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БИОЛОГИЧЕСКИ АКТИВНЫЕ ВЕЩЕСТВА СЕМЯН ЧИА (SALVIAHISPANICAL.)

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Аннотация. *Чиа (SalviahispanicaL.) является однолетним травянистым растением. Растение вновь становится чрезвычайно популярным в современном питании в нескольких странах мира. В последние годы использование семян чиа значительно возросло из-за их высокой пищевой и биологической ценности. Текущие результаты исследований показывают высокую питательную ценность семян чиа и подтверждают обширные полезные для здоровья свойства. Семена чиа содержат огромное количество биологически активных веществ с высокой концентрацией полезных ненасыщенных жирных кислот, безглютенового белка, витаминов и минеральных веществ. Высокая доля α-линоленовой кислоты делает чиа превосходным источником жирных кислот омега-3, которая связана с большим количеством физиологических функций в организме человека. Кроме того, семена чиа являются отличным источником фенольных соединений и антиоксидантов, таких как хлорогеновая кислота, кофейная кислота, мирицетин, кверцетин и кемпферол, которые, как считается, обладают защитным действием по отношению к болезням сердца и печени, а также антивозрастными и антиканцерогенными свойствами. Помимо этого, это источник пищевых волокон, полезных для контроля сахарного диабета и пищеварительной системы. В настоящем исследовании проводится обзор семян чиа, их химического состава, питательных свойств, антиоксидантной активности, пищевой безопасности, а также потенциального применения семян чиа в производстве продуктов питания и их положительное влияние при их потреблении на здоровье человека.*

Ключевые слова. *Биологически активные вещества; чиа; пищевая ценность; антиоксидантная активность; шалфей испанский; фенольные соединения.*

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Original article

BIOLOGICAL ACTIVESUBSTANCES BASED ON CHIA SEEDS *(SALVIA HISPANICA L.)*

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Abstract. *Chia (Salvia hispanica L.) is an annual herbaceous plant. The ancient seed is becoming immensely popular in contemporary food regimen in several countries. In recent years, usage of Chia seeds has greatly grown due to their high nutritional and medicinal values. Current research results reveal a high nutritive value for chia seeds and confirm their extensive health-promoting properties. Chia seeds contain enormous amount of biological active substances with higher concentration of beneficial unsaturated fatty acids, gluten free protein, vitamins, and minerals. the higher proportion of α-linolenic acid makes chia the superb source of omega-3 fatty, in which it has been associated with a large number of physiological functions in human body. Besides this, the chia seeds are an excellent source of phenolic compounds and antioxidants, such as chlorogenic acid, caffeic acid, myricetin, quercetin, and kaempferol which are believed to have cardiac, hepatic protective effects, anti-ageing and anti-carcinogenic characteristics. It is also an excessive source of dietary fiber which is useful for the controlling diabetes mellitus and digestive system. In the present study, an extensive overview of chia seeds, chemical composition, nutritional properties, antioxidant activity, safety, along with the potential application of chia seeds in food production and the positive effect of their consumption on human health are discussed.*

Keywords: *biologically active substances: chia; nutritional properties, antioxidant activity, Salvia hispanica L., phenolic compounds.*

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1. Introduction

Natural products form a central pillar of the modern pharmaceutical industry as the use of new chemical entities derived from natural sources has risen to values between 45 % and 75 % [1]. Moreover, secondary metabolites determine important aspects of food quality and lately the role of some of them, as protective dietary constituents, has become an increasingly important area of human nutritional research.In numerous studies, herbs of the *Lamiaceae* family have been indicated as considerable potential sources of secondary active compounds [2]. “Sage”, the traditional name of the genus Salvia is attributed to different species that are widely used in the food, drug and fragrance industry.

Salvia hispanica L. (Chia), an annual herbaceous plant of the *Lamiaceae* (mint) family, is a native of Central America's highland [3], [4]. Which usually cultivates about 1 m in height and produces raceme inflorescence bearing slight purple flowers. It is a short-day flowering plant (photoperiod-sensitive).Recently,its consumption has grown outside South America due to its rich nutritional and gluten-free characteristics [5]. Chia seeds contain ~40 % oil by weight the majority of whichare omega-3 and omega-6 polyunsaturated fatty acids (PUFAs) [5]. The seeds are also rich in protein (15-20 %), dietary fiber (20-40 %), minerals (4-5 %), vitamins, minerals and wide range of polyphenolic antioxidants which act as antioxidant and safeguard the seeds from chemical and microbial breakdown [6]. These

nutritional attributes have made Chia a desirable superfood and a pseudocereal. Most of the species from genus Salvia have medicinal and horticultural importance as a source of many useful natural constituents including terpenes and flavonoids. Although knowledge and use of several Salvia species (Salvia officinalis; Salvia fruticosa; Salvia pomifera) can be dated back to ancient Greek Era and have a long history of culinary and effective medicinal use, still there is a remarkable attention regarding their chemistry and specifically their phenolic composition [7]. There is no official criterion for the minimum content of phenols in sage covered by current regulations [8], neither the European Pharmacopoeia monographs [9] nor the ISO 11165 standard [10].

Phenolic compounds are extensively distributed in plants and serve as important components in our daily diets. As secondary metabolites, phenolicsare synthesized in plants from phenylalanine and to a lesser extent tyrosine during normal growth and development as well as in response to stress conditions [11], [12]. To date, more than 8000 phenolic compounds have been identified in fruits, vegetables, seeds and related products. Most common phenolics are simple phenols, phenolic acids and their derivatives, flavonoids and their derivatives, coumarins, stilbenes, lignans and their polymerized counterparts such as tannins and lignins [12].

The interest in phenolic compounds has grown over recent years, particularly because they are excellent antioxidants that inhibit oxidative deterioration of foods. Consumption of antioxidants has shown its efficiency in the prevention of cancer, cardiovascular diseases, osteoporosis, obesity, diabetes and against skin aging [13], [14]. The antioxidant properties of plant phenolic compounds are relevant in the field of food (inhibition of lipid oxidation), physiology (protection against oxidative stress) and cosmetology. They reflect the UV filter and reducing properties of these compounds and their ability to interact with metal ions and proteins [15] In particular; phenolic compounds provide antioxidant activity by direct reducing of reactive oxygen species (ROS), inhibiting enzymes involved in oxidative stress, binding metal ions responsible for the production of ROS and stimulating the endogenous antioxidant defense systems [16].

The largest cultivation of seeds of this genus occurs in mountainous regions from temperate to subtropical [17]. The chemical composition and nutritional value of chia seed may vary according to climatic conditions, geographic location, nutrients, and soil conditions, as well as year of cultivation [18]. For example, the composition of fatty acids varies according to climate and the altitude of the plant; the colder and higher the region, the higher the content of omega-3 unsaturated fatty acids [19]. The quality and quantity of phenolic compounds in plants are generally influenced by the stage of growth, the parts of the plant to be used and the environmental growing conditions. The massive nutritional and therapeutic potential of chia is little known, chia offers a great future perspective for feed, food, medical, pharmaceutical and nutraceutical sectors. Information contained in this review can be useful for health-conscious people who want to be healthy through natural foods. This paper describes the enormous nutritional andpotential application of Chia in food products for better health and longevity.

2. Chia seed history

Chia (Salvia hispanica L.) belongs to the family Labiatae, originated from Mexico and northern Gualtemala. The Chia seeds have been the portion of human nutrition since 1500 BC [20].

Pre-Columbian populations consumed chia in the 16th century to provide energy, endurance, and strength. During the battles and expeditions, Aztec soldiers consumed chia to meet their nutritional needs. The oil extracted from the seeds has been used to produce cosmetics. In addition, chia seed was an offering to the gods in religious ceremonies or used as a form of payment of taxes and other parts of the plant, such as thebranches, leaves and roots, were used less commonly to fight respiratory infections [21]. Moreover, during the year 2009, European Parliament classified chia to be the novel food item by passing a Regulation with EC No. 258/97. The chia seed is widely used in many countries since thousands of years due to its massive nutritional and therapeutic potential [22]. All over the world, chia seeds got attention and offered researches over a wide range of applications starting from food, medicine and to other food and non-food industrial products. Being used in 30 countries, the future of chia seeds is very promising. The reason lies in its unique constituents and their possible health and technological advantages [23].

3. Botanical and Taxonomic Description

Chia *(Salvia hispanica L.)* is an herbaceous plant that belongs to the order Lamiales, family Lamiaceae, subfamily Nepetoideae, and genus Salvia. The Salvia genus is considered the most numerous in the family Lamiaceae. It consists of approximately 900 species [24]. Its taxonomic description is as follows: **Kingdom**: Plantae, **Subkingdom**: Tracheobionta**, Super division**: Spermatophyta, **Division**: Magnoloiphyta,

Class: Magnoliopsida **Subclass**: Asteridae **Order**: Lamiales, **Family**: Lamiaceae, **Subfamily** Nepetoideae, **Genera**: Salvia, **Specie**: hispanica.

The chia plant (Figure 1) is about 1 m tall and has simple leaves, which measure 4 to 8 cm long and 3 to 5 cm wide, oval-elliptical shape, pubescent, and with acute apex. A chia seed is quasi-oval, with a length between 1 and 2 mm, a diameter between 0.8 and 1.3 and a width between 0.8 and 1.4 mm. It has a smooth and shiny peel and coloring that can be black, brown, gray, blackspotted, or white. The mucilage is present inside the epidermal cells of mature chia seeds and when they come into contact with water it immediately expands rupturing the primary cell layer that protrudes from these epidermal cells thus surrounding the seed, which increases its size and imparts a characteristic gel appearance to chia [25].

Plant is an annual herb bears flower in summer, with a height of about one meter with reverse petiolate and serrated leaves (4–8 cm long; 3–5 cm wide) with hermaphrodite flowers [26]. Plant can grow in a wide range of well drained clay and sandy soils with reasonable salt and acid tolerance. It can produce 500–600 kg seed/acre but under appropriate agronomic conditions the yield of 2500 kg/acre has also been reported [27].

Figure 1 – Chia (Salvia hispanica L.) Source: (https://www.istockphoto.com/ru/search/2/image?phrase=chia+plant)

Рисунок 1 – Чиа (Salvia hispanica L.) Источник: (https://www.istockphoto.com/ru/search/2/image?фраза=чиа+растение)

4. Bioactive substances of Chia Seeds

The chemical composition of chia seedshas been analyzed by many researchers [28], [29], [30]. Chia seeds contain a high content of fats, dietary fiber, proteins, vitamins, minerals, with a wide range of phenols and antioxidants, (Figure 2) and (Table 1). The heavy metal content of seeds was within the safe limits with no potentially toxic mycotoxins and gluten [31]. Currently chia seed is widely used for the extraction of bioactive compounds for the development of functional foods [32]. Furthermore, [26] and [24] stated that the chemical composition of each product can vary due to different factors such as year of cultivation, environment of cultivation, and extraction method.

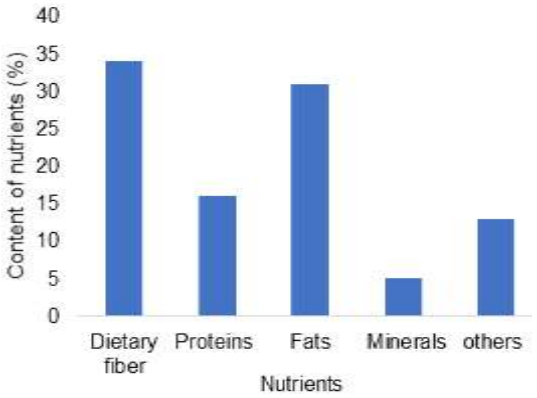

Figure 2 – Basic composition of chia seeds [33]

Рисунок 2 – Основной состав семян чиа [33]

A study by da Silva et al. [35] analysed chia seeds from two regions of Brazil which were found to contain 35 % dietary fibre, including 6 % soluble fibre, 31 % lipids, and an average of about 19 % protein, are similar to those for chia seeds growing in other countries and tothe guidelines of the EU. Another study of Brazilian seedsrevealed a moisture content of about 8 %, ash about 4 %, 20 % crude protein, 18 % lipid fraction and 40 % carbohydrates [36], according to this data, composition can vary depending on the region of growth even in one country.

Thus, although the composition of chia seeds varies depending on the region of growth, chia seeds represent a promising source of a number of biologically active substances.

4.1. Protein Content

Chia seeds are a good source of plant protein, which accounts for approximately 17 % their mass. They contain greater than the protein content in all other cereals (for instance, rice is 6.5 %, in corn the protein content is 9.4 %, in wheat 12.6 %) and quinoa 14.1 %, [37]. The amount of proteins in chia seeds depends mainly upon environmental and agronomical factors [37]. The absence of the protein gluten makes chia seeds highly valued to patients suffering from celiac disease. Moreover, food rich in proteins are highly recommend to people who are fighting to lose weight. Grancieri et al. [38] was exploring the composition and positive effects of chia seeds proteins, and peptides, and their effect on the human body. A total of 20 proteins

were obtained from chia seeds, eight of them were specially related to the production of the plant lipids, which cause the high concentrations of polyunsaturated fatty acids. Analyses of the amino acid composition confirmed the presence of 10 exogenous amino acids, among which the greatest contents were for arginine, leucine, phenylalanine, valine and lysine. Proteins in chia seeds are also rich in endogenous amino acids, mainly glutamic and aspartic acids, alanine, serine and glycine [39]. Moreover, Talia et al. [40] showed important contents proteins of *Salvia hispanica* seeds. The concentration of protein fractions from the four chia varieties were 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.

4.2 Fatty acid composition

Chia seeds are worldwide recognized for their high content of lipid, which comprised mainly polyunsaturated fatty acids that play an important role in health [41], [42] such as cardiovascular diseases, hypertension, obesity, diabetes other health related disorders [43]. The presence of higher concentration of polyunsaturated fatty acids in chia seeds has increased its popularity and cultivation many folds. 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. Chia seed with appreciable amounts ofω-3 alpha-linolenic acid (ALA) andω-6 linoleic acid. On an average it contains about 64 % ω-3 and 19 % ω-6 fatty acids [44]. Otherwise, the saturated fatty acids, palmitic (16:0) and stearic (18:0), were found in very low concentrations. [42], [45]. Of all the known food sources chia contains the highest concentration of these fatty acids, which is considered essential because the human body cannot produce it and is also a potent lipid antioxidant [42], [46].

4.3 Fiber Content

The fibre content in chia seeds is also very high. Chia seed contains between 34 and 40 g of dietary fibre per 100 g. This dietary fibre is (35 %) [18] in higher levels than other seeds, such as amaranth (7.3 %), quinoa (7.0 %), and corn (8.3 %) [47] (Figure 3). Insoluble fibre is also present in greater quantity in chia represents approximately 85–93 %, while the soluble fraction (SDF) represents between 7 % and 15 % [48]. It is primarily composed of lignin, cellulose, and hemicellulose, whereas mucilage is the main type of soluble fibre of the seed [49]. This mucilage has high capacity for water absorption and can absorb about 27 times its own weight [50]. Therefore, chia seed can be used in the prevention of many cardiovascular diseases and diabetes, among others, as demonstrated by a number of epidemiological studies (Figure 2). Reyes-Caudillo et al. [51] showed in their research that a high amount of fibre decreases the risk of coronary heart disease, risk for diabetes type 2, and several types of cancer, and a high amount of dietary fibre in daily meals decrease subsequent hunger.

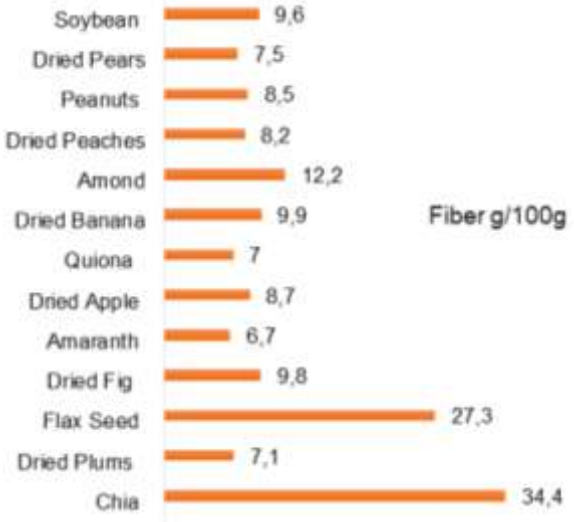

Figure 3 – Fiber contents of selected foods [34]

Рисунок 3 – Содержание клетчатки в выбранных продуктах питания [34]

4.4 Phenolic Compounds

Phenolic content, dry chia seeds contain 8.8 % of phenolic compounds. In addition, high levels of caffeic acid, chlorogenic acid, quercencetin, rosmarinic acid, gallic, cinnamic, myricetin, kaemferol are also reported. (Table 1). Rahman et al [52] reported that rosmarinic acid and daidzein are the major components found in chia seeds, along with caffeic acid, mycertin, quercetin, etc. Both [53] and [54] mentioned that chia seeds have no potentially toxic mycotoxins or gluten present. Furthermore, Uribe et al., [55] described that chia seeds are a great example of a food rich in antioxidants. Reyes-Caudilio et al., [56] also stated that chia seeds are a great source of antioxidants with a wide range of antioxidant compounds. Martinez-Cruz and Paredes-Lopez [57] used chia seeds for analyzing total phenolic contents, antioxidant activity, and qualification of phenolic acids and isoflavones by using ultra high-performance liquid

chromatography (UHPLC). All the active Phenolic compounds in *Slaviahispanica*are presented in Table 1.

Table 1 – The phenolic compounds and isoflavones content of chia seeds

Таблица 1 – Содержание фенольных соединений и изофлавонов в семенах чиа

	Compound	**µg/g Seed**	**Reference**
Polyphenols	Gallic acid	0.055 ;11	Jin et al [62], Martinez-Cruz and Paredes-Lopez [63]
	Caffeic acid	27; 30.89	Martinez-Cruz and Paredes-Lopez [63] Coelho and Salas-Mellado [64]
	Chlorogenic acid	4.68	Coelho and Salas-Mellado [43]
	Protocatechuic acid ethyl ester	0.74	
	Ferulic acid	trace	
	Quercetin	0.17	
	Kaempferol	0.13	Jin et al [62]
	Kaempferol 3-O-glucoside	0.029	
	Epicatechin	0.029	
	Rutin	0.22	
	P-Coumaric acid	0.24	
	Apigenin	0.005	
Isoflavones	Daidzin	6.6	Martinez-Cruz and Paredes-Lopez [63]
	Glycitin	1.4	
	Genistin	3.4	
	Glycitein	0.5	
	Genistein	5.1	

The total phenolic content, the highest amount was found in a study by Martinez-Cruz and Paredes-Lopez (2014) (1.6 mg GAE10/g of chia seeds). The authors compared this amount with the concentrations of total phenolic compounds in other foods of plant origin, such as raspberry (1.1 mg GAE/g), strawberry (1.6 mg GAE/g), banana (0.9 mg GAE/g), pink guava (1.3 mg GAE/g), mango (0.6 mg GAE/g), peach (0.8 mg GAE/g), papaya (0.6 mg GAE/g) and pineapple (0.02 mg GAE/g) [58].

Folin-Ciocalteu redox method (FC) method is based on a single electron transfer mechanism and is used to quantify the contents in total phenolic compounds in plant extracts using gallic acid as a standard. Since its mechanism is an oxidation/ reduction reaction, the FC method can be considered also a method for quantification of the antioxidant capacity. The FC method involves the reduction of the molybdenum component in the phosphotungstic phosphomolybdic complexing reagent [59].

Numerous reducing compounds could interfere in the quantification of polyphenols by the FC method, vitamin C being supposed to have the major contribution, but other reducing substances such as some sugars and amino acids could also interfere [60],[61]. Consequently, vitamin C quantification should be concomitantly performed in this method to get appropriate values for polyphenol contents.

The total phenolic content (Figure 4), the highest amount was reported by Martinez-Cruz and Paredes-Lopez [63] 1.6 mg GAE/g of chia seeds. Turck et al. [58] compared this amount with the concentrations of total phenolic compounds in other foods of plant origin, such as raspberry (1.1 mg GAE/g), strawberry (1.6 mg GAE/g), banana (0.9 mg GAE/g), pink guava (1.3 mg GAE/g), mango (0.6 mg GAE/g), peach (0.8 mg GAE/g), papaya (0.6 mg GAE/g) and pineapple (0.02 mg GAE/g).

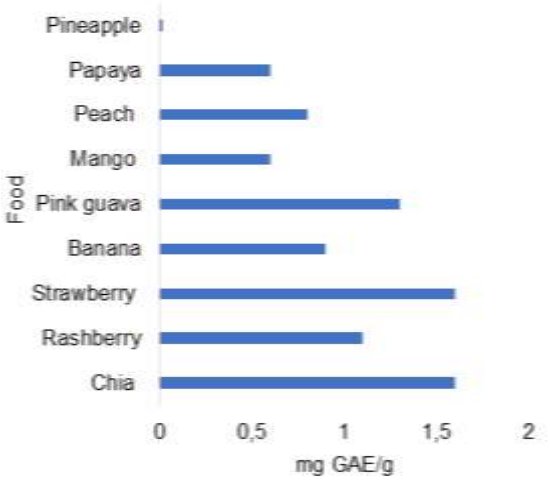

Figure 4 – TPC contents of selected foods [32]

Рисунок 4 – Содержание ТРС в выбранных продуктах питания [32]

5.AntioxidantActivity

Chia seeds and their oil contain a large number of natural antioxidants, such as tocopherols, phytosterols, carotenoids, and polyphenolic compounds. Polyphenolic compounds are the most important complexes that contribute to the antioxidant activity of chia seeds. It is well known that they have the ability to scavenge free radicals, to chelate ions, and to donate hydrogens [65]. Antioxidant compounds reduce the risk of chronic diseases (cancer and heart attack) and they offer protection against some disorders such as diabetes, Alzheimer's, and Parkinson's disease [66]. Polyphenols are compounds with one or more hydroxyl

groups attached to the benzene ring. This structural feature provides a stronger acidic character to phenol than does to other alcohol groups. This chemical reactivity is responsible for the antioxidant character of polyphenols. The ability of polyphenols to capture free radicals is largely dependent on the number of hydroxyl groups [67], [68], [69]. There is a strong correlation between total polyphenol contents and antioxidant activity [70].

Several studies provided evidence for the high antioxidant potential of chia seeds. Sargi et al., [71] showed that chia seeds are capable of deactivating ABTS cation radicals. However, a higher activity was recorded for seeds of brown and golden flax. Those authors also showed that chia seeds exhibit the capacity to scavenge synthetic DPPH radicals and reduce iron ions. Results obtained in both tests indicate a higher antioxidant activity of chia seeds in comparison to flax seeds. [71].

Antioxidant activity of chia seeds was also confirmed by Coelho and Salas-Mellado [72]. They showed that extracts from chia seeds are capable of quenching DPPH radicals and they cause their neutralisation by over 70 %. Antioxidant activity of compounds contained in chia seeds was also confirmed in the fat emulsion system. Reyes-Caudillo et al. [73] assessed the effect of chia seed extract addition on the degradation rate of beta-carotene in a model system of linoleic acid/beta-carotene in the course of heating at 50 °C. They observed that extracts from chia seeds exhibit antioxidant properties in the model emulsion amounting to 73.5 % and 79.3 %. Several authors investigated the positive effects of the polyphenolic compounds in chia seeds using different analytical techniques. Chemical compounds, such as caffeic acid, ferulic acid, chlorogenic acid, rosmarinic acid, and flavonoids (quercetin, kaempferol, daidzein, etc.), have been mainly investigated by different analytical techniques, where UHPLC (ultra-high performance liquid chromatography), HPLC (high performance liquid chromatography), and UPLC (ultra-performance liquid chromatography) particularly stand out. Antioxidants present in chia are of phenolic nature and can be in free form or bonded to sugars by glycosidic linkages, which increases their solubility in water. The most important phenolic compounds include chlorogenic and caffeic acids, and the flavanolsmyricetin, quercetin, and kaempferol [74].

DPPH radical scavenging method – the DPPH (2,2-diphenyl-1-picrylhydrazyl) method is the most frequently used assay for the evaluation of the free radical-scavenging capacity of plant extracts. The reaction mechanism involves the Htransfer from a phenolic compound to the DPPH radical (Figure II-2). Interaction of the DPPH radical (purple-coloured) with a phenolic compound, which is able to neutralize its free radical character, leads to the formation of yellow colorless hydrazine and the resulting effect can be quantified spectrophotometrically at 515 nm [75].

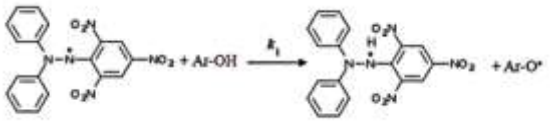

Figure 5 – The H-transfer reaction from a phenolic compound (AR-OH) to DPPH

Рисунок 5 – Реакция переноса H из фенольного соединения (AR-OH) в DPPH

In the DPPH test, the antioxidant activity of phenolic compounds is generally quantified by their EC50 values (concentration necessary to reduce 50 % of DPPH) or their stoichiometry (number of DPPH molecules reduced by one molecule of antioxidant) [76], [77] but also as micromoles Trolox equivalents [9].

6. Safety Aspects of Chia seeds

No doubt chia is a superfood, but “access of everything bad” fits all foodstuffs. Thus, the European parliament after declaring it a novel food in 2009 under (EC) No 258/97, set safety limits after 4 years in 2013 such that chia seeds can be used raw no more than 15g/day and no more than 10 % in processed foods and in 2018 they updated it (Table 2).

Table 2 – The usage limits of chia seeds

Таблица 2 – Пределы употребления семян чиа

Chiaseed	Products	Limit
Wholeseed	Dairy Products	1.3 g/100g
Wholeseed	Foodsupplements	2 g/day
Wholeseed	BakeryProducts	5-10 %
Wholeseed /grounded	Fruitand Vegetable Juice	10 %or 15g/day
Chiaseedoil	Fatbased Products	2 g/day
Grounded	Sterilizedcereals/pseudo cereal/pulses	5 %

Source: Commission implementing Regulation (EU) 2018/10237.

However, American guidelines recommended consumption of chia seeds about 48g/day [78]. The reason behind establishing safety limits by Europeans is due to the increase in processing contaminant acrylamide in a bakery produced processed at 190 °C and also of some rare cases reported regarding allergenic reactions to chia consumption.

7. Uses of chia seed

The approval of chia seed as a Novel Food by the European Parliament has led to high degree of usage of chia seed in a wide range of foods. It is already well established that chia does not have anti-allergic, anti-nutritional and toxic effect on human health. Biscuits, pasta, cereal bars, snacks and yoghurt and cake are usually supplemented with chia seed [14]. Chia is one of the few medicinal plants that produce essential oil in a great concentration, which is used for the preparation of omega-3 capsules.Phenolic compounds of chai contain excellent antioxidant. Consumption of antioxidants has shown its efficiency in the prevention of cancer, cardiovascular diseases, osteoporosis, obesity, diabetes and against skin aging.

Several studies have been performed on the usage of chia seeds in the food industry. Chia seeds can be used in different shapes: whole, ground, in the form of flour, gel and oil[79]. Nowadays, in the food industry in various countries, numerous products Chia seeds can be mixed or added into breakfast cereals, biscuits, yogurts, pasta, fruit juices, snacks, sauces, jams, cakes as supplements [80]. Due to the hydrophilic properties of chia seeds, they are used as substitutes for eggs and fat [81]. They can absorb 12 times their weight in water [79]. They provide food with characteristic consistency. Chia gel may be used as substitutes for oil or eggs in baked products. It was shown that chia oil can replace 25 % of the egg in cakes[82]. It has been found that the industrial use of chia as a fat or egg substitute in food products does not disturb significantly their technological or physical properties. Addition of chia seeds also triggered a reduction of the ratio of omega-6 to omega-3 acid contents as well as the ratio of monounsaturated to polyunsaturated fatty acids [83]. A constructive effect of chia flour addition on the nutritive value and sensory attributes of chips was observed by Coorey et al. [84]. They stated that a 5 % substitution of potato flour and rice flour with chia flour is the most advantageous for appearance, color, aroma, texture, taste and overall acceptability of the final product. The nutritional value of butter can be increased by mixing it with chia oil in a proportion from 6.5 % to 25 %, when the concentration of ω-3 fatty acid in chia fortified butter increases from 4.17 % to 16.74 % [14]. Furthermore, current studies presented that mucilage from chia seeds can be used as a functional coating with improved functional properties [14].not interrupt significantly their technological or physical characteristics. Addition of chia seeds also triggered a reduction of the ratio of omega-6 to omega-3 acid contents as well as the ratio of monounsaturated to polyunsaturated fatty acids [73]. A positive effect of chia flour addition on the nutritive value and sensory qualities of chips was reported by Coorey et al. [74]. They stated that a 5 % substitution of potato flour and rice flour with chia flour is the most advantageous for appearance, color, aroma, texture, taste and overall acceptability of the final product. The nutritional value of butter can be increased by mixing it with chia oil in a proportion from 6.5 % to 25 %, when the concentration of ω -3 fatty acid in chia fortified butter increases from 4.17 % to 16.74 % [14]. Moreover, recent studies obtained that mucilage from chia seeds can be used as a useful coating with enhanced functional characteristics [14].

8. Conclusions

Chia *(Salvia hispanica L.)*is a plant species used since antique times for food and medicinal purposes. Presently, there have been many thoughts and studies about the health benefits and use of this seed. Salvia hispanica seeds presented important contents of proteins, dietary fiber and healthy lipids. Additionally, chia seeds are a rich source of nutrients like polyunsaturated omega-3 fatty acids that defend from inflammation, improve cognitive performance, and lower the level of cholesterol. In addition, they were a good source of total phenols and have high antioxidant capacity, that reduce the risk of chronic diseases, diabetes, neurodegenerative diseases like Alzheimer's, and Parkinson's disease. Furthermore, the high amount of fiber reduces the risk for diabetes type 2, numerous types of cancer and risk of coronary heart disease. Chia seeds can be used in different forms in the food industry, as the whole seed, ground, in the form of flour, oil, and gel. It is already well recognized that chia does not have anti-allergic, anti-nutritional and toxic effect on human health. Yoghurt, pasta, cereal bars, biscuits, snacks and cake are usually accompanied with chia seed.Chia is one of the few medicinal plants that produce essential oil in a great concentration, which is used for the preparation of omega-3 capsules. Nutritional value of butter oil was enhanced by blending with chia oil. Further research is essential to advance novel chia cultivars with better nutraceutical attributes.

REFERENCES / СПИСОК ЛИТЕРАТУРЫ

1. D. J. Newman, G. M. Cragg, and K. M. Snader, "Natural products as sources of new drugs over the period 1981-2002," Journal of Natural Products, vol. 66, no. 7. pp. 1022–1037, Jul. 01, 2003. doi: 10.1021/np030096l.

2. S. Georgieva, "Comparative polyphenol composition and antioxidant capacity of the Bulgarian plants (dry herbs)." [Online]. Available: https://www.researchgate.net/publication/258926474.

3. V. Y. Ixtaina, S. M. Nolasco, and M. C. Tomás,

"Physical properties of chia (Salvia hispanica L.) seeds," Ind Crops Prod, vol. 28, no. 3, pp. 286–293, Nov. 2008, doi: 10.1016/j.indcrop.2008.03.009.

4. C. Baginsky [et al.] "Growth and yield of chia (Salvia hispanica L.) in the mediterranean and desert climates of Chile," Chil J Agric Res, vol. 76, no. 3, pp. 255–264, Sep. 2016, doi: 10.4067/S0718-58392016000300001.

5. N. Mohd Ali, S. K. Yeap, W. Y. Ho, B. K. Beh, S. W. Tan, and S. G. Tan, "The promising future of chia, Salvia hispanica L.," Journal of Biomedicine and Biotechnology, vol. 2012. 2012. doi: 10.1155/2012/171956.

6. L. A. Muñoz, A. Cobos, O. Diaz, and J. M. Aguilera, "Chia Seed (Salvia hispanica): An Ancient Grain and a New Functional Food," Food Reviews International, vol. 29, no. 4, pp. 394–408, Oct. 2013, doi: 10.1080/87559129. 2013.818014.

7. Y. Lu and L. Y. Foo, "Polyphenolics of Salvia-a review." [Online]. Available: www.elsevier.com/locate/ phytochem.

8. B. F. Zimmermann, S. G. Walch, L. N. Tinzoh, W. Stühlinger, and D. W. Lachenmeier, "Rapid UHPLC determination of polyphenols in aqueous infusions of Salvia officinalis L. (sage tea)," J Chromatogr B Analyt Technol Biomed Life Sci, vol. 879, no. 24, pp. 2459–2464, Aug. 2011, doi: 10.1016/j.jchromb.2011.06.038.

9. A. Faria [et al.] "Antioxidant Properties of Prepared Blueberry (Vacciniummyrtillus) Extracts," 2005, doi: 10.1021/jf0511300.

10. B. F. Zimmermann, S. G. Walch, L. N. Tinzoh, W. Stühlinger, and D. W. Lachenmeier, "Rapid UHPLC determination of polyphenols in aqueous infusions of Salvia officinalis L. (sage tea)," J Chromatogr B Analyt Technol Biomed Life Sci, vol. 879, no. 24, pp. 2459–2464, Aug. 2011, doi: 10.1016/J.JCHROMB.2011.06.038.

11. C. H. Beckman, "Phenolic-storing cells: Keys to programmed cell death and periderm formation in wilt disease resistance and in general defence responses in plants?," Physiol Mol Plant Pathol, vol. 57, no. 3, pp. 101–110, 2000, doi: 10.1006/pmpp.2000.0287.

12. M. Naczk and F. Shahidi, "Extraction and analysis of phenolics in food," Journal of Chromatography A, vol. 1054, no. 1–2. pp. 95–111, Oct. 29, 2004. doi: 10.1016/j.chroma.2004.08.059.

13. J. Dai and R. J. Mumper, "Plant phenolics: Extraction, analysis and their antioxidant and anticancer properties," Molecules, vol. 15, no. 10. pp. 7313–7352, Oct. 2010. doi: 10.3390/molecules15107313.

14. R. Ullah [et al.]. "Nutritional and therapeutic perspectives of Chia (Salvia hispanica L.): a review," Journal of Food Science and Technology, vol. 53, no. 4. Springer India, pp. 1750–1758, Apr. 01, 2016. doi: 10.1007/s13197-015-1967-0.

15. Véronique Cheynier, "Polyphenols in foods are more complex than often thought 1–3," Volume 81, Jan. 01, 2005. https://doi.org/10.1093/ajcn/81.1.223S (accessed Feb. 04, 2023).

16. O. Dangles, "Antioxidant Activity of Plant Phenols: Chemical Mechanisms and Biological Significance," Curr Org Chem, vol. 16, no. 6, pp. 692–714, Mar. 2012, doi: 10.2174/138527212799957995.

17. M. I. Capitani, V. Spotorno, S. M. Nolasco, and M. C. Tomás, "Physicochemical and functional characterization of by-products from chia (Salvia hispanica L.) seeds of Argentina," LWT, vol. 45, no. 1, pp. 94–102, 2012, doi: 10.1016/j.lwt.2011.07.012.

18. B. P. da Silva, P. C. Anunciação, J. C. da S. Matyelka, C. M. della Lucia, H. S. D. Martino, and H. M. Pinheiro-Sant'Ana, "Chemical composition of Brazilian chia seeds grown in different places," Food Chem, vol. 221, pp. 1709–1716, Apr. 2017, doi: 10.1016/j.foodchem.2016.10.115.

19. R. Ayerza h and W. Coates, "Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (Salvia hispanica L.)," Ind Crops Prod, vol. 34, no. 2, pp. 1366–1371, Sep. 2011, doi: 10.1016/j.indcrop.2010.12.007.

20. J. P. CAHILL Cahiil, "ETHNOBOTANY OF CHIA, SALVIA HISPANICA," 1996.

21. A. Sosa, "Chia Crop (Salvia hispanica L.): its History and Importance as a Source of Polyunsaturated Fatty Acids Omega-3 Around the World: a Review," JCRF, vol. 1, no. 1, pp. 1–4, Apr. 2016, doi: 10.17303/jcrf.2016.104.

22. I. Fernandez, S. M. Vidueiros, R. Ayerza, W. Coates, and A. Pallaro, "Impact of chia (Salvia hispanica L.) on the immune system: Preliminary study," in Proceedings of the Nutrition Society, May 2008. doi: 10.1017/S0029665108006216.

23. N. Mohd Ali, S. K. Yeap, W. Y. Ho, B. K. Beh, S. W. Tan, and S. G. Tan, "The promising future of chia, Salvia hispanica L.," Journal of Biomedicine and Biotechnology, vol. 2012. 2012. doi: 10.1155/2012/171956.

24. H. Busilacchi, M. Quiroga, M. Bueno, and O. di Sapio, "Evaluation of Salvia hispanica L. cultivated in the south of Santa Fe (Argentina)," CultivosTropicales, vol. 34, no. 4, 2013, [Online]. Available: http://ediciones.inca.edu.cu

25. L. A. Muñoz, A. Cobos, O. Diaz, and J. M. Aguilera, "Chia seeds: Microstructure, mucilage extraction and hydration," J Food Eng, vol. 108, no. 1, pp. 216–224, 2012, doi: 10.1016/j.jfoodeng.2011.06.037.

26. "Composition of Foods Raw, Processed, Prepared USDA National Nutrient Database for Standard Reference, Release 25," 2012. [Online]. Available: http://www.ars.usda.gov/ba/bhnrc/ndl

27. J. P. CAHILL Cahiil, "ETHNOBOTANY OF CHIA, SALVIA HISPANICA," 1996.

28. M. Grancieri, H. S. D. Martino, and E. Gonzalez de Mejia, "Chia Seed (Salvia hispanica L.) as a Source of Proteins and Bioactive Peptides with Health Benefits: A Review," Comprehensive Reviews in Food Science and Food Safety, vol. 18, no. 2. Blackwell Publishing Inc., pp. 480–499, Mar. 01, 2019. doi: 10.1111/1541-4337.12423.

29. A. Das, "Advances in Chia Seed Research," Advances in Biotechnology & Microbiology, vol. 5, no. 3, Aug. 2017, doi: 10.19080/aibm.2017.05.555662.

30. B. Kulczyński, J. Kobus-Cisowska, M. Taczanowski, D. Kmiecik, and A. Gramza-Michałowska, "The chemical composition and nutritional value of chia seeds—current state of knowledge," Nutrients, vol. 11, no. 6. MDPI AG, Jun. 01, 2019. doi: 10.3390/nu11061242.

31. P. G. Peiretti and F. Gai, "Fatty acid and nutritive quality of chia (Salvia hispanica L.) seeds and plant during growth," Anim Feed SciTechnol, vol. 148, no. 2–4, pp. 267–275, Jan. 2009, doi: 10.1016/j.anifeedsci.2008.04.006.

32. "Opinion on the safety of 'Chia seeds (Salvia hispanica L.) and ground whole Chia seeds' as a food ingredient," EFSA Journal, vol. 7, no. 4, Apr. 2009, doi: 10.2903/j.efsa.2009.996.

33. M. K. Hrnčič, M. Ivanovski, D. Cör, and Ž. Knez, "Chia Seeds (Salvia Hispanica L.): An overview-phytochemical profile, isolation methods, and application," Molecules, vol. 25, no. 1. MDPI AG, 2020. doi: 10.3390/molecules25010011.

34. David Haytowitz, "Composition of Foods: Raw, Processed, Prepared USDA National Nutrient Database for Standard Reference, Legacy (2018) Documentation and User Guide," 2018. [Online]. Available: http://www.ars.usda.gov/nutrientdata

35. B. P. da Silva, P. C. Anunciação, J. C. da S. Matyelka, C. M. della Lucia, H. S. D. Martino, and H. M. Pinheiro-Sant'Ana, "Chemical composition of Brazilian chia seeds grown in different places," Food Chem, vol. 221, pp. 1709–1716, Apr. 2017, doi: 10.1016/J.FOODCHEM.2016.10.115.

36. J. F. GANZAROLI, J. L. SANCHEZ, M. V. da SILVA, A. A. C. TANAMATI, R. H. B. FUCHS, and A. TANAMATI, "ABSOLUTE QUANTIFICATION OF FATTY ACIDS IN

CHIA SEEDS PRODUCED IN BRAZIL," Boletim do Centro de Pesquisa de Processamento de Alimentos, vol. 35, no. 1, Oct. 2017, doi: 10.5380/CEP.V35I1.55932.

37. R. Ullah et al., "Nutritional and therapeutic perspectives of Chia (Salvia hispanica L.): a review," Journal of Food Science and Technology, vol. 53, no. 4. Springer India, pp. 1750–1758, Apr. 01, 2016. doi: 10.1007/s13197-015-1967-0.

38. M. Grancieri, H. S. D. Martino, and E. Gonzalez de Mejia, "Chia Seed (Salvia hispanica L.) as a Source of Proteins and Bioactive Peptides with Health Benefits: A Review," Comprehensive Reviews in Food Science and Food Safety, vol. 18, no. 2. Blackwell Publishing Inc., pp. 480–499, Mar. 01, 2019. doi: 10.1111/1541-4337.12423.

39. S. Nitrayová, M. Brestenský, J. Heger, P. Patráš, J. Rafay, and A. Sirotkin, "Amino acids and fatty acids profile of chia (salvia hispanica L.) and flax (linumusitatissimum L.) seed," Potravinarstvo, vol. 8, no. 1, pp. 72–76, 2014, doi: 10.5219/332.

40. T. Hernández-Pérez, M. E. Valverde, D. Orona-Tamayo, and O. Paredes-Lopez, "Chia (Salvia hispanica): Nutraceutical Properties and Therapeutic Applications," MDPI AG, Sep. 2020, p. 17. doi: 10.3390/ proceedings2020053017.

41. M. R. Sandoval-Oliveros and O. Paredes-López, "Isolation and characterization of proteins from chia seeds (Salvia hispanica L.)," J Agric Food Chem, vol. 61, no. 1, pp. 193–201, Jan. 2013, doi: 10.1021/jf3034978.

42. R. Ayerza h and W. Coates, "Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (Salvia hispanica L.)," Ind Crops Prod, vol. 34, no. 2, pp. 1366–1371, Sep. 2011, doi: 10.1016/j.indcrop.2010.12.007.

43. B. Hansel [et al.], "Effect of low-fat, fermented milk enriched with plant sterols on serum lipid profile and oxidative stress in moderate hypercholesterolemia 13," 2007. [Online]. Available: https://academic.oup.com/ajcn/article/86/3/790/4649334.

44. N. Mohd Ali, S. K. Yeap, W. Y. Ho, B. K. Beh, S. W. Tan, and S. G. Tan, "The promising future of chia, Salvia hispanica L.," Journal of Biomedicine and Biotechnology, vol. 2012. 2012. doi: 10.1155/2012/171956.

45. N. Mohd Ali, S. K. Yeap, W. Y. Ho, B. K. Beh, S. W. Tan, and S. G. Tan, "The promising future of chia, Salvia hispanica L.," Journal of Biomedicine and Biotechnology, vol. 2012. 2012. doi: 10.1155/2012/171956.

46. R. da S. Marineli, S. A. Lenquiste, É. A. Moraes, and M. R. Maróstica, "Antioxidant potential of dietary chia seed and oil (Salvia hispanica L.) in diet-induced obese rats," Food Research International, vol. 76, pp. 666–674, Oct. 2015, doi: 10.1016/j.foodres.2015.07.039.

47. S. Srichuwong, D. Curti, S. Austin, R. King, L. Lamothe, and H. Gloria-Hernandez, "Physicochemical properties and starch digestibility of whole grain sorghums, millet, quinoa and amaranth flours, as affected by starch and non-starch constituents," Food Chem, vol. 233, pp. 1–10, Oct. 2017, doi: 10.1016/j.foodchem.2017.04.019.

48. J. M. Rodrigues Da Luz et al., "LIGNOCELLULOLYTIC ENZYME PRODUCTION OF PLEUROTUS OSTREATUS GROWTH IN AGROINDUSTRIAL WASTES," Brazilian Journal of Microbiology, pp. 1508–1515, 2012.

49. E. Reyes-Caudillo, A. Tecante, and M. A. Valdivia-López, "Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (Salvia hispanica L.) seeds," Food Chem, vol. 107, no. 2, pp. 656–663, Mar. 2008, doi: 10.1016/j.foodchem.2007.08.062.

50. L. A. Muñoz, A. Cobos, O. Diaz, and J. M. Aguilera, "Chia seeds: Microstructure, mucilage extraction and hydration," J Food Eng, vol. 108, no. 1, pp. 216–224, 2012, doi: 10.1016/j.jfoodeng.2011.06.037.

51. E. Reyes-Caudillo, A. Tecante, and M. A. Valdivia-López, "Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (Salvia hispanica L.) seeds," Food Chem, vol. 107, no. 2, pp. 656–663, Mar. 2008, doi: 10.1016/j.foodchem.2007.08.062.

52. M. J. Rahman, A. C. de Camargo, and F. Shahidi, "Phenolic and polyphenolic profiles of chia seeds and their in vitro biological activities," J Funct Foods, vol. 35, pp. 622–634, 2017, doi: 10.1016/j.jff.2017.06.044.

53. N. M. Ali, S. K. Yeap, W. Y. Ho, B. K. Beh, S. W. Tan, and S. G. Tan, "The Promising Future of Chia , Salvia hispanica L .," vol. 2012, 2012, doi: 10.1155/2012/171956.

54. R. Ullah [et al.], "Nutritional and therapeutic perspectives of Chia (Salvia hispanica L.): a review," J Food SciTechnol, vol. 53, no. 4, pp. 1750–1758, 2016, doi: 10.1007/s13197-015-1967-0.

55. J. Antonio [et al.], "The Journal of Supercritical Fluids Extraction of oil from chia seeds with supercritical CO 2," J Supercrit Fluids, vol. 56, no. 2, pp. 174–178, 2011, doi: 10.1016/j.supflu.2010.12.007.

56. M. A. Al-Farsi and C. Y. Lee, "Optimization of phenolics and dietary fibre extraction from date seeds," Food Chem, vol. 108, no. 3, pp. 977–985, 2008, doi: 10.1016/j.foodchem.2007.12.009.

57. O. Martínez-cruz and O. Paredes-lópez, "Phytochemical profile and nutraceutical potential of chia seeds (Salviahispanica L.) byultra high performance liquid chromatography," J Chromatogr A, vol. 1346, pp. 43–48, 2014, doi: 10.1016/j.chroma.2014.04.007.

58. D. Turck [et al.], "Safety of chia seeds (Salvia hispanica L.) as a novel food for extended uses pursuant to Regulation (EU) 2015/2283," EFSA Journal, vol. 17, no. 4, Apr. 2019, doi: 10.2903/j.efsa.2019.5657.

59. B. D. Craft, A. L. Kerrihard, R. Amarowicz, and R. B. Pegg, "Phenol-Based Antioxidants and the In Vitro Methods Used for Their Assessment", doi: 10.1111/j.1541-4337.2011.00173.x.

60. J. D. Everette, Q. M. Bryant, A. M. Green, Y. A. Abbey, G. W. Wangila, and R. B. Walker, "Thorough study of reactivity of various compound classes toward the folin-Ciocalteu reagent," J Agric Food Chem, vol. 58, no. 14, pp. 8139–8144, Jul. 2010, doi: 10.1021/jf1005935.

61. Y.-T. Ma and P. C. K. Cheung, "Spectrophotometric Determination of Phenolic Compounds by Enzymatic and Chemical MethodssA Comparison of Structure−Activity Relationship," 2007, doi: 10.1021/jf070084w.

62. F. Jin, D. C. Nieman, W. Sha, G. Xie, Y. Qiu, and W. Jia, "Supplementation of Milled Chia Seeds Increases Plasma ALA and EPA in Postmenopausal Women," Plant Foods for Human Nutrition, vol. 67, no. 2, pp. 105–110, Jun. 2012, doi: 10.1007/s11130-012-0286-0.

63. O. Martínez-Cruz and O. Paredes-López, "Phytochemical profile and nutraceutical potential of chia seeds (Salvia hispanica L.) byultra high performance liquid chromatography," J Chromatogr A, vol. 1346, pp. 43–48, Jun. 2014, doi: 10.1016/j.chroma.2014.04.007.

64. M. Silveira Coelho and M. de las Mercedes Salas-Mellado, "Chemical Characterization of CHIA (Salvia hispanica L.) for Use in Food Products," Journal of Food and Nutrition Research, vol. 2, no. 5, pp. 263–269, May 2014, doi: 10.12691/jfnr-2-5-9.

65. B. de Falco, M. Amato, and V. Lanzotti, "Chia seeds products: an overview," Phytochemistry Reviews, vol. 16, no. 4. Springer Netherlands, pp. 745–760, Aug. 01, 2017. doi: 10.1007/s11101-017-9511-7.

66. M. Grancieri, H. S. D. Martino, and E. Gonzalez de Mejia, "Chia Seed (Salvia hispanica L.) as a Source of Proteins and Bioactive Peptides with Health Benefits: A Review," Comprehensive Reviews in Food Science and Food Safety, vol. 18, no. 2. Blackwell Publishing Inc., pp. 480–499, Mar. 01, 2019. doi: 10.1111/1541-4337.12423.

67. A. Zaiter et al., "Antioxidant and antiacetylcholinesterase activities of different granulometric classes of Salix alba (L.) bark powders," Powder Technol, vol. 301, pp. 649–656, Nov. 2016, doi: 10.1016/j.powtec.2016.07.014.

68. R. Subramanian, V. Raj, K. Manigandan, and N.

Elangovan, “Antioxidant activity of hopeaphenol isolated from Shorearoxburghii stem bark extract ,” Journal of Taibah University for Science, vol. 9, no. 2, pp. 237–244, Apr. 2015, doi: 10.1016/j.jtusci.2014.11.004.

69. D. H. Kim [et al.], “Changes of phytochemical components (urushiols, polyphenols, gallotannins) and antioxidant capacity during fomitellafraxinea–mediated fermentation of toxicodendronvernicifluum bark,” Molecules, vol. 24, no. 4, Feb. 2019, doi: 10.3390/molecules24040683.

70. V. Kumar, N. Sharma, A. Sourirajan, P. K. Khosla, and K. Dev, “Comparative evaluation of antimicrobial and antioxidant potential of ethanolic extract and its fractions of bark and leaves of Terminalia arjuna from north-western Himalayas, India,” J Tradit Complement Med, vol. 8, no. 1, pp. 100–106, Jan. 2018, doi: 10.1016/j.jtcme.2017.04.002.

71. S. C. Sargi [et al.], “Antioxidant capacity and chemical composition in seeds rich in omega-3: Chia, flax, and perilla,” Food Science and Technology, vol. 33, no. 3, pp. 541–548, 2013, doi: 10.1590/S0101-20612013005000057.

72. M. Silveira Coelho and M. de las Mercedes Salas-Mellado, “Chemical Characterization of CHIA (Salvia hispanica L.) for Use in Food Products,” Journal of Food and Nutrition Research, vol. 2, no. 5, pp. 263–269, May 2014, doi: 10.12691/jfnr-2-5-9.

73. E. Reyes-Caudillo, A. Tecante, and M. A. Valdivia-López, “Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (Salvia hispanica L.) seeds,” Food Chem, vol. 107, no. 2, pp. 656–663, Mar. 2008, doi: 10.1016/j.foodchem.2007.08.062.

74. R. Ayerza h and W. Coates, “Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (Salvia hispanica L.),” Ind Crops Prod, vol. 34, no. 2, pp. 1366–1371, Sep. 2011, doi: 10.1016/j.indcrop.2010.12.007.

75. S. Vladimir-Knežević, B. Blažeković, M. B. Štefan, and M. Babac, “9 Plant Polyphenols as Antioxidants Influencing the Human Health”, Accessed: Feb. 04, 2023. [Online]. Available: www.intechopen.com

76. P. Goupy, A.-B. Bautista-Ortin, H. Fulcrand, and O. Dangles, “Antioxidant Activity of Wine Pigments Derived from Anthocyanins: Hydrogen Transfer Reactions to the DPPH Radical and Inhibition of the Heme-Induced Peroxidation of Linoleic Acid,” J. Agric. Food Chem, vol. 57, pp. 5762–5770, 2009, doi: 10.1021/jf900841b.

77. D. M. Vučić, M. R. Petković, B. B. Rodić-Grabovac, O. D. Stefanović, S. M. Vasić, and L. R. Čomić, “African Journal of Microbiology Research Antibacterial and antioxidant activities of bilberry (Vacciniummyrtillus L.) in vitro,” vol. 7, no. 45, pp. 5130–5136, 2013, doi: 10.5897/AJMR2013.2524.

78. M. Cardenas, C. Carpio, D. Morales, M. Álvarez, M. Silva, and W. Carrillo, “Content of nutrients component and fatty acids in chia seeds (Salvia hispanica l.) cultivated in ecuador,” Asian Journal of Pharmaceutical and Clinical Research, vol. 11, no. 2, pp. 387–390, Feb. 2018, doi: 10.22159/ajpcr.2018.v11i2.17096.

79. A. Das, “Advances in Chia Seed Research,” Advances in Biotechnology & Microbiology, vol. 5, no. 3, Aug. 2017, doi: 10.19080/aibm.2017.05.555662.

80. V. Zettel and B. Hitzmann, “Applications of chia (Salvia hispanica L.) in food products,” Trends in Food Science and Technology, vol. 80. Elsevier Ltd, pp. 43–50, Oct. 01, 2018. doi: 10.1016/j.tifs.2018.07.011.

81. L. R. dos R. Gallo, R. B. AssunçãoBotelho, V. C. Ginani, L. de Lacerda de Oliveira, R. F. R. Riquette, and E. dos S. Leandro, “Chia (Salvia hispanica L.) Gel as Egg Replacer in Chocolate Cakes: Applicability and Microbial and Sensory Qualities After Storage,” Journal of Culinary Science and Technology, vol. 18, no. 1, pp. 29–39, Jan. 2020, doi: 10.1080/15428052.2018.1502111.

82. B. Kulczyński, J. Kobus-Cisowska, M. Taczanowski, D. Kmiecik, and A. Gramza-Michałowska, “The chemical composition and nutritional value of chia seeds—current state of knowledge,” Nutrients, vol. 11, no. 6. MDPI AG, Jun. 01, 2019. doi: 10.3390/nu11061242.

83. A. Antruejo [et al.], “Omega-3 enriched egg production: the effect of α-linolenic ω-3 fatty acid sources on laying hen performance and yolk lipid content and fatty acid composition,” Br PoultSci, vol. 52, no. 6, pp. 750–760, Dec. 2011, doi: 10.1080/00071668.2011.638621.

84. R. Coorey, A. Grant, and V. Jayasena, “Effects of Chia Flour Incorporation on the Nutritive Quality and Consumer Acceptance of Chips,” J Food Res, vol. 1, no. 4, p. 85, Oct. 2012, doi: 10.5539/jfr.v1n4p85.

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