Salvia hispanica and Salviae hispanicae semen

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Salvia hispanica L. is a plant species that has been used since antiquity and is now highly valued for its unique nutritional and potential medicinal properties. Chia seeds have recently become one of the most popular food ingredients, with a number of beneficial effects on the functioning of the human body. The data presented under our review indicate that they are also a valuable health-promoting dietary supplement as well as cosmetic ingredient. Scientific studies on pharmacological activities of chia seeds proved their potential valuable role in the prevention of diseases which currently are considered a global health problem. The research confirmed the cardioprotective, antihypertensive, antidiabetic, antiatherosclerotic, nephroprotective, anti-inflammatory, as well as antioxidant properties.

Salvia hispanica | chia | chia seeds | essential fatty acids | essential amino acids | biological activity | medicinal uses | cosmetological application | functional food

1. Introduction

Salvia hispanica L. is a herbaceous plant from the genus *Salvia* (sage) and *Lamiaceae* family (*Labiatae*). The genus *Salvia* is comprised of about 900 species which occur in almost all parts of the world (North, Central, and South America, South Africa, Southeast Asia, and Europe) [1][2][3][4][5][6][7][8][9]. The current European Pharmacopoeia (10th edition) [10] contains monographs of raw materials obtained from different *Salvia* spp., namely, *S. officinalis* (medical sage), *S. lavandulifolia* (lavender sage), *S. triloba* (Greek sage), *S. miltiorrhiza* (red root sage or red sage), and *S. sclarea* (clary sage). These monographs indicate the valuable healing properties of *Salvia* ssp. [11]. Among the mentioned *Salvia* spp., *S. officinalis* has long been used in European medicine [12]. The other species (except *S. miltiorrhiza*) were introduced to official European therapy in 2008 and were included in the 6th edition of the European Pharmacopoeia. The pharmacopoeial raw materials obtained from *S. officinalis* and *S. triloba* are leaves (*folium*). They are a source of tannins, which have an astringent effect, and also contain essential oil (Latin: *Salviae aetheroleum*), which has an anti-inflammatory effect [12][13]. Essential oils extracted from the leaves of *S. lavandulifolia* and *S. sclarea* also have anti-inflammatory and disinfectant properties [14][15]. A unique species of *Salvia* is *S. miltiorrhiza*, which was first introduced to official European healthcare in 2013 and included in the 7th edition of the European Pharmacopoeia. The raw material obtained from this species is the root and rhizome (*radix et rhizoma*) which is rich in diterpenes (tanshinones) and salvianolic acid B. It is mainly used to treat cardiological disorders, and also has antimicrobial effects [16].

Among *Salvia* spp., currently one of the most valuable and widely used is undoubtedly *S. hispanica* L. (chia). The raw material obtained from this species is seed (*Salviae hispanicae semen*) (**Figure 1**). The species name "*hispanica*" incorrectly refers to the Spanish origin of the plant. This error resulted from the mistake by Carl Linnaeus who confused *S. hispanica* with *S. lavandulifolia* [17], which is known in English as "Spanish sage" and is native to Spain (and southern France) [17][18].

Figure 1. Morphological appearance of S. hispanica seeds.

S. hispanica, according to historic sources, was already known to the Aztecs, who used chia seeds in food and as an ingredient in many herbal mixtures, although no specific healing properties were assigned to them [3]. Oil obtained from chia seeds was also used to produce cosmetics, as a solvent for painting, and in religious rituals [19]. The term "chia" is derived from the Spanish word "chian," which means "oily" [2][4][9][20][21][22][23]. It is also thought that the word "chia" originated from the word “chihaan,” from the Mayan language, meaning “strong” or “strengthening” [3]. The Plant List database provides the following Latin synonyms for *S. hispanica*: *Kiosmina hispanica* (L.) Raf., *Salvia chia* Colla, *Salvia chia* Sessé & Moc., *Salvia hispanica* var. *chionocalyx* Fernald, *Salvia hispanica* var. *intonsa* Fernald, *Salvia mexicana*, *Salvia neohispanica* Briq., *Salvia prysmatica* Cav., *Salvia schiedeana* Stapf., and *Salvia tetragona* Moench [24]. The most common and colloquial name of *S. hispanica* is chia. Other names, such as “chan,” “ican,” and “cueruni”, are used in the areas of natural habitats of the plant [3]. In Portuguese and Spanish, *S. hispanica* is also known as chia [25]. The species is also called chian, salvia chia, salvia chian, salba, and black chia [17].

The species *S. hispanica* does not have its monograph in the European Pharmacopoeia, nor in any national pharmacopoeias of the European Union and other European countries [26][27]. In 2019, the seeds of *S. hispanica* were approved by the European Food Safety Authority (EFSA) as a “novel food for extended uses, which allowed the inclusion of chia seeds in a variety of foods” [28][29]. Moreover, chia seeds have been added to the list of cosmetic raw materials in the CosIng database (Cosmetic Ingredient Database) which was developed by the European Commission [30].

Chia seeds, as a valuable and increasingly popular component of “healthy food”, have been the focus of previously published review articles [6][9][31][32][33][34][35][36][37][38][39]. The authors emphasized the importance of chia seeds as a valuable new food resource with high health and antioxidant potential.

Their unique chemical composition and high nutritional value make chia seeds a very valuable raw material used on an industrial scale. In order to preserve all essential nutrients at high levels, the latest techniques used in nanotechnology are applicable. Nanotechnology promotes improved quality, safety, bioavailability, better controlled release, more accurate targeting, and enhances applicability. In the case of seeds obtained from oil plant species, nanoemulsions derived from seed oils are widely used to create nanocarriers that transport valuable biologically active compounds. The small particle size determines high bioavailability and gravitational stability. Encapsulation of chia seed oil results in increased bioavailability of the encapsulated active ingredient, protection from adverse effects, both natural and processed, such as chemical action, enzymatic action, and physical instability observed during processing. Encapsulation represents a very important and innovative way to improve biological performance and enhance health outcomes by controlling the delivery of active ingredients and preventing the appearance of side effects. Numerous scientific studies confirm the use of the lipid fraction of chia seeds to create nanoemulsions and nanoliposomes, which have a wide range of health-promoting therapeutic applications [39][40][41][42][43][44][45][46].

2. Application of S. hispanica in Cosmetology

CosIng (Cosmetic Ingredient Database), a database developed by the European Commission, contains information on cosmetic substances authorized by the European legislation for the production of cosmetics.

The CosIng database provides information on six raw materials obtained from *S. hispanica*: whole and powdered seeds, chia seed extract and oil, and *S. hispanica* herb extract and oil. It also has data on the activity profile of raw materials, including the peeling and softening of seeds, as well as moisturizing and nourishing effects of seed oil. In addition, *S. hispanica* oil and herb extract are used for flavoring and recommended for the production of perfumes (**Table 1**) [30].

Table 1. Raw materials obtained from S. hispanica registered in the CosIng database along with their uses [30].

Name according to CosIng	Application
S. hispanica seed	Abrasive, scrubbing agent
S. hispanica seed powder	Abrasive, scrubbing agent
S. hispanica seed oil	Moisturizing agent, nourishing effect on the epidermis
S. hispanica seed extract	Emollient, nourishing effect on the epidermis
S. hispanica herb oil	For the production of perfumes and aromas, functional fragrances
S. hispanica herb extract	For the production of perfumes and aromas, functional fragrances

The health-promoting effects of phenolic acids present in chia seeds, which have antioxidant and antimicrobial properties, are particularly exploited in cosmetology. Due to these properties, phenolic acids are used in cosmetology and dermatology. These compounds can be found in both generally available cosmetic preparations, as well as in professional preparations used for treatments in beauty salons. Treatments with these acids counteract photoaging of the skin and also show depigmentation properties by controlling the activity of tyrosinase, which maintains an even pigmentation of the skin. In addition, phenolic acids alleviate the symptoms of acne and atopic dermatitis [47]. **Table 1** shows the main raw materials extracted from *S. hispanica* registered in the CosIng database along with their uses.

The raw materials obtained from *S. hispanica* are especially applied in the production of natural and vegan cosmetics that are currently widely available on the market. The most common ingredients used in these cosmetics are chia seed oil and extract. Chia seed oil is also sold alone as a cosmetic product. The cosmetics prepared using *S. hispanica* extract and seed oil include hand and face creams, face oils, masks, foundations, micellar lotions, body lotions, shower gels, soaps, deodorants, shampoos, and hair conditioners. In all these cosmetics, chia extract and seed oil serve as a nourishing and moisturizing agent [48][49]. In addition, oil-in-water emulsions containing chia seeds are widely used in cosmetology, where they show a moisturizing effect on the skin (**Table 1**). Researchers at Korea University, College of Medicine (Ansan, South Korea), evaluated the benefits of topical application of omega-3-rich foods to the skin. They tested an oil/water emulsion containing 4% *S. hispanica* seed oil on five healthy volunteers with symptoms of xerotic pruritus and five patients with pruritus caused by end-stage renal disease or diabetes. After eight weeks of use, all patients showed a significant improvement in skin hydration, as well as an improvement in the epidermal barrier function, as confirmed by reduced transepidermal water loss and increased skin hydration. Application of the topical preparation with chia seed oil also reduced itching in all patients, with no adverse effects [50].

3. Applications of Chia Seeds in the Food Industry

Chia seeds are widely used in food production, especially in the functional food, due to their high lipid content (30–33%), proteins (15–25%), carbohydrates (26–41%), vitamins, bioelements, and dietary fiber (18–30%) [33][51][52][53]. The caloric value of 100 g of dry seeds is 486 kcal [54]. In 2019, the EFSA confirmed that chia seeds are safe to use in food products [28][29]. It was also shown that chia seeds do not contain mycotoxins or harmful levels of heavy metals [28][55]. According to the Advisory Committee on Novel Foods and Processes in the UK, adults should consume on average 2.1 g of chia seeds per day, with a maximum of 12.9 g (approximately a spoonful). The average level of consumption for children aged 1.5–4.5 years should be 1.1 g/day (maximum 3.2 g/day), and for those aged 4.5–19 years, the daily intake should not exceed 4.3 g/day [56].

Chia seeds are used in the food industry in the form of whole seeds, ground seeds, seed flour, or seed oil [7][57]. They can be added to various food products, such as juices, yogurts, cakes, cookies, bread, pasta, ice cream, desserts, breakfast cereals, and even sausages and hams. Chia seed oil is also available on the market and is recommended as an additive for sandwiches, salads, cottage cheese, and spreads. The US dietary guidelines published in 2000 recommend that chia seeds can be consumed at an amount not exceeding 48 g/day [8]. In addition, a new regulation was implemented in 2017 stating the maximum amount of chia seeds that can be included in bread products (5% whole seeds), breakfast cereals (10% whole seeds), baked goods (10% whole seeds), fruit and seed mixtures (10% whole seeds), fruit spreads (1% whole seeds), yogurts (1.3 g whole seeds/100 g yogurt or 4.3 g/330 g yogurt), fruit and vegetable juices and drinks (15 g/d whole or ground seeds), and ready-to-eat products (5% whole seeds) [29].

Due to their hydrophilic properties, chia seeds are used as an alternative to eggs and fat [58][59][60][61]. The seeds provide a characteristic mucilage texture to food and can absorb water up to 12 times their own weight [62]. Chia seed mucilage can stabilize emulsions; however, this property is influenced by the composition of the emulsion, and compared to other hydrocolloids, such as acacia gum, modified starch, and cellulose, chia seed mucilage has a low emulsifying activity index. Moreover, mucilage obtained from chia seeds is a rich source of polysaccharides, mainly cellulose, and hence can be used in the production of edible films and coatings [2][23].

Due to the fact, that chia seeds are a good source of omega-3 fatty acids (and have a favorable ratio of omega-3 to omega-6 fatty acids), they are commonly used by people on plant-based diets such as vegetarians or vegans [63]. In addition, due to the absence of gluten, chia seeds are a valuable ingredient for people with celiac disease to increase the nutritional value of the diet and for people on a gluten-free diet. Furthermore, wheat flour is substituted by chia seed skim flour as it contains more protein, dietary fiber, and bioactive compounds. In a study by Martinez et al., the nutritional and sensory properties of wheat flour biscuits were compared with biscuits containing skimmed chia, sesame, linseed, and poppy seeds. The authors found that biscuits baked using flour from various types of skimmed seeds contained twice as much protein as those made of wheat flour. Moreover, the content of dietary fiber and protein was the highest in cookies prepared using chia seed flour [64][65].

Chia seeds have also been used in meat processing, as an additive to sausages, for improving their nutritional and technological value. A study assessed the effect of *S. hispanica* seeds on lipid oxidation and proved that the addition of 0.5–1% chia seeds resulted in a reduction of fat oxidation in the meat product. This was attributed to the presence of numerous polyphenolic compounds, characterized by antioxidant activity, in chia seeds [33][66].

4. Plant Biotechnology Studies of S. hispanica

A review of the scientific literature shows that there are very few scientific papers on in vitro cultures studies of *S. hispanica*. These studies mainly concern the elaboration of micropropagation protocols—a technique used for rapid multiplication in vitro. Their short descriptions to date are briefly described below.

The aim of the study conducted by Carvalho et al. was to produce micropropagated *S. hispanica* embryos on two types of liquid medium. The researchers created Murashige–Skoog (MS) liquid medium, which differed in the presence of sucrose. After disinfecting the seeds, they were placed in glass vials with MS liquid medium with sucrose (30 g/L), (and without sucrose) and with plant growth regulators (PGRs). Cultures were grown at 25 ± 2 °C in a photoperiod of 16/8 h. Higher germination was observed in cultures grown on sucrose-containing media compared to media without sucrose. It was found that seedlings at day 14 had the highest shoot and root growth [67].

Zayova et al. conducted also a study on micropropagation of *S. hispanica*. High percentage of seed germination (100%) was recorded on MS medium enriched with 0.4 mg/L gibberellic acid (GA_3) and 10 mg/L ascorbic acid after one week of culture. The maximum number of shoots per explant was obtained in cultures conducted on MS medium with 2 mg/L 6-benzyladenine (BA) after five weeks of culture. The best rooting of plants was achieved on MS medium with 0.1 mg/L indolyl-3-butyric acid (IBA) after four weeks of culture. Many plants were successfully adapted to ex vitro conditions with 95% survival rate [68].

Yadav et al. developed another micropropagation protocol for *S. hispanica*. *S. hispanica* seeds were germinated aseptically on ½ MS medium. Nodal explants obtained from in vitro germinated seedlings were maintained on MS medium with BA (1–5 mg/L) or kinetin (KIN) (1–5 mg/L) individually or with the addition of 1-naphthaleneacetic acid (NAA) (0.1–1 mg/L) and indolyl-3-acetic acid (IAA) (0.1–1 mg/L). The highest number of shoots per explant (9.02 ± 2.65) was found on culture medium containing 3 mg/L BA, which was also optimal for growth of regenerated shoots. Rooting was obtained on ½ MS medium with 1 mg/L IBA. The rooted shoots were acclimatized and transferred to natural conditions with 75% survival rate [69].

Marconi et al. initiated and optimized culture conditions for shoot and callus cultures of *S. hispanica*. Stem fragments were the best explant source to initiate in vitro cultures. Both used PGRs, IAA (0.57, 2.85, 5.70 µmol/L) and NAA (0.54, 2.70, 5.40 µmol/L), with or without BA (0.50 µmol/L) or KIN (0.46 µmol/L), induced adventitious root formation, both in the dark and in the light. In the dark, 2,4-dichlorophenoxyacetic acid (2,4-d) stimulated the development of *S. hispanica* embryogenic tissues, while in the light it promoted the initiation and formation of green and fast-growing callus, which lost their fragility over time. However, callus cultured on MS medium with NAA as PGR, maintained vitality for two years. Fatty acids were determined in the obtained callus cultures, but their content (0.73 g/100 g fresh weight) was much lower than in the seeds of parent plants (30.22 g/100 g fresh weight) [70].

Bueno et al. evaluated the in vitro behavior of different *S. hispanica* explants as material for the initiation of in vitro cultures. The explants tested were: young leaves, cotyledons, and stem fragments with two lateral buds. Explants were inoculated on MS culture medium with 0.1 µM of NAA; 0.1 µM of GA_3; and 0, 0.5, 0.75, or 1 µM of BA. Inoculation of both leaves and cotyledons was unsuccessful. The good results of in vitro shoot survival were obtained for stem fragments. Furthermore, the greater plant proliferation, with up to 6.63 shoots per bud, was observed for BA in concentrations 0.75 and 1 µM. Higher concentrations of BA increased in vitro shoot formation [71].

5. Conclusions

Currently, chia seeds and products containing S. hispanica seed or herb extract or oil are widely available in health food stores, pharmacies, cosmetic stores, hypermarkets, and online stores.

The properties of S. hispanica species thanks to the seeds, undoubtedly merit special attention and interest. Due to their wide range of action and therapeutic value, chia seeds may be more widely used in the future, and Salviae hispanicae semen can be possibly included in the pharmacopoeial monographs of the European Union and other countries.

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