM	0.43 ± 0.02^{a}	0.34 ± 0.01^{b}
Lauric acid	g·kg^{-1} DM	0.43 ± 0.02^{a}	0.34 ± 0.01^{b}
Myristic acid	g·kg^{-1} DM	2.00 ± 0.81	2.07 ± 0.13
Palmitic acid	g·kg^{-1} DM	24.55 ± 3.03	23.34 ± 0.95
Palm-oleic acid	g·kg^{-1} DM	0.43 ± 0.02	0.56 ± 0.54
Heptadecanoic acid	g·kg^{-1} DM	0.43 ± 0.02^{a}	0.34 ± 0.05^{b}
Stearic acid	g·kg^{-1} DM	10.85 ± 2.11	7.41 ± 0.53
Oleic acid	g·kg^{-1} DM	65.51 ± 7.29^{a}	23.06 ± 1.08^{b}
Linoleic acid	g·kg^{-1} DM	57.84 ± 5.87	59.32 ± 3.57
α-linolenic acid	g·kg^{-1} DM	223.19 ± 20.53^{a}	168.20 ± 11.80^{b}
Arachidic acid	g·kg^{-1} DM	0.50 ± 0.17^{a}	0.90 ± 0.18^{b}
Eicosenoic acid	g·kg^{-1} DM	0.57 ± 0.23^{a}	0.34 ± 0.01^{b}
Arachidonic acid	g·kg^{-1} DM	0.43 ± 0.23^{a}	0.34 ± 0.01^{b}
Behenic acid	g·kg^{-1} DM	0.50 ± 0.23	0.39 ± 0.01
SFA	g·kg^{-1} DM	37.82 ± 3.84	34.35 ± 1.62
MUFA	g·kg^{-1} DM	66.01 ± 7.26^{a}	23.73 ± 0.93^{b}
PUFA	g·kg^{-1} DM	273.52 ± 39.05^{a}	227.57 ± 14.67^{b}
n6 : n3 ratio	–	0.3 ± 0.0^{a}	0.4 ± 0.0^{b}
AI	–	0.098 ± 0.015^{a}	0.128 ± 0.006^{b}
TI	–	0.506 ± 0.014^{a}	0.653 ± 0.018^{b}
TAA	mg TEAC·g^{-1} extract	2.1 ± 0.3^{a}	2.9 ± 0.3^{b}

$^{a, b}$ statistically significant differences ($P < 0.05$); SD – standard deviation; SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; DM – dry matter; AI – atherogenicity index; TI – thrombogenicity index; TAA – total antioxidant activity; TEAC – trolox-equivalent antioxidant capacity

https://doi.org/10.17221/159/2022-CJFS

dietary intake is necessary (Gorjão et al. 2009). Flaxseed and chia seed are good sources of PUFA, however, the content of PUFA is higher in flaxseed in comparison with chia seed. Similar results were reported by other studies (Kaur et al. 2018).

The positive effect of ALA on human health is well documented (The European Food Safety Authority, EFSA 2011). The content of ALA is greater in flaxseed in comparison with chia seed. Contrary to our results, Nitrayová et al. (2014) reported no difference in the content of ALA between chia seed and flaxseed. However, in their study, the content of FA was expressed as of FA ratio (%). When the content of ALA in the present study was expressed per 100 g of fat, no differences were observed in the content of ALA between the flax and chia seeds (Table 2). The content of SFA expressed per 100 g of fat was greater ($P < 0.05$) in chia seed compared with flaxseed, however, the content of MUFA was 54% greater ($P < 0.05$) in flaxseed in comparison with chia seed.

Dietary n6 : n3 ratio. The ideal dietary ratio intake of n6 : n3 FA for humans should be in the range of 1 : 1 to 3 : 1. However, a modern western diet provides a dietary ratio of n6 : n3 which is considerably higher. Therefore, the inclusion of dietary fats with low n6 : n3 ratio will be beneficial to health of the body (Simopoulos 2016). The n6 : n3 ratio was lower in flaxseed when compared with chia seed (0.3 vs. 0.4; $P < 0.05$) (Table 1). Similarly, Dubois et al. (2007) reported the n6 : n3 ratio in flaxseed 0.3, however, for comparison, in sunflower seed, olive seed and soybean the ratio was 131, 16 and 6.7, respectively.

Atherogenicity and thrombogenicity indices. The quality of fats may also be expressed by AI and TI. The TI shows to form clots in blood vessels, while the AI indicates the relationship between the sum of the main SFA and that of the main classes of unsaturated fatty acids, the former being considered proatherogenic (favouring the adhesion of lipids to cells of the immunological and circulatory system), and the latter anti-atherogenic (inhibiting the aggregation of plaque material and diminishing the levels of esterified fatty acids, cholesterol, and phospholipids, thereby preventing the appearance of micro- and macro-cor-

Table 2. The content of fatty acids in tested flaxseed and chia seed (means of all treatments ± SD; $n = 12$)

Item	Unit of measurement	Tested seed	
		flaxseed	chia seed
Caprylic acid	g·(100 g)$^{-1}$ fat	0.10 ± 0.00	0.15 ± 0.00
Capric acid	g·(100 g)$^{-1}$ fat	0.10 ± 0.01	0.10 ± 0.01
Lauric acid	g·(100 g)$^{-1}$ fat	0.10 ± 0.00	0.10 ± 0.00
Myristic acid	g·(100 g)$^{-1}$ fat	0.47 ± 0.18	0.62 ± 0.04
Palmitic acid	g·(100 g)$^{-1}$ fat	5.73 ± 0.52	6.93 ± 0.25
Palm-oleic acid	g·(100 g)$^{-1}$ fat	0.10 ± 0.00	0.17 ± 0.16
Heptadecanoic acid	g·(100 g)$^{-1}$ fat	0.10 ± 0.01	0.10 ± 0.01
Stearic acid	g·(100 g)$^{-1}$ fat	2.54 ± 0.49	2.20 ± 0.14
Oleic acid	g·(100 g)$^{-1}$ fat	15.30 ± 1.25^{a}	6.85 ± 0.30^{b}
Linoleic acid	g·(100 g)$^{-1}$ fat	13.51 ± 0.96^{a}	17.62 ± 1.00^{b}
α-linolenic acid	g·(100 g)$^{-1}$ fat	52.15 ± 3.46	49.95 ± 3.17
Arachidic acid	g·(100 g)$^{-1}$ fat	0.12 ± 0.04^{a}	0.27 ± 0.05^{b}
Eicosenoic acid	g·(100 g)$^{-1}$ fat	0.13 ± 0.05	0.10 ± 0.01
Arachidonic acid	g·(100 g)$^{-1}$ fat	0.10 ± 0.01	0.10 ± 0.00
Behenic acid	g·(100 g)$^{-1}$ fat	0.12 ± 0.04	0.12 ± 0.04
SFA	g·(100 g)$^{-1}$ fat	8.83 ± 0.64^{a}	10.20 ± 0.44^{b}
MUFA	g·(100 g)$^{-1}$ fat	15.42 ± 1.25^{a}	7.05 ± 0.28^{b}
PUFA	g·(100 g)$^{-1}$ fat	63.77 ± 6.97	67.58 ± 4.16
n6 : n3 ratio	–	0.3 ± 0.0^{a}	0.4 ± 0.0^{b}

$^{a, b}$ statistically significant differences ($P < 0.05$); SD – standard deviation; SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids

https://doi.org/10.17221/159/2022-CJFS

Table 3. The effect of different heat treatments on the studied parameters in tested flaxseed and chia seed (mean ± SD; n = 4)

Item	Unit of measurement	Flaxseed treatment			Chia seed treatment		
		20 °C	40 °C	150 °C	20 °C	40 °C	150 °C
Dry matter	%	96.12 ± 0.57^{ab}	96.86 ± 0.45^{ab}	97.79 ± 1.38^{b}	94.63 ± 1.24^{a}	95.39 ± 0.78^{a}	96.52 ± 0.68^{ab}
Fat	g·kg^{-1} DM	430.93 ± 13.36^{a}	438.93 ± 19.27a	413.07 ± 28.32^{a}	338.28 ± 6.38^{b}	334.53 ± 2.88^{b}	337.28 ± 2.68^{b}
Caprylic acid	g·kg^{-1} DM	0.430 ± 0.019	0.440 ± 0.023	0.413 ± 0.030	0.331 ± 0.010	0.841 ± 0.712	0.336 ± 0.004
Capric acid	g·kg^{-1} DM	0.432 ± 0.018^{a}	0.439 ± 0.024^{a}	0.414 ± 0.030^{a}	0.338 ± 0.010^{b}	0.335 ± 0.003^{b}	0.332 ± 0.005^{b}
Lauric acid	g·kg^{-1} DM	0.431 ± 0.019^{a}	0.432 ± 0.022^{a}	0.415 ± 0.031^{a}	0.337 ± 0.010^{b}	0.334 ± 0.002^{b}	0.337 ± 0.004^{b}
Myristic acid	g·kg^{-1} DM	1.31 ± 1.26	2.41 ± 0.21	2.30 ± 0.47	2.03 ± 0.03	2.01 ± 0.02	2.19 ± 0.22
Palmitic acid	g·kg^{-1} DM	23.04 ± 0.19	26.18 ± 3.94	24.43 ± 4.52	23.00 ± 0.92	23.92 ± 0.91	23.11 ± 1.37
Palm-oleic acid	g·kg^{-1} DM	0.432 ± 0.010	0.439 ± 0.024	0.414 ± 0.032	1.005 ± 0.932	0.335 ± 0.003	0.332 ± 0.009
Heptadecanoic acid	g·kg^{-1} DM	0.431 ± 0.019	0.437 ± 0.023	0.412 ± 0.030	0.332 ±0.010	0.333 ± 0.003	0.337 ± 0.049
Stearic acid	g·kg^{-1} DM	12.00 ± 3.89	10.55 ± 1.07	10.00 ± 1.36	7.45 ± 1.09	7.53 ± 0.30	7.25 ± 0.18
Oleic acid	g·kg^{-1} DM	63.66 ± 5.33^{a}	69.50 ± 9.87^{a}	63.38 ± 9.59^{a}	22.66 ± 0.43^{b}	23.92 ± 0.91^{b}	22.60 ± 1.91^{b}
Linoleic acid	g·kg^{-1} DM	57.01 ± 4.01	62.02 ± 8.31	54.51 ± 5.39	58.37 ± 2.77	61.90 ± 2.90	57.70 ± 5.23
α-linolenic acid	g·kg^{-1} DM	224.99 ± 17.99^{a}	235.45 ± 28.64^{a}	209.13 ± 16.17^{a}	164.62 ± 8.13^{b}	175.65 ± 7.19^{b}	164.33 ± 18.48^{b}
Arachidic acid	g·kg^{-1} DM	0.646 ± 0.283^{a}	0.439 ± 0.023^{a}	0.414 ± 0.030^{a}	1.014 ± 0.165^{b}	0.671 ± 0.009^{a}	1.015 ± 0.007^{b}
Eicosenoic acid	g·kg^{-1} DM	0.645 ± 0.284	0.435 ± 0.024	0.637 ± 0.034	0.337 ± 0.010	0.332 ± 0.002	0.338 ± 0.004
Arachidonic acid	g·kg^{-1} DM	0.432 ± 0.019^{a}	0.439 ± 0.023^{a}	0.414 ± 0.030^{a}	0.338 ± 0.010^{b}	0.335 ± 0.003^{b}	0.337 ± 0.003^{b}
Behenic acid	g·kg^{-1} DM	0.646 ± 0.282	0.438 ± 0.022	0.413 ±0.031	0.509 ± 0.230	0.334 ± 0.002	0.335 ± 0.005
SFA	g·kg^{-1} DM	37.22 ± 2.81	39.57 ± 4.84	36.68 ± 5.74	34.18 ± 1.59	35.47 ± 2.19	33.39 ± 1.22
MUFA	g·kg^{-1} DM	64.31 ± 5.62^{a}	70.15 ± 9.59^{a}	63.56 ± 5.40^{a}	24.01 ± 0.50^{b}	24.26 ± 0.91^{b}	22.94 ± 1.14^{b}
PUFA	g·kg^{-1} DM	281.77 ± 22.33	297.41 ± 37.00	241.38 ± 49.08	223.15 ± 10.67	237.55 ± 10.09	222.02 ± 23.71
n6 : n3 ratio	–	0.3 ± 0.0^{a}	0.3 ± 0.0^{a}	0.3 ± 0.0^{a}	0.4 ± 0.0^{b}	0.4 ± 0.0^{b}	0.4 ± 0.0^{b}
AI	–	0.084 ± 0.021^{a}	0.099 ± 0.004^{ab}	0.112 ± 0.001^{bc}	0.127 ± 0.001^{c}	0.123 ± 0.001^{c}	0.132 ± 0.113^{c}
TI	–	0.501 ± 0.004^{a}	0.504 ± 0.005^{a}	0.518 ± 0.037^{a}	0.652 ± 0.026^{b}	0.647 ± 0.001^{b}	0.666 ± 0.026^{b}

$^{a, b, c}$statistically significant differences ($P < 0.05$); SD – standard deviation; SFA – saturated fatty acids; DM – dry matter; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; AI – atherogenicity index; TI – thrombogenicity index

https://doi.org/10.17221/159/2022-CJFS

Table 4. Total antioxidant activity (TAA) in flaxseed and chia seed at different heat treatments (mean ± SD; n = 4)

Item	Unit of measurement	Flaxseed treatment			Chia seed treatment		
		20 °C	40 °C	150 °C	20 °C	40 °C	150 °C
TAA	mg TEAC·g^{-1} extract	2.4 ± 0.2^{a}	2.0 ± 0.1^{ab}	1.7 ± 0.1^{b}	2.8 ± 0.3^{c}	3.0 ± 0.1^{c}	3.0 ± 0.3^{c}

$^{a, b, c}$ statistically significant differences (P < 0.05); SD – standard deviation; TAA – total antioxidant activity; TEAC – trolox-equivalent antioxidant capacity

onary diseases) (Ulbricht and Southgate 1991; Senso et al. 2007). Healthy food is characterized by low AI and TI (Razmaitė et al. 2021). In the present study, differences were observed between flaxseed and chia seed in AI and TI; both were lower (P < 0.05) in flaxseed (Table 1). Similar results were reported in other studies (Nitrayová et al. 2014). For a comparison, AI and TI in salmon meat are 0.543 and 0.209, respectively (Moussa et al. 2014), while for pig meat they are 0.52 and 1.23, respectively (Razmaitė et al. 2011).

Effect of heat treatment on individual parameters. Flaxseed and chia seed contain PUFA which have a positive effect on human health; however, they are not stable under high temperatures (Bowen et al. 2016; Opyd et al. 2018). It has been documented that during the heat treatment of some foods, the content of FA is changed, and the quality of fats is adversely affected (Moussa et al. 2014). Chia seed or flaxseed are usually included in the products like cakes or porridges, which are prepared under the high temperatures and therefore, there is a possibility that the content of FA will change (Ganorkar and Jain 2014). Although flaxseed and chia seed contain PUFA which are not stable under thermal conditions (Schorno et al. 2010), in the present study there were observed no differences in the content of FA, n6 : n3 ratio, AI or TI between the different heat treatments of seeds (Table 3). The differences were observed only between the chia seed and flaxseed. Similarly, Imran et al. (2016) reported that the content of ALA in flaxseed is stable after extrusion at a temperature of 150 °C. This was observed also during roasting for 15 min (Epaminondas et al. 2011). Opposite to these results, other studies reported differences in the content of FA in flaxseeds at different heat treatments (Moknatjou et al. 2015). However, the temperatures used in these studies were in the range of 150 – 350 °C. It has been reported that in extracted flaxseed oil the temperature up to 75 °C did not affect FA content, however, at the temperature above 105 °C, an adverse effect on the content of FA was observed (Zhang et al. 2013).

Antioxidant activity. Flaxseed and chia seed contain flavonoids and polyphenols, which are characterized by antioxidative activity, and they have a protective effect against antioxidative damage (Nykter et al. 2006). In the present study, the TAA was 28% lower (P < 0.05) in flaxseed compared with chia seed (Table 1). This is in accordance with other studies (Sargi et al. 2013). Moreover, TAA in chia seed was not changed under the different heat treatments, however, in flaxseed it decreased (P < 0.05) at 150 °C in comparison with temperatures of 20 °C or 40 °C (Table 4). Although the oxidative stability of flaxseed oil decreases at a high temperature, it remains still high (Herchi et al. 2016). The flavonoids and polyphenols, which are beneficial to oil stability during heating (Marinova et al. 2012), have a protective effect against FA damage at high temperatures, even though the seeds are milled and the coating layer, which protects seeds, is broken (Cämmerer and Kroh 2009). This is the reason for the greater stability of FA in flax and chia seeds under different ambient conditions. The intensity of the temperature and the length of the time used during the heat treatment are factors that influence changes in FA contents, as was observed in the studies in which the heat treatment up to 350 °C or for a long time was performed (Moknatjou et al. 2015; Herchi et al. 2016).

CONCLUSION

Content of fat in flaxseed is 21% higher in comparison with chia seed. The major FA in flax and chia are palmitic, stearic, oleic acid, LA and ALA. Greater content of ALA was observed in flaxseed, however, when the content of FA was expressed per 100 g of fat, no difference was observed in the content of ALA between flax and chia seeds. The content of MUFA and PUFA is lower in flaxseed when compared with chia seed. Both flaxseed and chia seed have low n6 : n3 ratio, AI and TI, however, lower values were observed in flaxseed. The TAA is higher in chia seed when compared with flaxseed. No effect of heat treatment of flaxseed and chia seed was observed at 40 °C or 150 °C for 20 min on the content of FA, AI and TI when compared with 20 °C. However, in flaxseed, the TAA decreased at 150 °C in comparison with 20 °C and 40 °C.

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REFERENCES

Bowen K.J., Harris W.S., Kris-Etherton P.M. (2016): Omega-3 fatty acids and cardiovascular disease: Are there benefits? Current Treatment Options in Cardiovascular Medicine, 18: 69.

Cämmerer B., Kroh L.W. (2009): Shelf life of linseeds and peanuts in relation to roasting. LWT – Food Science and Technology, 42: 545–549.

Dubois V., Breton S., Linder M., Fanni J., Parmentier M. (2007): Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. European Journal of Lipid Science and Technology, 109: 710–732.

EFSA (2011): Scientific Opinion on the substantiation of health claims related to alpha-linolenic acid (ALA) and brain and neurological development (ID 491), 'molecule precursors regulating cell functions' (ID 492, 4671), maintenance of normal cardiac function (ID 509, 579), 'nutrient tasks and interactions' (ID 576), maintenance of normal blood pressure (ID 575), and enhancement of mood (ID 578, 601, 3182) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. EFSA Journal, 9: 2050.

Epaminondas P.S., Araújo K.L.G.V., Nascimento J.A., Silva M.C.D., Rosenhaim R., Soledade L.E.B., Queiroz N., Souza A.L., Santos I.M.G., Souza A.G. (2011): Influence of toasting and the seed variety on the physico-chemical and thermo-oxidative characteristics of the flaxseed oil. Journal of Thermal Analysis and Calorimetry, 106: 545.

Ganorkar P.M., Jain, R.K. (2014): Effect of flaxseed incorporation on physical, sensorial, textural and chemical attributes of cookies. International Food Research Journal, 21: 1515–1521.

Ghafoor K., Aljuhaimi F., Özcan M.M., Uslu N., Hussain S., Babiker E.E., Fadimu G. (2018): Effects of roasting on bioactive compounds, fatty acid, and mineral composition of chia seed and oil. Journal of Food Processing and Preservation, 42: 1–7.

Gorjão R., Azevedo -Martins A.K., Rodrigues H.G., Abdulkader F., Arcisio-Miranda M., Procopio J., Curi R. (2009): Comparative effect of DHA on cell function. Pharmacology and Therapeutics, 122: 56–64.

Herchi W., Ben Ammar K., Bouali I., Bou Abdallah I., Guetet A., Boukhchina S. (2016): Heating effects on physicochemical characteristics and antioxidant activity of flaxseed hull oil (*Linum usitatissimum* L.). Food Science and Technology (Campinas), 36: 97–102.

Imran M., Nadeem M., Manzoor M.F., Javed A., Ali Z., Akhtar M.N., Ali M., Hussain Y. (2016): Fatty acids characterization, oxidative perspectives and consumer acceptability of oil extracted from pre-treated chia (*Salvia hispanica* L.) seeds. Lipids in Health and Disease, 1: 162.

Kaur P., Waghmare R., Kumar V., Rasane P., Kaur S., Gat Y. (2018): Recent advances in utilization of flaxseed as potential source for value addition. Oilseeds and Fats, Crops and Lipids, 25: A304.

Marinova E.M., Seizova K.A., Totseva I.R., Panayotova S., Marekov I.N., Momchilova S.M. (2012): Oxidative changes in some vegetable oils during heating at frying temperature. Bulgarian Chemical Communications, 44: 57–63.

Matthäus B., Özcan M.M. (2017): Fatty acid composition, tocopherol and sterol contents in linseed (*Linum usitatissimum* L.) varieties. Iranian Journal of Chemistry and Chemical Engineering, 36: 147–152.

Moknatjou R., Hajimahmoodi M., Toliyat T., Moghaddam G., Sadeghpour O., Monsef-Esfahani H., Shams-Ardekani M.R. (2015): Effect of roasting on fatty acid profile of brown and yellow varieties of flaxseed (*Linum usitatissimum* L.). Tropical Journal of Pharmaceutical Research, 14: 117–123.

Moussa E., Shereen A., Manal A., Mehanni A., Rasha A. (2014): Nutritional value and fatty acid composition of household cooking on fish fatty acids profile using atherogenicity and thrombogenicity indices. Journal of Food Chemistry and Nutrition, 2: 27–41.

Nitrayová S., Brestenský M., Heger J., Patráš P., Rafay J., Sirotkin A. (2014): Amino acids and fatty acids profile of chia (*Salvia hispanica* L.) and flax (*Linum usitatissimum* L.) seed. Slovak Journal of Food Sciences, 8: 72–76.

Nykter M., Kymäläinen H.R., Gates F., Sjöberg A.M. (2006): Quality characteristics of edible linseed oil. Agricultural and Food Science, 15: 402–413.

Opyd P.M., Jurgoński A., Juśkiewicz J., Fotschki B., Koza J. (2018): Comparative effects of native and defatted flaxseeds on intestinal enzyme activity and lipid metabolism in rats fed a high-fat diet containing cholic acid. Nutrients, 10: 1181.

Razmaitė V., Švirmickas G.J., Šiukščius A., Šveistienė R. (2011): Comparative characterization of fatty acid profiles in intramuscular lipids from different domestic and wild monogastric animal species. Veterinarija ir Zootechnika, 53: 45–50.

Razmaitė V., Pileckas V., Bliznikas S., Šiukščius A. (2021): Fatty Acid composition of *Cannabis sativa*, *Linum usitatissimum* and *Camelina sativa* seeds harvested in Lithuania for food use. Foods, 10: 1902.

Sánchez-Moreno C., Larrauri A., Saura-Calixto F. (1998): A procedure to measure the antioxidant efficiency of polyphenols. Journal of the Science of Food and Agriculture, 76: 270–276.

Sargi S.C., Silva B.C., Santos H.M.C., Montanher P.F., Boeing J.S., Santos Júnior O.O., Souza N.E., Visentainer J.V. (2013): Antioxidant capacity and chemical composition in seeds rich in omega-3: chia, flax, and perilla. Food Science and Technology (Campinas), 33: 541–548.

https://doi.org/10.17221/159/2022-CJFS

Schorno A.L., Manthey F.A., Hall C.A. (2010): Effect of particle size and sample size on lipid stability of milled flaxseed (*Linum usitatissimum* L.). Journal of Food Processing and Preservation, 34: 167–179.

Senso L., Suárez M.D., Ruiz-Cara T., García-Gallego M. (2007): On the possible effects of harvesting season and chilled storage on the fatty acid profile of the fillet of farmed gilthead sea bream (*Sparus aurata*). Food Chemistry, 101: 298–307.

Simopoulos A.P. (2016): An increase in the omega-6/omega-3 fatty acid ratio increases the risk for obesity. Nutrients, 8: 128.

Ulbricht T.L., Southgate D.A. (1991): Coronary heart disease: Seven dietary factors. Lancet, 338: 985–992.

Zettel V., Hitzmann B. (2018): Applications of chia (*Salvia hispanica* L.) in food products. Trends in Food Science and Technology, 80: 43–50.

Zhang Z.S., Li D., Zhang L.X. (2013): Effect of heating on the fatty acid composition and oxidation products of flaxseed oil. Asian Journal of Chemistry, 25: 10082–10086.

Received: August 31, 2022
Accepted: December 19, 2022
Published online: January 24, 2023