Potravinarstvo, vol. 8, 2014, no. 1, p. 72-76
doi:10.5219/332
Received: 10 February 2014. Accepted: 20 Februaryl 2014.
Available online: 7 May 2014 at www.potravinarstvo.com

ISSN 1337-0960 (online)

AMINO ACIDS AND FATTY ACIDS PROFILE OF CHIA (*SALVIA HISPANICA* L.) AND FLAX (*LINUM USITATISSIMUM* L.) SEED

Soňa Nitrayová, Matej Brestenský, Jaroslav Heger, Peter Patráš, Ján Rafay, Alexander Sirotkin

ABSTRACT

The seeds of most plants are rich in various nutrients and can provide a lot of useful health benefits. The objective of this study was to determine and compare differences in fat, fatty acids, crude protein and amino acids concentrations for chia and flax seeds. Study was carried out using brown and gold seeds of Flax (*Linum usitatissimum* L.) and Chia (*Salvia hispanica* L.). The mean protein content in tested seeds ranged from 211.8 to 252.5 g/kg dry matter and in chia seed was about 13.10% higher than the average value of crude protein content in brown and gold flax seed (223.25 g/kg dry matter). Differences in the content of individual amino acids among the seeds were not statistically significant ($P < 0.05$), except that for glutamic acid. Percentage of the essential to the total amino acids, which is considered as indicator of protein quality, was 37.87%, 33.76% and 35.18%, for chia, brown and gold flax seed respectively, which demonstrates the high quality of these proteins. The average fat content of flax seeds was about 71.42 g/kg higher than that in chia seed (321.37 g/kg dry matter). The fatty acids composition showed the presence of palmitic, stearic, oleic, linoleic, α- linolenic and arachidic fatty acids in all tested samples. The α-linolenic acid constitutes on average 54.38% of the total fatty acids of flax seeds and 63.79% of chia seed, and for linoleic acid it was 15.30% and 18.89%. All seeds had low n-6 PUFA / n-3 PUFA ratio. Results of our study confirmed the excellent quality of protein and fat in chia seed, brown and gold flax seed samples. There was no significant effect of the flax seed coat colour for all measured values. Chia seed is the richest of n-3 PUFA α-linolenic fatty acid in the vegetable world. Both, flax seed and chia seed are the good choice of healthy food to maintain a balanced serum lipid profile. It must be pointed that flax seeds must be ground to release their nutrients, but chia seeds do not.

Keywords: amino acid; α-linolenic fatty acid; chia seed; fatty acid; flax seed

INTRODUCTION

Plant products are currently popular to combat various physiological threats. Scientific evidence has been provided that dietary phytochemicals can play important roles in the treatment and prevention of many diseases. With increasing public health awareness, demand for functional foods with multiple health benefits has also increased. It is possible to say that all foods are functional because they provide varying amounts of nutrients for growth or support of vital processes. Functional foods are generally considered as the foods which offer various benefits that may promote optimal health or reduce the risk of disease **(Hasler et al., 2000)**.

The seeds of most plants are rich in various nutrients and can provide a lot of health benefits. Flax seed and chia seed are renowned as good nutritional sources. These seeds originate from agricultural crops: Flax (*Linum usitatissimum* L.) and Chia (*Salvia hispanica* L.).

Flax is a member of the family *Linaceae*. It is a food and fibre crop (Flax varieties grown for human consumption are different from flax varieties grown to produce fibre) that is grown in cooler regions of the world. Flax is an annual plant growing to about 1.2 m tall, with slender stems. The flowers are usually blue, with five petals; they can also be bright red. The fruit is a round and dry capsule (5-9 mm), contains several glossy, flat, oval seeds with a pointed tip, 4 - 6 mm in length **(Daun, et al., 2003)**. The seeds have a chewy texture and a pleasant nutty taste **(Carter, 1996)**. There are two basic varieties, brown and yellow or golden. Seed colour is determined by the amount of pigment in the outer seed coat.

Salvia hispanica, or more commonly known as chia, has a long history of use as a food in South and Central America, not only for humans but for animals as well. It was one of the main foods of the old Aztecs and Mayas. Chia is a biannually cultivated plant which is a member of the family Labiatae. It is a low water user plant which is well adapted to arid and semiarid climates **(Ayerza, 1995)**. Chia can grow up to 1 m tall, has opposite arranged leaves and chia flowers are small and usually purple (3-4 mm) with small corollas. The seed coat colour ranges from black, grey, and black spotted to white and the shape is oval with size varying from 1 to 2 mm **(Ixtaina et al., 2008)**.

Polyunsaturated fatty acids (PUFA): linoleic acid (C18:2 n-6) and α-linolenic (C18:3 n-3) are essential nutrients, i.e. humans and animals must obtain them by food because the body requires them for many metabolic processes, but

cannot synthesize them **(Gorjao et al., 2009)**. Then highly unsaturated metabolites can be created from these fatty acids; arachidonic acid and γ-linolenic acid (n-6 PUFA) from linoleic acid (LA) and the most important metabolites: eicosapentaenoic acid and docosahexaenoic acid (n-3 PUFA) from α-linolenic acid (ALA).

The well-known source of n-3 PUFAs are marine fish **(Gorjao et al., 2009)**, but flax seeds and chia seeds are important plant sources as well. These are the two vegetal species having the highest concentration of ALA **(Ayerza, 1995; Coates and Ayerza, 1998; Oomah et al., 1995)**. Most of studies have been carried out with fish and fish oils, which are rich in eicosapentaenoic acid and docosahexaenoic acid, but also with various plant seeds and their oils as a source of ALA.

A low ratio of n-6 PUFA / n-3 PUFAs in daily food is the best way how to help many metabolic processes in the body. The problem is that for today's diets the high content of saturated fatty acids and n-6 PUFA and low content of n-3 PUFA is typical **(Simopoulos, 2004)**. Typically modern diets have greater ratio n-6 PUFA / n-3 PUFA than 15:1. This imbalance increases the risk of heart disease and support body's inflammatory processes. The ideal ratio is from 1:1 to 3:1.

The aim of this study was to determine and compare differences in nutrient content (fat, fatty acids, crude protein and amino acids concentrations) for chia and flax seed.

MATERIAL AND METHODOLOGY

The object of our analyses were six samples of brown and gold flax seed (Figure 1) and three samples of chia seed (Figure 2) which were obtained from health food stores.

Tested seeds were milled and analyzed for content of dry matter, crude protein and ether extract in accordance with **AOAC (1990)** standard procedures.

The amino acid composition of tested samples was analyzed by ion-exchange chromatography **(Llames and Fontaine, 1994)**. The content of amino acids after hydrolysis with 6 M HCl and Met with Cys after oxidative hydrolysis were determined using an automatic AA analyzer (AAA 400; Ingos, Prague, Czech Republic).

The content of long chain fatty acids we analysed after extraction of samples with petroleum ether and subsequent esterification with esterifying agent such as methyl esters of fatty acids by gas chromatography using gas chromatograph GC 6890N (Agilent Technologies).

Experimental data were analysed by ANOVA using Statgraphic Plus package (version 3.1; Statistical Graphics Corp.,Rockville, MD). Differences were considered statistically significant if $P < 0.05$. When a significant value for treatment means was observed, differences between means were assessed using Fisher's LSD procedure.

RESULTS AND DISCUSSION

The main values for studied nutrients: dry matter, fat, crude protein and amino acids are summarized in Table 1. The values of dry matter show a close similarity between the chia seed, brown and gold flax seed.

The concentration of crude protein in all samples ranged from 211.8 to 252.5 g/kg dry matter. Numerically highest content of crude protein was determined in chia seed (252.5g/kg dry matter) and this value was about 13.10% higher than the average value of crude protein content in brown and gold flax seed (223.25 g/kg dry matter). Difference in the content of crude protein between brown and gold flax seed was also close to ten percent (9.78%). Our values of crude protein content correspond to those in the literature. **Sammour (1999)** reported that the total proteins in flax seed represent about 20-30% of the seed meal, which makes it a good source of proteins.

The highest amount of total amino acids was in brown flax seed (202.0 g/kg dry matter). Crude protein content was higher in chia seed but total amino acid content was higher in brown flax seed, due to higher content of nonessential amino acids especially glutamic acid, glycine and aspartic acid (Table 1). There was only one statistically significant difference - for glutamic acid in chia and brown flax seed. The amount of total essential amino acids was the lowest in the gold flax seed (64.0 g/kg dry matter) and almost practically the same in chia and gold flax seed (68.6 and 68.2 g/kg dry mater). All the above mentioned differences were not statistically significant ($P < 0.05$).

Figure 1 Flax (*Linum usitatissimum*) and flax seed

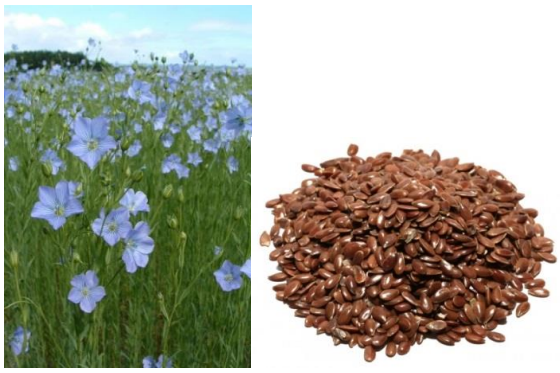

Figure 2: Chia (**Salvia** *hispanica*) and chia seed

Table 1 Content of studied nutrients in analysed seeds, g/kg DM

	Chia seed	Brown Flax seed	Gold Flax seed	SEM
Dry matter	930.3	935.0	925.1	0.1
Fat	321.37	383.44	402.13	0.1
CP*	252.5	234.7	211.8	0.1
Arginine	20.0	24.0	20.7	0.1
Phenylalanine	11.6	10.2	9.2	0.1
Histidine	6.1	5.1	4.8	0.0
Isoleucine	7.4	8.6	7.7	0.1
Leucine	14.2	12.9	11.7	0.2
Lysine	9.3	9.1	8.8	0.3
Methionine	6.7	4.9	5.1	0.3
Threonine	5.4	7.1	7.5	0.5
Valine	7.9	10.3	9.2	0.1
Alanine	9.4	9.9	9.1	0.1
Aspartic acid	12.8	14.1	11.3	1.1
Cystine	4.2	3.2	2.8	0.0
Glutamic acid	28.7[a]	45.1[b]	39.6[b]	0.8
Glycine	9.1	13.3	12.0	0.1
Proline	12.8	9.1	8.3	0.2
Serine	9.4	10.2	9.4	0.2
Tyrosine	6.1	4.9	4.7	0.0
Total AA*	181.1	202.0	181.9	1.4
Total EAA*	68.6	68.2	64.0	1.1
Total NEAA*	112.5	133.8	117.9	2.7

[abc] means in row are significantly different ($P < 0.05$)

*CP - crude protein, AA - amino acids, EAA - essential amino acids, NEAA - non-essential amino acids

When comparing the proportions of amino acids in brown and gold flax seed, except methionine and threonine, all other amino acids in gold flax seed were lower compared with brown flax seed, but differences were not statistically significant ($P < 0.05$). Proteins of flax seeds are limited by lysine, threonine and tyrosine **(Thompson and Cunnane, 2003)**. Our values of lysine content in both colour varieties of flax seeds were lower than the content of lysine in chia seed (Table 1). Proteins of flax seeds are characterized by a high coefficient of digestibility (89.6%) and biological value (77.4%) **(Martinchik, 2012)**. Brown flax seed proteins contain relatively higher levels of aspartic acid, glutamic acid and arginine (Table 1). These values indicate the high content of amides **(Ayad, 2010)**. The amino acid pattern of flax protein is similar to that of soybean protein, which is viewed as one of the most nutritious of the plant proteins **(Oomah and Mazza, 1993)**. Flax seed proteins, brown and gold variety, contain 33.76% and 35.18% as percentage of the essential to the total amino acids. The value of this indicator for chia seed was 37.87%. Proteins with such high values are considered as a high quality protein. **Ayad (2010)** reported 36% for flax seed protein in his study.

The protein quality of chia has been demonstrated to be higher than that of common cereals and oil seeds **(Weber et al., 1991; Reyes-Caudillo et al., 2008)**, which is in accordance with our results. All tested seeds were rich in fat (Table 1). The average fat content of both varieties of flax seed was about 71.42 g/kg higher than that in chia seed, but there were no significant differences in total fat content. There was close similarity to the results of **Capitany et al. (2013)**, which present 327 ±8.0 g/kg for chia seed in his study.

Gas chromatography analysis of the fatty acids composition showed the presence of palmitic, stearic, oleic, linoleic, α-linolenic and arachidic fatty acids in all tested samples. In addition, three more fatty acids were identified in all analyses: lauric, myristic and palmitooleic. However, all of them were present just in traces. Only one significant difference among fatty acids was detected, it was for oleic acid (Table 2). The fatty acid profile for

Table 2 Content of fatty acids, %

		Chia seed	Brown Flax seed	Gold Flax seed	SEM
12:0	Lauric acid	0.03	0.03	0.03	0.00
14:0	Myristic acid	0.06	0.06	0.04	0.01
16:0	Palmitic acid	7.04	6.14	5.39	0.04
16:1 n-7	Palmitoleic acid	0.03	0.05	0.02	0.01
18:0	Stearic acid	2.84	4.23	3.17	0.00
18:1 n-9	Oleic acid	7.30[a]	22.43[b]	18.70[b]	0.22
18:2 n-6	Linoleic acid	18.89	14.47	16.13	0.02
18:3 n-3	α- linolenic acid	63.79	52.38	56.37	0.16
20:0	Arachidic acid	0.02	0.21	0.15	0.00
	Σ n-6	18.89	14.47	16.30	0.02
	Σ n-3	63.79	52.38	56.37	0.16
n-6 PUFA / n-3 PUFA		0.30	0.28	0.29	0.04

[abc] means in row are significantly different (P <0.05)

tested seeds was similar to that reported by another authors **(Ayerza, 1995, 2009, 2010; Coates and Ayerza, 2009; Martinchik, 2012)**. ALA constitutes on average 54.38% of the total fatty acids of flax seeds and 63.79% of chia seed and for LA it was 15.30% and 18.89%. Our results are in accordance with **Bhatty (1993)** who reported the ratio of LA in chia seed with about 18% and ALA with about 64% as unique. There was 53.3% of ALA for flax seed in his study. All these dates are close to ours. Both chia and flax seeds are rich in ALA, but chia seed is the highest plant-based source of ALA **(Ayerza and Coates, 2011)**.

All seeds had low n-6 PUFA / n-3 PUFA ratio (Table 2). This observation has important health implications. The best way to lower the risk of coronary heart disease is to keep dietary n-6 PUFA / n-3 PUFA ratios as low as possible **(Jones et al., 2006)**.

The 2010 Dietary Guidelines for Americans states reported that an adequate intake of ALA ranges between 1.1 and 1.6 grams/day for adults. Since 12 to 18 grams (2 to 3 teaspoons) of chia contain between 2.5 and 3.6 grams of ALA, this is more than a sufficient amount to meet this recommendation.

The EFSA Journal (2009) published labelling reference value for the n-3 PUFA ALA which is 2 g per day. This amount is consistent with recommended intakes for individuals in the general population in European countries based on considerations of cardiovascular health.

Flax seeds and chia seeds can be also used for feeding to animals to enrich their eggs and meat with omega 3 fats. Eggs from hens fed with chia had higher ALA content as compared to hens fed with flax seed **(EFSA Journal, 2009; Coates and Ayerza, 2009)**.

It is necessary to know that chia seeds can be consumed directly and do not need to be ground unlike flax, which must be ground or milled prior to consumption. Since flax seed content is protected by a thick shell and to obtain benefits from flax seeds it is necessary to use not whole seeds. Whole seeds passing through the digestive system undigested.

CONCLUSION

The quality of protein and fat in chia seed, brown and gold flax seed samples is excellent. Chia seed is the best known plant source with the highest content of n-3 PUFA α-linolenic fatty acid. Both flax seed and chia seed are the good choice of healthy food to maintain a balanced serum lipid profile. These seeds can be an appropriate alternative to n-3 PUFA sources for vegetarians and people allergic to fish. Flax seeds must be ground to release their nutrients, but chia seeds do not.

REFERENCES

Association of Official Analytical Chemists (AOAC). 1990. Official Methods of Analysis. 15th ed. AOAC, Arlington, VA.

Ayad A. A. 2010. *Characterization and properties of flaxseed protein fractions: dissertation theses.* Montreal, Canada: MC Gill University. p. 180.

Ayerza, R., Coates, W., 2011. Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (*Salvia hispanica* L.). *Industrial Crops and Products*, vol. 34, no. 2, p. 1366-1371. http://dx.doi.org/10.1016/j.indcrop.2010.12.007

Ayerza, R. 1995. Oil content and fatty acids composition of chia (Salvia hispanica L.) from five Northwestern locations in Argentina. Journal of the American Oil Chemist's Society, vol. 72, no. 9, p. 971-1090. [cit. 2014-02-13] Retrieved from the web: http://link.springer.com/article/10.1007%2FBF02660727

Ayerza, R. 2009. The seeds protein and oil content, fatty acids composition, and growing cycle length of a single genotype of chia (*Salvia hispanica* L.) as affected by environmental factors. *Journal of Oleo Science*, vol. 58, no.7, p. 347-54. http://dx.doi.org/10.5650/jos.58.347

Ayerza, R. 2010. Effect of seed color and growing locations on fatty acid content and composizion of two chia (*Salvia hispanica* L.) genotypes.as affected by environmental factors.

Journal of the American Oil Chemist's Society, vol. 87, no. 10, p. 1161-1165. http://dx.doi.org/10.1007/s11746-010-1597-7

Bhatty, R.S. 1993. Further compositional analyses of flax: mucilage, trypsin inhibitors and hydrocyanic acid. *Journal of American Oil Chemists´ Society*, vol. 70, no. 9, p. 899-904. http://dx.doi.org/10.1007/BF02545351

Capitani, M. I., Ixtaina, V. Y., Nolasco, S. M., Tomás, M. C. 2013. Microstructure, chemical composition and mucilage exudation of chia (*Salvia hispanica* L.) nutlets from Argentina. *Journal of the Science of Food and Agriculture*. vol. 93, no. 15, p. 3856-3862. http://dx.doi.org/10.1002/jsfa.6327

Carter, J. F. 1996. Sensory evaluation of flaxseed of different varieties. *Proceedings Flax Institute*, vol. 56, p. 201-203.

Coates, W., Ayerza. R. 1998. Commercial production of chia in Northwestern Argentina. *Journal of the American Oil Chemist's Society*, vol. 75, no. 10, p. 1417-1420. http://dx.doi.org/10.1007/s11746-998-0192-7

Coates, W., Ayerza. R. 2009. Chia (*Salvia hispanica* L.) seed as an n-3 fatty acids source for finishing pigs: effect on fatty acids composition and fat stability of the meat and internal fat, growth performance, and meat sensory characteristics. *Journal of Animal Science*, vol. 87, no. 11, p. 3798-804. http://dx.doi.org/10.2527/jas.2009-1987

Daun, J. K., Barthet, V. J., Chornick, T. L., Duguid, S. 2003. *Structure, composition, and variety development of flaxseed*. Flaxseed in Human Nutrition, 2nd ed, Champaign, IL: AOCS Press, p. 1-40, ISBN: 978-1-893997-38-7 http://dx.doi.org/10.1201/9781439831915.ch1

Gorjao, 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 Therapeutic*, vol. 122, no.1, p. 56-64. http://dx.doi.org/10.1016/j.pharmthera.2009.01.004

Hasler, C. M., Kundrat, S., Wool, D. 2000. Functional foods and cardiovascular disease. *Journal Current Atherosclerosis*, vol. 2, no. 6, p. 467-75. http://dx.doi.org/10.1007/s11883-000-0045-9

Ixtaina ,V. Y., Nolasco, S. M., Tomás, M. C. 2008. Physical properties of chia (*Salvia hispanica* L.) seeds. *Industrial Crops and Products*, vol. 28, no. 3, p. 286-293. http://dx.doi.org/10.1016/j.indcrop.2008.03.009

Jones, J. R., Lineback, D. M., Levine, M. J. 2006. Dietary Reference intakes: implications for fiber labeling and consumption: a summary of the International Life Sciences Institute North America Fiber Workshop, June 1-2, 2004, Washington, DC. *Nutrition Reviews*, vol. 64, no. 1, p. 31-38. http://dx.doi.org/10.1111/j.1753-4887.2006.tb00170.x PMid:16491667

Llames, C. R., J. Fontaine. 1994. Determination of amino acids in feeds: Collaborative study. *Journal of AOAC (Association of Official Analytical Chemists) International*, vol. 77, no. 5, 1362-1402.

Martinchik, A. N., Baturin, A. K., Zubtsov, V. V., Molofeev, V.I. 2012. Nutritional value and functional properties of flaxseed. *Voprosy pitaniia*, vol. 81, no. 3, p. 4-10.

Oomah, B. D., Kenaschuk, E. O., Mazza, G. 1995. Phenolic acids in flaxseed. *Journal of Agricultural and Food Chemistry*, vol. 43, no. 8, p. 2016-2019. http://dx.doi.org/10.1021/jf00056a011

Oomah, B. D., Mazza, G. 1993. Flaxseed proteins - A review. *Food Chemistry*, vol. 48, no. 2, p. 109-114. http://dx.doi.org/10.1016/0308-8146(93)90043-F

Reyes-Caudillo, E., Tecante, A., Valdivia-Lopez, M. A. 2008. Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (*Salvia hispanica* L.) seeds. *Food Chemistry*, vol. 107, no. 2, p. 656-663. http://dx.doi.org/10.1016/j.foodchem.2007.08.062

Sammour, R. H. 1999. Proteins of linseed (*Linum usitatissimum* L.), extraction and characterization by electrophoresis. *Botanical Bulletin of Academia Sinica*, vol. 40, no. 2, p. 121-126.

Scientific Opinion of the Panel on Dietetic products, Nutrition and Allergies on a request from European Commission related to labelling reference intake values for n-3 and n-6 polyunsaturated fatty acids. *The EFSA Journal*, 2009, 1176, p. 1-11.

Simopoulos, A. P. 2004. Omega-6/Omega-3 essential fatty acid ratio and chronic diseases. *Food Review International*. vol.1, no. 1, p. 77-90. http://dx.doi.org/10.1081/FRI-120028831

Weber, C. W., Gentry, H. S., Kohlhepp, E. A., McCrohan, P. R. 1991. The nutritional and chemical evaluation of chia seeds. *Ecology of Food and Nutrition*, vol. 26, no. 2, p. 119-125. http://dx.doi.org/10.1080/03670244.1991.9991195

Acknowledgments:

This article was written during realization of the project "ZDRAVIE no. 26220220176" supported by the Operational Programme Research and Development funded from the European Regional Development Fund.

Contact address:

MVDr. Soňa Nitrayová, PhD., National Agricultural and Food Center, Reasearch Institute of Animal Production Nitra, Institue of Nutrition, Hlohovecká 2, 951 41 Lužianky, Slovakia, E-mail: nitrayova@vuzv.sk

Ing. Matej Brestenský, PhD., National Agricultural and Food Center, Reasearch Institute of Animal Production Nitra, Institue of Nutrition, Hlohovecká 2, 951 41 Lužianky, Slovakia, E-mail: m_brestensky@vuzv.sk

Doc. Ing. Jaroslav Heger, PhD., National Agricultural and Food Center, Reasearch Institute of Animal Production Nitra, Institue of Nutrition, Hlohovecká 2, 951 41 Lužianky, Slovakia, E-mail: jaroslavheger@gmail.com

Ing. Peter Patráš, PhD., National Agricultural and Food Center, Reasearch Institute of Animal Production Nitra, Institue of Nutrition, Hlohovecká 2, 951 41 Lužianky, Slovakia, E-mail: patras@vuzv.sk

Doc. Ing. Ján Rafay, PhD., National Agricultural and Food Center, Reasearch Institute of Animal Production Nitra, Institute of Small Farm Animals, Hlohovecká 2, 951 41 Lužianky, Slovakia, E-mail: rafay@vuzv.sk

Prof. Ing. Alexander Sirotkin, DrSc., National Agricultural and Food Center, Reasearch Institute of Animal Production Nitra, Institute for Farm Animal Genetics and Reproduction, Hlohovecká 2, 951 41 Lužianky, Slovakia, E-mail: sirotkin@vuzv.sk