

CHIA SEEDS (*SALVIA HISPANICA*): HEALTH PROMOTING PROPERTIES AND THERAPEUTIC APPLICATIONS – A REVIEW

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ABSTRACT

Chia has been known for over 5,500 years. Chia seeds were one of the most important components of the diet of Mayas and Aztecs. The chemical composition and technological properties of chia give the plant a high nutritional potential. Chia is a good source of polyunsaturated fatty acids: *omega-3* and *omega-6*, soluble dietary fiber. It also contains appreciable amount of proteins and phytochemicals. Nutritional value of chia is the reason why it is used in prophylaxis of several non-infectious diseases such as obesity, hypertension, cardiovascular diseases (CVDs), cancer and diabetes. Nutritional and therapeutic aspects of chia are currently being researched by many scientific centres. The aim of this article is to present the nutritional and therapeutic values of chia.

Key words: *chia seeds, Salvia hispanica, health, fatty acids*

STRESZCZENIE

Szałwia hiszpańska jest znana od ponad 5500 lat. Nasiona szalwii hiszpańskiej były jednym z najważniejszych składników pożywienia dla Majów i Azteków. Skład chemiczny oraz właściwości technologiczne szalwii hiszpańskiej sprawiają iż roślina ta posiada duży potencjał żywieniowy. Szałwia hiszpańska jest dobrym źródłem niezbędnych wielonienasyconych kwasów tłuszczowych *omega-3* i *omega-6* oraz rozpuszczalnego błonnika. Zawiera także znaczne ilości białka i związków fitochemicznych. Wartość odżywcza szalwii sprawia iż roślina ta wykorzystywana jest wspomagająco w profilaktyce wielu chorób niezakaźnych, takich jak: otyłość, nadciśnienie, choroby sercowo-naczyniowe, a także chorób nowotworowych czy cukrzycy. Aspekty żywieniowe i zdrowotne szalwii hiszpańskiej są obecnie przedmiotem badań w wielu ośrodkach naukowych. Niniejszy artykuł ma na celu przybliżenie czytelnikowi walorów żywieniowych i zdrowotnych szalwii hiszpańskiej.

Słowa kluczowe: *nasiona chia, Salvia hispanica, zdrowie, kwasy tłuszczowe*

INTRODUCTION

Salvia is a genus of about 900 species of green plants, shrubs, subshrubs and bushes of the *Salvia* L. family. Chia (*Salvia hispanica* L.) is a representative of the *Salvia* genus. Among the species of the *Labiatae* family chia is distinguished by both high nutritional and therapeutic potential. *Salvia hispanica* L. is an annual plant growing in an area stretching from western Mexico to northern Guatemala. The optimal development of the plant is guaranteed by the warm climate, high rainfall and temperatures of 15-30 °C [13, 14]. The maximum height of the plant is 1 m. It has opposite leaves, which are 4-8 cm long and 3-6 cm wide [38]. The flowers are purple or white and

sized 3-4 mm. They are gathered in whorls on top of shoots. The fruits (schizocarps) contain numerous oval seeds, which are about 2 mm long. The seeds are mottle-coloured with brown, grey, black and white [23, 33, 39]. The word ‘chia’ derives from the Náhuatl word ‘Chian’, which means ‘oily’. The other part of the name *Salvia hispanica* was given to the plant by *Carl Linnaeus* (1707-1778), who discovered the wild-growing plant in the new world and confused it with a native plant from Spain [16]. However, chia comes from Mexico and it was imported to Spain by *Hernán Cortés* [40].

Chia has a high nutritional potential due to the seed composition. The composition depends on genetic factors and on the effect of the ecosystems where the

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plants were grown [5]. Chia seeds contain 16-26% of protein, 31-34% of fat, 37-45% of carbohydrates in total, 23-35% of total dietary fibre (Table 1). Apart from that, they are a source of minerals (calcium, phosphorus, potassium and magnesium), vitamins (thiamine, riboflavin, niacin, folic acid, ascorbic acid and vitamin A) and antioxidant compounds [23, 33].

The energetic value of chia seeds is 459-495 kcal/100 g [15, 27].

The influence of bioactive compounds in chia seeds is the subject of research conducted in numerous scientific centres. The aim of this article is to present the nutritional and therapeutic values of chia.

Table 1. The chemical composition of chia seeds

Component	Content of nutrients in chia seeds [g/100 g d.w.]				
	Reference [38]	Reference [5]	Reference [44]	Reference [5]	Reference [34]
Protein	16.54	19.6	21.52	16.45-26.03	18.65
Fats	30.47	34.4	21.69	29.98-33.50	33.00
Ash	-	4.6	3.63	-	4.35
Carbohydrates	-	41.4	45.30	-	37.73
Dietary fibre	34.4	23.7	-	-	28.36

'-' no data

NUTRITIONAL PROPERTIES OF CHIA SEEDS

Lipids

Lipids are bioactive substances which the human organism needs to accumulate energy, form structural elements of cell membranes and regulate physiological functions. If there are no enzymatic systems capable of forming double bonds at positions n-3 and n-6, the organism cannot synthesise fatty acids, such as ω -3 *alpha*-linolenic acid and ω -6 *alpha*-linoleic acid. Therefore, it is necessary to provide the organism with a supply of lipids in food. Chia seeds contain 25 - 40% of fat, most of which is in the form of polyunsaturated fatty acids, such as ω -3 *alpha*-linolenic acid and ω -6 *alpha*-linoleic acid [33]. As a result of the processes of desaturation and elongation these acids are converted into long-chain polyenoic acids, such as eicosapentaenoic acid (EPA)

and docosahexaenoic acid (DHA) [18]. In comparison with other vegetable oils chia seed oil is characterised by high content of polyunsaturated fatty acids (Table 2). The therapeutic quality of a diet is affected not only by the amount of *omega*-3 PUFAs consumed but also by their proportion to *omega*-6 acids. The adequate ratio between the supply of ω -6 and ω -3 acids is 4-5:1 [25, 46]. However, this proportion is far from recommended (15-20:1) in the diet of an average European inhabitant due to excessive consumption of ω -6 fatty acids and saturated fatty acids. In chia seed oil the ratio between ω -6 and ω -3 acids is 0.32-0.35 [12, 44]. The high content of ω -3 acids in chia seed oil enables reduction of the share of ω -6 acids in daily food rations. Apart from that, an adequate supply of unsaturated fatty acids reduces the risk of ischaemic heart disease and increases immunity of the organism [32].

Table 2. The composition of fatty acids in chia seed oil

Fatty acids	Content of individual fatty acids [% of total fat content]					
	Ref. [12]	Ref. [3]	Ref. [1]	Ref. [22]	Ref.[15]	Ref.[44]
Palmitic acid 16:0	7.10	9.66	6.30	7.2	6.69	5.85
Stearic acid 18:0	3.24	4.34	3.10	3.8	2.67	2.49
Oleic acid 18:1	10.53	6.84	7.50	15.2	10.55	6.16
ω -6 <i>alpha</i> -linolenic acid 18:2	20.37	17.65	19.90	19.1	17.36	17.47
ω -3 <i>alpha</i> -linolenic acid 18:3	59.76	64.08	63.4	64.7	62.02	54.49

Proteins

Proteins, peptides, amino acids being different matrices are necessary cell components enabling normal function of the organism. The content of proteins in chia seeds is 16-26%, most of them being prolamins (538 g/kg of crude protein), followed by glutelins (230 g/kg of crude protein), globulins (70 g/

kg of crude protein) and albumins (39 g/kg of crude protein) [5, 38, 39]. Patients suffering from coeliac disease can consume chia seeds because they do not contain gluten proteins [35]. Chia seeds contain more proteins than rice, maize, barley or oats seeds [2]. According to the data of the United States Department of Agriculture [38], chia seeds contain 18 amino

acids, including 7 exogenous amino acids, which are considered to be indispensable. The study by *Olivos-Lugo et al.* [39] revealed that glutamic acid, which is responsible for proper functioning of the brain, is the predominant amino acid in chia seeds.

Table 3. The percentage of polyunsaturated fatty acids [PUFAs] in chia oil vs other vegetable oils

Type of oil	PUFAs (% of total fatty acids)			References
	ω -3	ω -6	Total	
Chia	59.76	20.64	80.40	[12]
Perilla	60.93	14.72	75.85	[12]
Flax	42.90	30.90	73.80	[29]
Wheat germ	2.90	56.60	59.60	[29]
Sunflower	0.50	55.90	56.40	[29]
Pumpkin seed	0.50	47.30	47.80	[29]
Rapeseed	9.80	20.30	30.20	[29]

Table 4. The content of indispensable amino acids in chia seeds

Amino acid [g/100 g]	USDA [38]	Amino acid [mg/kg/day]	WHO data for 2002 [54]	WHO data for 1985 [54]
Arginine ^a	2.14	Histidine	10	8-12
Lysine	0.97	Isoleucine	20	10
Histidine	0.53	Leucine	39	14
Phenylalanine	1.01	Lysine	30	12
Leucine	1.37	Methionine + cysteine	15	13
Methionine	0.59	Phenylalanine + tyrosine	25	14
Valine	0.95	Threonine	15	7.0
Threonine	0.71	Tryptophan	4.0	3.5
Total	8.27	Total	184	93.5

^a not recognised as indispensable in the report published by the FAO/WHO/UNU [WHO 2007]

Dietary fibre

Dietary fibre is an important component of everyday diet. Optimal consumption of dietary fibre, i.e. 25-30 g/day has positive influence on health. The American Dietetic Association established the preferable ratio between insoluble and soluble dietary fibre fractions at 3:1 [9]. The content of fibre in chia seeds is 23-41%, where the insoluble fraction makes about 85% and the soluble fraction makes about 15% [30, 42]. The content of fibre in chia seeds depends on the region of cultivation and climate. Chia seeds contain about twice as much fibre as bran, 4-5 times more than almonds, soy, quinoa or amaranth [38]. They may play an important role in preventing and treating diseases of the digestive and circulatory systems, diabetes, colorectal cancer, kidney stones, haemorrhoids and metabolic disorders [3, 26].

Vitamins and minerals

Vitamins and minerals are necessary for normal function of the organism. An adequate supply of these elements enables optimal control of the amount of

hormones, growth regulators and differentiation of cells and tissues. It also protects the organism from oxidative stress. Chia seeds are a source of B vitamins: thiamine (0.62 mg/100 g), riboflavin (0.17 mg/100 g), niacin (883 mg/100 g) and folic acid (49 mg/100 g) [38]. In comparison with rice and maize seeds chia seeds contain more niacin and comparable amounts of thiamine and riboflavin [7].

Table 5. Content of minerals in chia seeds

Minerals	Content of minerals (mg/100 g)		
	Ref. [38]	Ref. [8]	Ref. [28]
Calcium	631	624	580
Phosphorus	860	799	696
Potassium	407	666	870
Magnesium	335	369	403
Iron	7.7	24.4	10.9
Zinc	4.6	6.9	6.0
Selenium*	55.2	78.0	-

* μ g/100 g; - no data

Apart from that, chia seeds are a source of minerals. They contain 6 times more calcium, 11 times more phosphorus and 4 times more potassium than cow's milk [7].

Antioxidants

Oxidation is an important biological process, which is indispensable for the production of energy in the human organism. During metabolism molecular oxygen is reduced to water. When electrons are being transferred, free reactive forms of oxygen are being generated, such as hydrogen peroxide, hydroxyl and peroxide radicals. Free radicals are considered to be the cause of neurological diseases, inflammations, immunodeficiency, ageing, ischaemic heart disease, strokes, *Alzheimer's and Parkinson's* diseases and cancers [21, 41].

The following substances have been detected in chia seeds: tocopherols, sterols (approx. 50% β -sitosterol), and polyphenolic compounds, such as protocatechuic acid, gallic and p-coumaric acids, caffeic acid, chlorogenic acid as well as epicatechin, quercetin, kaempferol, rutin and apigenin (Table 6) [12, 24, 42].

The total content of vitamin E in chia seeds is 238-427 mg/kg and it is comparable to peanut oil (398.6 mg/kg), but it is lower than in linseeds (588.5 mg/kg), sunflower (634.4 mg/kg) or soybean (1,797.6 mg/kg). *Reyes-Caudillo et al.* [42] observed that the content of antioxidants was different, depending on the method of their extraction (Table 7).

Table 6. Content of antioxidants in chia seed extracts (mg/g)

Antioxidant	Reference [42]	Reference [6]	Reference [15]
Polyphenols	0.511-0.881	0.914-0.975	0.641
Chlorogenic acid	0.0459-0.102	0.214-0.235	0.00468
Caffeic acid	0.003-0.0068	0.141-0.156	0.03089
Quercetin	0.15-0.268	0.006	0.17
Kaempferol	0.360-0.509	0.024-0.025	0.00017

Table 7. Content of polyphenols in chia seed extracts (mg/g)[42]

Antioxidant	Crude extract	Hydrolysed extract
Polyphenols	0.757-0.881	0.511-0.777

THERAPEUTIC AND DIETETIC PROPERTIES OF CHIA SEEDS

The nutritional properties of chia seeds, such as: high content of polyunsaturated fatty acids, vegetable protein, dietary fibre, vitamins, minerals and bioactive substances result in numerous studies on these seeds in order to prove their therapeutic properties. Hypotensive [52], antineoplastic, laxative and analgesic properties are attributed to chia seeds. They are said to protect the cardiovascular system [2], exhibit anti-inflammatory properties, control lipid metabolism [10, 11, 43], have anti-oxidative properties and increase the performance of athletes [49] (Table 8). A randomized, single-blind trial on 20 adults with type 2 diabetes found significant reduction in systolic blood pressure and C-reactive protein concentration in blood plasma even after ingesting 37g chia seeds added to bread per day for 12 weeks, a double increase of α -linolenic acid and eicosapentaenoic acid in plasma was noted as compared to the control group. Anticoagulant and anti-inflammatory effect of chia seeds may help in preventing strokes and heart attacks in type-II diabetic patients [52]. Increase of unsaturated fatty acids in plasma blood was observed also in the study of postmenopausal healthy women supplemented with 25 g milled chia seeds per day for 7 weeks [24].

Effect of ingesting 50 g chia seeds for 12 weeks was examined on 76 adults. This study found no significant reduction in inflammatory markers, body weight, blood pressure, lipid profile and blood sugar levels [36]. Similar results were obtained in the study conducted with 62 obese women supplemented with 25g whole or 25g milled chia seeds [37]. However, reduction in postprandial glycaemia in healthy subjects was showed in another studies [20, 51, 53].

Effect of dietary intervention in checking metabolic syndromes was evaluated through randomized double-blind trial. This trial conducted on 67 adults found significant reduction of triacylglycerols, C-reactive protein concentrations and insulin resistance in group with chia-based diet [19]. It was observed that ingesting 35 g chia flour for 12 weeks decreased total cholesterol level and increased LDL cholesterol [47]. Although the presence of active ingredients in chia seeds contributes to health benefits, safety and efficiency of this medicinal food or natural product, they need to be validated by scientific protocols, since clinical studies on the safety and efficiency of chia seeds are still limited and those reported have not shown conclusive results [50].

Table 8. The therapeutic properties of chia seeds.

Duration of study	Population under study	Supplementation form	Results	References
12 weeks	26 men and women aged 45-55 years (placebo 7; chia flour 19)	35 g chia flour/day	Decreased body weight in the group consuming chia flour, a greater decrease in obese people, no difference from the placebo group. Reduced total cholesterol and increased LDL cholesterol in the supplemented group.	[47]
6-12 weeks	36 young obese rats	133 g chia seeds/ 1 kg diet or 40 g chia oil/ 1 kg diet	Chia seeds and oil reduced oxidative stress in vivo by improving the antioxidant status and reducing lipid peroxidation in diet-induced obese rats.	[31]
5-6 weeks	Hypercholesterolaemic rabbits	10 g chia oil/1kg diet [CD] or 10 g chia oil + 1g cholesterol/ 1 kg diet [HD-Cd]	Reduced concentration of triacylglycerols and increased content of α -linolenic acid in the serum in HD-cd group. Chia seed oil may have protective effect on blood vessels.	[45]
120 minutes	Randomized double-blind trial, 13 healthy people	50 g bread with 0, 7, 15, 24 g chia seeds added	The blood test showed reduced postprandial glycaemia.	[20]
10 weeks	Randomized double-blind trial, 62 overweight women aged 49-75 years	25 g whole chia seeds /day or 25 g ground chia seeds /day	No influence of [whole/ground] seeds on inflammatory markers, blood pressure, body composition. Increased concentration of α -linolenic and eicosapentaenoic acids in the blood serum of obese women consuming ground seeds vs the control group and the group consuming whole chia seeds.	[37]
2 months	Randomized double-blind trial, 67 men and women aged 20-60 years	4 g of chia seeds mixed with palm, oats and soy powder diluted in 250 mL of water/2 per day + reduction diet	Reduced concentration of triacylglycerols, CRP and insulin resistance in the supplemented group.	[19]
7 weeks	10 women after menopause	25 g ground chia seeds / day	Increased concentration of α -linolenic and eicosapentaenoic acids in the serum of women supplemented with ground chia seeds.	[24]
120 minutes	11 healthy men and women	0, 7, 15, 24 g chia seeds added to bread /day	Postprandial glycaemia significantly reduced in comparison with the control group.	[51]
12 weeks	Single-blind trial, 76 obese people (placebo 37; chia seeds 39)	25 g chia seeds in 250 mL water twice a day	Increased concentration of α -linolenic acid in the serum of the group under study vs placebo. No influence of seeds on inflammatory markers, blood pressure, body composition.	[36]
1 month	18 male Wistar rats	150g chia seeds /kg diet or 50g chia oil /kg diet	No influence on IgE concentration in the serum, body weight and thymus weight.	[17]
1 month	32 male rats	160g whole chia seeds/kg diet [T2] or 160g ground chia seeds/kg diet [T3] or 53.4g chia seed oil/kg diet [T4]	Reduced triglyceride concentration in the serum of T2 rats and increased HDL content in the serum of T3 rats in comparison with the control group. Increased concentration of fatty acids 18: 3n-3, 20: 5n-3 and 22: 6n-3 in the serum of T2-T3 rats in comparison with the control group.	[4]
12 weeks	Randomized single-blind trial; 20 men and women aged 18-75 years with type 2 diabetes	37g ground chia seeds added to bread /day	Reduced systolic blood pressure and CRP concentration, a double increase in the concentration of α -linolenic and eicosapentaenoic acids in the serum of patients supplemented with ground chia seeds in comparison with the control group.	[52]
120 minutes	Randomized, controlled, crossover study 15 healthy adults	25 g ground chia seeds with 50 g glucose or 25 g flax with 50 g glucose or alone 50 g glucose	Postprandial glycaemia significantly reduced in comparison with the control group. Chia significantly reduced the mean ratings of desire to eat, prospective consumption and overall appetite score, when compared with flax.	[53]

CONCLUSIONS

Chia seeds are traditionally consumed in Mexico and south-western United States. In the Europe Union countries the marketing of chia (*Salvia hispanica*) seeds as new food ingredients has been permitted only since 13 October 2009 according to the Regulation No. 258/97 of the European Parliament and Council. Due to the chemical composition of chia seeds, which prove their nutritional potential, if they are added to food, they may improve its nutritional value and a diet with chia seeds may be an element of prevention of civilisation-related-diseases.

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