



INTRODUCTION: PHARMACOLOGICAL ACTIVITIES OF CHIA SEEDS – A COMPREHENSIVE REVIEW

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Abstract

Chia seeds (*Salvia hispanica**) have garnered significant attention for their diverse pharmacological properties and health benefits. This comprehensive review aims to elucidate the pharmacological activities of chia seeds, focusing on their anti-inflammatory, antioxidant, and metabolic effects. Rich in essential nutrients such as omega-3 fatty acids, dietary fiber, proteins, and minerals, chia seeds have demonstrated substantial potential in enhancing overall health. Studies highlight their effectiveness in reducing inflammation, combating oxidative stress, and modulating glucose metabolism, suggesting beneficial roles in managing chronic diseases such as diabetes, cardiovascular conditions, and metabolic syndrome. Despite promising results, there remains a need for further research to validate these effects through rigorous clinical trials and to understand the underlying mechanisms better. This review provides a detailed analysis of current evidence and identifies gaps for future research, positioning chia seeds as a valuable natural resource with potential therapeutic applications.

Keywords: chia seeds, Pharmacological Activities, Omega-3 Fatty Acids, Dietary Fiber, Nutritional Benefits, Clinical Research, Health Benefits

1. Introduction

Salvia hispanica L., or chia seeds, have drawn a lot of interest lately because of its remarkable nutritional makeup and possible health advantages. Chia seeds are native to Central and South America, and ancient societies have long used them for their nutritional benefits and ability to increase energy. They are now known to be a superfood because of their abundance in proteins, vitamins, minerals, dietary fiber, and omega-3 fatty acids [1]. Because of its rich composition, chia seeds' pharmacological properties have drawn the attention of researchers, who believe they may have a number of health benefits.

Nutritional pharmacology is interested in chia seeds because of its anti-inflammatory, antioxidant, hypoglycemic, and hypolipidemic properties, which have been demonstrated in recent investigations. Chia seeds' soluble fiber content promotes glycemic control and digestive health, while their high levels of alpha-linolenic acid (ALA) have been connected to better cardiovascular health [2]. Furthermore, phenolic acids and flavonoids, two bioactive components found in chia seeds, have

shown antioxidant qualities that may help lessen the risk of chronic diseases and buffer oxidative stress [3].

Furthermore, research is being done on the potential of chia seeds as a functional food in a number of settings, such as the management of obesity and the prevention of metabolic syndrome [4]. As more is learned about the pharmacological properties of chia seeds, it's becoming evident that these seeds have potential as a natural supplement to improve wellbeing and health.[5] Perhaps the most beneficial food on the planet, chia seeds are packed with nutrients and health benefits for both the body and the mind. Benefits to health include strengthening bones and muscles, improving skin health, reducing the risk of diabetes, heart disease, and aging symptoms, and providing nourishment to the digestive system. [6]

Because the epidermal cells of mature chia seeds contain mucilage, when the seed is submerged in water, it ruptures the primary cell layer that protrudes from the epidermal cells, forming a covering that encircles the seed, grows larger, and gives the chia a gel-like look [7]. Due to the chia seed's inherent gelling property, functional food items including thickeners, emulsifiers, and stabilizers could be developed with considerable potential [8].Furthermore, the use of chia as feed has received increased attention throughout time. For example, the dairy industry has investigated ways to enhance the nutraceutical profile of milk by raising its amount of omega-3 polyunsaturated fatty acids (PUFA) [9]. The lipid profile of milk can be considerably changed by feeding animals forages high in omega-3 fatty acids and supplementing them with oilseeds or marine oils.Because of its remarkable functional, nutritional, and health benefits, chia offers a plethora of nutritional and therapeutic prospects, as well as a promising future for the food, feed, pharmaceutical, and nutraceutical industries. The purpose of this essay is to provide a thorough analysis of chia as a crop that promotes food security and nutrition. The history, cultivation, distribution, physical and nutritional traits, health advantages, functional qualities, and potential uses in the food business will all be covered in detail. [10]

2. Origin, Cultivation and Distribution of Chia

There are around nine hundred species in the genus *Salvia*, and they are found in many different parts of the world, including South and North America, Southern Africa, South-East Asia, and Central America. In addition, chia has been cultivated in Europe, Argentina, Bolivia, Columbia,andPeru.[11] The low latitudes of Mexico and Guatemala are where chia originated. It was one of the four basic meals of the Aztec and Maya peoples, along with other crops like maize, quinoa, and amaranthus [12]. Chia was cultivated as a major crop in pre-Colombian society, second only to maize and beans [13]. Chia seeds were first consumed by humans around 3500 BC, and between 1500 and 900 BC, Central Mexico embraced chia as a staple diet [14,15].

Since chia is a macro thermal short-day flowering plant, it is best to grow it in late spring so that it can bloom in late summer or fall in high latitudes [16]. However, because frost prevents grain filling, the chances of producing seed are low. Early chia blooming plants were created through genetic changes as a result of this impact. After analysis, the early flowering seeds yielded different results. The coat color of commercial chia seeds varies from white to black spotted to grey. It has been established that there is no difference in the chemical composition of the two genotypes [17].

3. Nutritional Composition of chia Seeds

Seeds are highly valued for their health benefits and medicinal qualities. These humble seeds were used as the primary source of nutrition for a very long period. The ancient Aztec warriors used these seeds as a nutritious and high-quality food. Use of *S. hispanica* is an excellent source of dietary fiber and omega-3 unsaturated fats for healthy skin, hair, and nails as well as effective weight loss programs. Additionally, these mostly unsaturated oils are also useful starting points for a few unlimited illnesses. Growing concerns about overall health have led to the development of strong, practical foods with intricate health benefits [26].

3.1 Protein Content

Agronomic parameters can range from 15% to 23%, and the protein content of chia seeds varies depending on where they are grown [6, 27, 29]. Compared to other cereals like oats (13.6 g), wheat (11.8 g), barley (11.5 g), corn (11.1 g), and rice (6.8 g), chia seeds have more proteins (16.54 g) per 100 g. [6], [30], and [15].

The body benefits greatly from chia seeds, which are a great source of vital amino acids [30], [31] produces almost 52% of the total amino acids found in chia seeds, making it the most prevalent protein. Globulin has a molecular size range of 15 to 50 kDa and contains the most 7s and 11s proteins [25]. The essential and non-essential amino acids in chia seeds are well-balanced [43]. The table below displays the amino acid makeup of chia seeds.

Amino acid	Gram/100 grams	Amino acid	Gram/100 grams
Serine	1.05	Threonine	0.709
Tyrosine	0.563	Glutamic acid	3.5
Arginine	2.14	Isoleucine	0.801
Cystine	0.407	Tryptophan	0.436
Leucine	1.37	Lysine	0.970
Proline	0.776	Methionine	0.588
Aspartic acid	1.69	Histidine	0.531
Glycine	0.943	Valine	0.95
Alanine	1.044	Phenylalanine	0.95

TABLE I: AVERAGE AMINO-ACID COMPOSITION OF CHIA SEED

3.2 Dietary Fibre

Chia has a high dietary fiber content; each 100-gram serving of chia includes 34–40 grams of dietary fiber. Dietary fibers are categorized according to their constituents, with soluble fiber accounting for roughly 7% to 15% and insoluble fiber holding the highest amount at around 85% to 90% [21], [32]. Type-2 diabetes, stroke, hypertension, hyperlipidemia, myocardial infarction, hyperglycemia, coronary heart disease, and several types of cancer are among the diseases that the fiber in chia seeds reduces the risk of [22], [6].

The nutritional fiber content of chia seeds ranges from 34 to 40 g per 100 g, which is 100% of the daily recommended amount for adults and significantly greater than that of other grains and vegetables like flaxseed, quinoa, and sunflower [6], [34]. Chia contains 5–10% soluble fiber, or mucilage [35], [36]. By retaining water during hydration, chia seed insoluble fiber can provide bulk, extend the time that food passes through the gastrointestinal tract, increase blood sugar, and decrease insulin resistance [33].

3.3 Minerals and Vitamins

Chia seeds contain minerals like potassium, phosphorus, magnesium, and calcium. Vitamins A, B, E, K, D, B1, B2, and niacin are among those found in chia [37], [38]. The mineral content of chia is 2.4 times higher than that of liver and iron spinach, respectively, and higher than that of corn, rice, oats, and wheat, according to research [39]. Compared to 100g of milk, chia has four times the potassium, six times the calcium, and eleven times the phosphorus [40]. The average mineral and vitamin composition of chia seeds is displayed in Table III below.

vitamins	Per 100 gram	Minerals	Per100 gram
Vitamin-E (alphatocopherol) (mg)	0.50	Iron (mg)	7.72
Vitamin-A (IU)	54	Potassium (mg)	407
Niacin (mg)	8.83	Zinc (mg)	4.58
Thiamine (mg)	0.62	Magnesium (mg)	335
Vitamin C, Total ascorbic acid (mg)	1.6	Phosphorus (mg)	860
Riboflavin (mg)	0.17	Sodium (mg)	16
Folate, total (µg)	49	Calcium (mg)	631
Folate, food (µg)	49	Copper (mg)	0.924
Vitamin B- 12	0	Manganese (mg)	2.72
		Selenium (mg)	

TABLE II: AVERAGE MINERALS AND VITAMIN CONTENT OF CHIA SEEDS

3.4 Total Fats

On average, 30.74% of total lipids are found in chia seeds [38]. Alpha-linolenic fatty acids, an omega-3 fatty acid that encourages a low omega-6 to omega3 fatty acid ratio linked to decreased risks of chronic disorders like cancer, heart disease, and inflammatory diseases, are abundant in it [31].

Chia seeds contain omega-3 fatty acids, which help prevent chronic diseases linked to nutrition. Since alpha-linolenic acid makes up more than half of all fatty acids, chia seeds provide a natural source of omega-3, which is essential for human nutrition and health [41]. Using the positive ion simple ambient sonic-spray ionization mass spectrometry method, the percentage composition of fatty acids is as follows: palmitic (7.07%), α -linolenic (62.8%), linoleic (18.23%), oleic (7.04%), and stearic (3.36%) [19]. The extraction method and geographic location can have a major impact on the fat composition. Chia seeds have a higher concentration of omega-3 fatty acids (68%) than flaxseeds (57.5%) and menhaden fish (1.5%). [28]

4. Pharmacological activity of chia seeds

4.1 Antioxidant and antimicrobial activity

Phenolic substances with antioxidant properties [42] found in chia seeds have the ability to deactivate ABTS cation radicals. Additionally, [43] has validated the chia seed's antioxidant capacity. Chia contains phenolic antioxidants in the form of free sugars or glycosidic bonds. The high solubility of chia in water is attributed to the glycosidic connections, according to [44].

Antioxidants and phenolic chemicals promote health and guard against degenerative diseases like diabetes, heart disease, and cancer. [45], [46]. Bioactive substances like myricetin, quercetin, kaempferol, caffeic acids, and chlorogenic acids are found in chia seeds [38]. These polyphenols assist lower lipid autoxidation levels and have strong antioxidant properties [48]. Because they can scavenge free radicals, donate hydrogen, and chelate metal ions, this class of chemicals is what gives chia its antioxidant properties [20]. By transferring electrons and hydrogen to hydroxyl, peroxy, and peroxyl radicals, the flavones' benzene rings scavenge reactive oxygen species and help stabilize them by generating stable flavonoid radicals [36]. The chia phenolic components rosmarinic and caffeic acids [18], [24], and [22] have been shown to aid in the prevention and treatment of neurological disorders such as epilepsy [49].

The existence and activity of reactive oxygen species generate oxidative stress in cell structures and biomolecules. DNA, proteins, and lipids are all destroyed by reactive oxygen species. Cancer, thrombosis, diabetes, and chronic inflammation are only a few of the diseases and disorders that arise from the steady accumulation of such devastation [47].

Reactive oxygen species can be scavenged and intracellular transition metal ions that produce reactive oxygen species can be chelated with the aid of flavonoids such myricetin, quercetin, and kaempferol [23]. By stopping free radicals from attacking cells, the flavonoids can trigger the production of the glutathione S-transferase enzyme, which helps shield cells from oxidative stress [11]. Chia seeds include antioxidants that aid in the body's defense against free radicals. Oxidative stress and cell death

are caused by free radicals [19]. Consuming foods high in antioxidants, like chia seeds, can help reduce diseases linked to free radicals, like cancer, heart disease, and cognitive decline [50].

4.2 Anti-carcinogenic activity

Chia seeds are a great source of omega-3 unsaturated fats, fiber, vitamin B, protein, calcium, magnesium, zinc, and a host of other minerals and vitamins. All of these contribute significantly to the strength of the human body [51]. Alpha linolenic acid (ALA) has been found to cause apoptosis in specific cervical tumor and bosom growth cell lines while sparing non-dangerous cells. The body's natural mechanism for eliminating damaged or useless cells is called apoptosis; however, disease cells typically lack this mechanism, which allows them to proliferate uncontrollably [52, 53].

Chia seeds help shield cells from mutations that cause cancer [54]. Chia seeds contain myricetin, which reduces the risk of skin tumorigenicity caused by polycyclic aromatic hydrocarbons including the highly carcinogenic benzo(a)pyrene [55], [85]. By halting the growth of skin tumors, it will provide protection [29]. The mutagenesis process brought on by carcinogenic hydrocarbons is less effective as a result of the inhibition of genetic mutation. Chia seeds have anticancer properties because they stop the cells that cause cancer from growing. Extracts from chia seeds suggest that they may be used to cure cancer [54].

Myricetin has the highest concentration of phenolic hydroxyl groups among the chia flavonoids, according to study, and as the amount of hydroxyl groups rises, so does its antioxidant activity. Isoproterenol-induced cardiotoxic effects can be avoided by myricetin flavonoids [56]. [57] found that males who consumed more myricetin were less likely to develop prostate cancer.

4.3. Anti-inflammatory and Anticholesterolemic

The body's natural reaction to damage or illnesses is inflammation. Inflammation can occasionally assist the body fight off dangerous germs, which can occasionally cause injury. This is typical of chronic inflammation, which has been connected to heart disease and cancer [58]. Chronic inflammation typically shows no outward symptoms, but blood inflammatory markers can be measured to assess it. While some nutritious foods, like including chia in your diet, have been shown to lower the inflammatory markers known as hs-CRP in the blood, unhealthy lifestyle choices, such as smoking, eating poorly, and not exercising, have been shown to raise the risk of chronic inflammation [59].

Chia seeds have anti-inflammatory properties since they help reduce edemas brought on by carrageenan and croton oil. Myricetin and quercetin are two flavonoids that have demonstrated anti-inflammatory properties [60].

Flavonoids' anti-inflammatory properties prevent the production of cytokines, which are produced during inflammation. The cytokines, such as interleukin-12 and interleukin-1 β , are produced by downregulating transcriptional factors and mediators. Flavonoids have the ability to suppress the function of tumor necrosis factor-alpha and kinases, two inflammatory pathways [61], [62]. Cancer and heart disease are among the illnesses brought on by chronic inflammation. Chia seeds contain caffeic acid, which helps the body avoid inflammation. Consuming chia seeds helps reduce inflammatory indicators, which indicate the existence of inflammatory diseases. By scavenging free radicals that trigger transcription factors that generate cytokines, quercetin reduces inflammation [63], [64].

Heart disease is associated with high-density lipoprotein. Because chia seeds include dietary fiber and omega-3 fatty acids, they have been shown to lower serum cholesterol levels. Chia protein and bioactive peptides have been shown to inhibit 3 hydroxy-3-methylglutaryl coenzyme A reductase (HMGCoA reductase), one of the key markers of cholesterol synthesis [64, 65]. Consuming chia improves lipid redistribution, which is connected to cardioprotection and hepatoprotection. Rats fed a hyperglycemic and hyperlipidemic diet demonstrated this by exhibiting impairments in the liver and cardiac enzyme stearyl-CoA 9-desaturase [66].

4.4 Anti-hypersensitive

Many people have high blood pressure, which is now considered a risk factor [67]. Chia seeds have been shown in studies to help reduce blood pressure [59]. According to rat studies, consuming chia seeds raises excellent HDL cholesterol while lowering triglycerides, insulin resistance, inflammation, and belly fat [68], [69].

However, one investigation involving humans found no improvement in risk variables [70]. According to a few previous research, eating chia seeds significantly lowers blood pressure in people with hypertension [59], [71]. It is recommended that people with hypertension consume chia seeds [72], [73]. It has been demonstrated that omega-3 fatty acids lower blood pressure [71].

Chia seeds have been found to have impacts on hypertension using enzymatic analysis. Synthetic angiotensin-converting enzyme-I (ACE-I) inhibitors also impede the function of angiotensin-converting enzyme-I, as demonstrated by the proteins hydrolyzed in chia [73]– [75]. Chia's hydrophobic protein residues have a similar synthetic ACE-I inhibitory effect; they help block the production of angiotensin II. It has been demonstrated that substituting other oils for chia oil in hypertensive environments can help lower blood pressure, so consuming more chia is beneficial to health [76].

Quercetin, an antioxidant found in chia seeds, helps prevent the development of heart disease and other health issues [77]. The fiber found in chia seeds helps to decrease high blood pressure. Chia fiber lowers insulin resistance and raises blood glucose levels, which lowers the risk of metabolic syndrome and type 2 diabetes [69]. Chia seed-based foods decrease high blood sugar levels by lowering the blood sugar response. Eicosapentaenoic and alpha-linoleic acids aid in the synthesis of vital biochemical substances used for a variety of physiological functions, such as prostaglandins, thromboxane, and leukotrienes. Omega-3 fatty acids have been shown to improve parasympathetic function, prevent ventricular arrhythmia, and regulate heart rate fluctuations while also preventing sodium and calcium channel dysfunctions that may result in hypertension [78].

4.5 Reduce Blood Sugar Levels

High fasting blood sugar levels have been linked to untreated type 2 diabetes, and these levels may subsequently raise the risk of developing chronic conditions including heart disease [79]. If they happen frequently, short-term blood sugar rises following meals may have negative consequences later [80].

Research conducted on animals has demonstrated that chia seeds improve insulin sensitivity and control blood sugar, preserving blood sugar levels after meals [66], [69], and [81]. This is corroborated by human research, which shows that eating bread containing chia seeds lowers the post-meal spike in blood sugar compared to eating bread without chia seeds [82], [83]. Chia seeds may assist people with type-2 diabetes by lowering their risk of elevated blood sugar after consuming a high-carb meal.

4.6 Weight Loss

Chia seeds are recommended for people who need to reduce weight since they include a higher amount of protein. A serving of chia seeds provides 39% of the recommended daily intake of fiber. One feels fuller for longer and eats less because the soluble fiber and mucilage absorb water, which causes the seeds to expand inside the stomach [84], [85]. Chia seeds aid in weight maintenance or weight loss in this way. Chia seeds have been shown to have the capacity to reduce hunger and promote satiety due to their high dietary fiber content and low carbohydrate content [86]. Consuming chia seeds has been linked to weight loss, and studies have indicated that C-reactive protein increases adiponectin and decreases waist circumference [21]. According to research, chia fiber can ferment in the gut to produce short-chain fatty acids (SCFAs) and enhance colon health [84], [87], and [88].

5. Conclusion:

As we conclude our investigation into the pharmacological properties of chia seeds, it is evident that these minuscule seeds have a surprisingly strong impact. Beyond their modest appearance, chia seeds

are a health powerhouse with remarkable hypoglycemic, antioxidant, and anti-inflammatory properties. Because of their high content of fiber, vital minerals, and omega-3 fatty acids, they provide a natural way to support metabolic health and fight chronic illnesses. Chia seeds are unique not only because of their high nutritional value but also because of their many health benefits. Imagine including a single food item in your diet that may improve blood sugar regulation, cardiovascular health, and digestive wellness—all at once. But despite the intriguing potential, it's important to keep in mind that further research is needed to completely comprehend the pharmacological potential of chia seeds. Unlocking their entire range of advantages and successfully incorporating them into individualized health plans will require more research. For the time being, chia seeds provide a hopeful example of how the most basic products found in nature might revolutionize the way we think about health.

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