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Chia (*Salvia hispanica*): Nutraceutical Properties and Therapeutic Applications †

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Abstract: Chia seeds (*Salvia hispanica* L.) have high amounts of nutraceutical compounds and a great commercial potential. The aim of this work was to identify proximate composition, fatty acids profile, total phenolics and antioxidant capacity of chia, as well the protein fractions and determine their antihypertensive potential. The seeds exhibited high content of protein, fiber, and lipids, mainly polyunsaturated fatty acids. Important amounts of phenols and a high antioxidant activity (DPPH and ABTS) were found. Globulins fraction showed the most abundant concentration followed by albumins. Peptides from albumins and globulins exhibited the strongest potential against the angiotensin-converting enzyme (ACE) activity. In brief, this study demonstrates that chia can be considered a seed with high nutritional content, antioxidant activity and as a novel antihypertensive agent; important factors for the frequent incorporation of chia in the human diet.

Keywords: antioxidants; antihipertensive; chia; phenolics; nutraceutical; *Salvia hispanica*

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1. Introduction

Salvia genus has around 900 species and belongs to the Plantae Kingdom and Lamiaceae family. Chia (*Salvia hispanica* L.) is an annual herb that can grow up to 1 m tall and has oppositely arranged leaves with small white or purple flowers, and oval seeds showing black, gray, and black spotted to white color (Figure 1) [1,2].

Chia is native to central Mexico up to northern Guatemala and began to be used as food in 3500 BC. Chia was a main crop of pre-Columbian societies; Aztecs, Mayas, and Incas (1500–900 BC) used it as medicine, food, painting, and as energizer. Aztecs received it as annual tributes, and as offering to gods. The Spanish conquest suppressed its use due to religious beliefs. In 2009, chia was approved as novel food by the European Parliament and the European Council. Chia seeds are good source of macronutrients, B vitamins, calcium, phosphorus, potassium, magnesium, iron, zinc, and copper, as well as phenolic compounds. Additionally, it can be incorporated to celiac diets due to the absence of gluten [2,3]. Nowadays, chia has shown several health benefits, i.e., antioxidant potential and antihypertensive, between others [1,4]. Thus, the aim of this work was to determine the proximate composition, fatty acid profile, total phenolic content and antioxidant capacity of chia, as well as its protein fractions in terms of their antihypertensive potential.

Figure 1. Chia plants, flowers and seeds. (**a**) Purple and white flowers, (**b**) Seeds from different commercial lines cultivated in Mexico.

2. Materials and Methods

Seeds from four varieties of commercial chia (*Salvia hispanica*): Black from Puebla, White and Pinta Jalisco (PJ) from Jalisco, and Xonotli from Guanajuato, Mexico, were soaked in distilled water (1:10, *w*/*v*) for 1 h to allow mucilage production. They were frozen overnight (−80 °C) and freeze-dried, the dry mucilage was removed mechanically. Mucilage-free seeds were milled into flour and passed through a 0.5 mm mesh to obtain a uniform particle size. The flour was defatted with hexane (1:10, *w*/*v*) in a Soxhlet unit at 65–70 °C and dried overnight at room temperature to remove remaining hexane; a second grinding was performed to obtain a smaller particle size (0.18 mm), and it was stored at 4 °C until use. Proximate composition was evaluated based on Sandoval-Oliveros and Paredes-López [5] method. Fatty acid profile was made using Guzmán-Maldonado et al. [6] procedure. Total phenolic compounds and antioxidant capacity were performed according to Martínez-Cruz and Paredes-López [3]. Antihypertensive potential was determined using the method reported by Orona-Tamayo et al. [7].

3. Results

3.1. Proximate Composition

The different types of chia analyzed presented an average of 22.7, 32.5 and 33.6 g/100 g dry basis of protein, lipids and dietary fiber, respectively (Table 1). As can be observed, these results agree with those previously reported by Ayerza and Coates [1]. Soluble and insoluble fiber fractions found in chia samples may improve glucose and lipidic profile, and intestinal function, thus reducing the risk for obesity, coronary heart disease, type II diabetes mellitus, metabolic syndrome and several types of cancer. It also is associated to increase post-meal satiety, decreasing subsequent hunger [6]. Chia fiber content (35–40 g/100 g) is equivalent to 100% of the daily recommendations for adult population [8]. On the other hand, protein content in chia seeds was higher than most of the traditionally staple grains, i.e., wheat (14%), corn (14%), rice (8.5%), oats (15.3%), and barley (9.2%) [1].

Table 1. Proximate composition and dietary fiber of chia seed.

Component	g/100 g Dry Basis
Moisture	4.5 ± 0.0
Lipids	32.5 ± 2.7
Protein	22.7 ± 0.7
Ash	3.7 ± 0.3
Soluble Dietary fiber	8.2 ± 0.8
Insoluble Dietary fiber	25.4 ± 2.2
Total Dietary fiber	33.5 ± 2.7
Carbohydrates (by difference)	3.1

Values are the mean ± SD of three determinations.

3.2. Fatty Acids Profile

S. hispanica seeds are worldwide recognized for their high content of lipid, which comprised mainly polyunsaturated fatty acids that play an important role in health [5,9]. The average amount of fatty acids in the chia varieties evaluated was 11.9 and 87.6 g/100 g of saturated and polyunsaturated fatty acids (PUFAs), respectively (Table 2). As it can be seen, three healthy fatty acids were identified in elevated amounts in the chia samples: linolenic (ω-3), linoleic (ω-6), and oleic (ω-9). Otherwise, the saturated fatty acids, palmitic (16:0) and stearic (18:0), were found in very low concentrations. These data are in accordance with previous studies by Ayerza and Coates [9] and Mohd Ali et al. [2]. They have established that *S. hispanica* is an outstanding source of PUFAs (25–40%), comprising 55–60% linolenic and 18–20% linoleic acids. Chia oil has the highest percentage (of any plant source) of α-linolenic acid, which is considered essential because the human body cannot produce it and is also a potent lipid antioxidant [9,10].

Table 2. Fatty acid profile of chia cultivated in Mexico.

Fatty Acid		g/100 g Oil
Polyunsaturated	Linolenic (ω-3)	59.1 ± 0.23
	Linoleic (ω-6)	21.2 ± 0.12
Monounsaturated	Oleic (ω-9)	7.3 ± 0.09
	Total	87.6
Saturated	Palmitic (16:00)	7.9 ± 0.15
	Estearic (18:00)	4.0 ± 0.06
	Total	11.9

Values are the mean ± SD of three determinations.

3.3. Protein

The mean content of protein (22.7 g/100 g dry basis) of the evaluated chia seeds was high and is similar to that reported by Ayerza and Coates [1], and it provides essential amino acids to the daily diet [5]. Several important storage protein fractions have been found within chia. Based on solubility criteria, storage protein fractions were extracted. Table 3 shows the concentration of protein fractions from the four chia varieties evaluated. The fraction of globulins was the most abundant in all the lines studied, it ranged from 11.6 to 15.5 μg/mL, followed by the fraction of albumins 9.5 to 13.1 μg/mL, and glutelins with a concentration of 7.4 to 8.7 μg/mL, and the fraction of prolamins was found in the lowest concentration 4.4 to 5.2 μg/mL. These data were comparable to results obtained by Sandoval-Oliveros and Paredes-López [5] and Orona-Tamayo et al. [7].

Table 3. Concentration of proteic fractions from chia seeds.

Line	Albumins	Globulins	Prolamins	Glutelins
	(μg/mL, Dry Basis)			
Xonotli	10.8 ± 0.9	14.6 ± 0.1	4.4 ± 0.1	8.1 ± 0.3
Pinta Jalisco	9.5 ± 0.3	11.6 ± 0.0	4.4 ± 0.1	8.3 ± 0.1
Black	13.1 ± 0.5	15.5 ± 0.1	5.2 ± 0.1	7.4 ± 0.1
White	10.8 ± 0.3	13.2 ± 1.2	4.8 ± 0.0	8.7 ± 0.2

Values are the mean ± SD of three determinations.

3.4. Phenolic Compounds and Antioxidant Capacity

The concentration of total phenolic compounds of the *S. hispanica* lines evaluated was in the range of 0.78 and 0.97 g/100 g dry basis (Table 4). It can be observed that chia comprises a high concentration of phenolic compounds, thus, the antioxidant capacity was evaluated using the radical scavenging assays, DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS [2,2′-azinobis (3-ethylbenzothiazoline-6-sulphonic acid)]. Values for DPPH were in the range between 1.0 and 1.2 μg/g, and for ABTS from 1.0 to 1.6 μg/g. The concentration of total phenols and the antioxidant capacity of the chia seeds cultivated in different States of Mexico are remarkable and consistent with results obtained by Martínez-Cruz and Paredes-López [3] from *S. hispanica* cultivated in the Central area of Mexico.

Table 4. Total phenolic compounds and antioxidant capacity in chia.

Line	Total phenols (g/100 g)	DPPH (IC_{50}, μg/g)	ABTS (IC_{50}, μg/g)
Xonotli	0.78 ± 0.04	1.0 ± 0.05	1.6 ± 0.2
Pinta Jalisco	0.92 ± 0.17	1.1 ± 0.1	1.4 ± 0.03
Black	0.97 ± 0.03	1.1 ± 0.07	1.0 ± 0.1
White	0.83 ± 0.05	1.2 ± 0.02	1.4 ± 0.005

DPPH, 2,2-diphenyl-1-picrylhydrazyl; ABTS, 2,2′-azinobis (3-ethylbenzothiazoline-6-sulphonic acid). Values are the mean ± SD of three determinations.

3.5. Antihypertensive Effect

Chia contains high concentration of hydrophobic amino acids (proline, leucine, phenylalanine, and isoleucine) that generate peptides with high angiotensin converting enzyme (ACE)-inhibitory activity [11]. ACE controls blood pressure by regulating the volume of fluids in the body. It converts the hormone angiotensin I to the active vasoconstrictor angiotensin II. Our results indicate that the peptides obtained from the fraction of globulins promoted the highest inhibitory effect against ACE with an IC_{50} of 203.61, 148.23 and 110.11 μg/mL for White, Black, and Pinta Jalisco chia lines, respectively. Albumins, glutelins and prolamins demonstrated lower capacity against ACE, which is in accordance to data reported by Orona-Tamayo et al. [7]. They found that peptides from albumin and globulin fractions exhibited the highest ACE-inhibitory activity (IC_{50} 377 and 339 μg/mL, respectively), followed by chia seed flour (IC_{50} 516 μg/mL). It is interesting to note that albumin and globulins from Adzuki or red beans (*Vigna angularis*) [12] required higher protein concentration to inhibit ACE enzyme activity than the equivalent proteins of chia seeds from our study.

4. Conclusions

Salvia hispanica seeds showed important contents of proteins, dietary fiber and healthy lipids. In addition, they were a good source of total phenols and have high antioxidant capacity, which suggest that the scavenge ROS (reactive oxygen species) and may decrease or prevent chronic degenerative diseases, cancer and ageing. The chia protein profile showed that globulins are the major protein fraction followed by albumins, glutelins and prolamins. Chia peptides from the protein fractions exhibited capacity as ACE inhibitors, particularly, peptides from globulin and albumin fractions showed the strongest potential against ACE. These results can suggest that chia peptides could be outstanding natural antioxidants and ACE inhibitors for human health. Further research is required to develop novel chia cultivars with better nutraceutical attributes.

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