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# CHIA SEEDS (*SALVIA HISPANICA L.*): A COMPREHENSIVE LOOK AT THEIR ATTRIBUTES, PHYTOCHEMICAL PROFILE, AND IMPACT ON HEALTH

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## ABSTRACT

This article presents a comprehensive review of the characteristics, phytochemical profile and health effects of chia seeds. Chia seeds belong to the *Lamiaceae* family, and are small, oval and colored seeds that grow in tropical and temperate climates. Chia seeds are rich in protein, fiber, minerals, phenolic compounds and polyunsaturated fatty acids. These nutrients give chia seeds functional properties such as antioxidant, anti-inflammatory, hypolipidemic, hypoglycemic and prebiotic. Chia seeds may play a potential role in the prevention and treatment of chronic diseases such as cardiovascular diseases, diabetes, obesity, digestive system diseases and cancer. Chia seeds can be consumed whole, ground into flour or extracted into oil and added to various foods. Moreover, chia seeds have technological functions such as water retention, emulsification and viscosity enhancement in the food industry. Chia seeds have become a popular functional food in recent years and are being researched. However, more clinical studies and meta-analysis studies are needed on the health effects of chia seeds.

**Keywords**: Chia seeds, chronic disease, obesity

# CHIA TOHUMU (*SALVIA HISPANICA L.*): GENEL BAKIŞ, FITOKİMYASAL PROFİLİ VE SAĞLIK ÜZERİNE ETKİSİ

## ÖZ

Bu makale, chia tohumunun (*Salvia hispanica L.*) özellikleri, fitokimyasal profili ve sağlık üzerindeki etkilerine ilişkin kapsamlı bir inceleme sunmaktadır. Chia tohumu, *Lamiaceae* ailesine ait, tropik ve ılıman iklimlerde yetişen, küçük, oval ve renkli tohumlara sahip bir bitkidir. Chia tohumu, yüksek oranda protein, lif, mineral, fenolik bileşik ve çoklu doymamış yağ asidi içermektedir. Bu besin öğeleri, chia tohumunun antioksidan, anti-inflamatuar, hipolipidemik, hipoglisemik ve prebiyotik gibi fonksiyonel özelliklere sahip olmasını sağlamaktadır. Chia tohumu, kalp-damar hastalıkları, diyabet, obezite, sindirim sistemi hastalıkları ve kanser gibi kronik hastalıkların önlenmesi ve tedavisinde potansiyel bir rol oynayabilir. Chia tohumu, sade olarak, un haline getirilerek veya yağı çıkarılarak çeşitli gıdalara katılabilir. Ayrıca, gıda sanayisinde su tutma, emülsifiye etme ve kıvam artırma gibi teknolojik fonksiyonlara da sahiptir. Chia tohumu, son yıllarda popüler bir fonksiyonel gıda olarak

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tüketilmekte ve araştırılmaktadır. Ancak, chia tohumunun sağlık etkileri ile ilgili daha fazla klinik çalışma ve meta-analiz çalışmasına ihtiyaç vardır.
**Anahtar kelimeler**: Chia tohumu, kronik hastalıklar, obezite

## INTRODUCTION

### General Characteristics of Chia Plant

The plant identified as the chia seeds belongs to the *Lamiaceae* family, with origins traced back to northern Guatemala and southern Mexico. The Salvia genus, comprising approximately 900 species, has been prevalent across diverse regions globally for millennia, including South Africa, Central America, North and South America, and Southeast Asia (Kulczyński et al., 2019; Rabail et al., 2021).

Currently, chia cultivation extends globally, reaching regions such as Bolivia, Colombia, Peru, Argentina, Brazil, the United States, Australia, and Europe (Selvi et al., 2022; Enes et al., 2020). Mexico is presently acknowledged as the foremost global producer of chia seeds. Historical records indicate the use of chia seeds by ancient Mesoamerican civilizations, specifically the Aztecs and Mayans, for traditional remedies and culinary practices. This usage was often intertwined with staple crops like maize, beans and amaranth (Salgado et al., 2023; Chen et al., 2024). Chia gained prominence as a primary crop in pre-Columbian societies, following beans. The diverse utilization of various plant species within Aztec communities served purposes ranging from sustenance to cosmetic applications and religious ceremonies (Knez et al., 2020; Tsatsoulis A et al., 2020). Figure 1 illustrates the global distribution of chia seeds.


Figure 1. Worldwide distribution of chia seed (Ivanovski et al.,2019)

### Botanical Information

*Chia seed* is a highly valued plant, commonly known as the chia plant, grown mainly for its seeds. The plant boasts white and purple flowers, measuring around 3-4 mm, and exhibits hermaphroditic characteristics. With phototropic tendencies, it can reach a maximum height of 1 meter. The leaves are arranged in an opposite-petioled manner with serrated margins, measuring 4 to 8 cm in length and 3 to 5 cm in width (Ivanovski et al., 2019; Sur and Çiçek, 2021). Chia seeds are small, oval-shaped, measuring about 2 mm in length, 1 to 1.5 mm in width, and less than 1 mm in thickness. The plant thrives in acidic soil, showing optimal growth within a pH range of 6.5 to 8.5. According to Fernandes et al. (2023) and Enes et al. (2020), the ideal temperature for seed growth falls within the range of 11 to 36 °C.

Figure 2. *S. hispanica* (chia seed) plant

### Chemical Composition

Chia seeds are the principal industrially sourced raw material from *chia seed.* They are recognized for their rich nutritional profile, encompassing polyunsaturated fatty acids, dietary fiber, protein, phenolic compounds, vitamins and essential minerals. Previous studies have affirmed the favorable chemical composition and nutritional richness of chia seed sprouts (da Silva et al., 2020; Miranda-Ramos and Haros, 2020; Senna et al., 2024).

Chia seeds chemical composition varies due to a range of external factors, including plant origin, harvest timing, storage conditions, drying techniques, cultivation region, terrain features, germination period, nutrient availability, and rainfall patterns. The empirical evidence supports this conclusion with confidence. (Agarwal et al., 2023; Motyka et al., 2023).

These factors contribute to the variability in seed characteristics, such as quantity, frequency, and intensity. The fatty acid composition experiences fluctuations due to climate changes and the plant's altitude. In a given region, the content of omega-3 unsaturated fatty acids tends to increase with decreasing temperature and increasing altitude. However, it is important to note that the existing scholarly literature predominantly focuses on the raw material of chia seeds, with limited exploration of the chemical composition of other components, notably the leaf (Ravlić et al., 2023; Enes et al., 2020; Sosa-Baldivia et al., 2018; Katunzi-Kilewela et al., 2021). Chia seeds stand out as a nutritional powerhouse, boasting high levels of dietary fiber and oil. With an impressive 30-35 grams of dietary fiber, they play a crucial role in supporting a healthy digestive system. The fiber composition in chia seeds is predominantly insoluble, accounting for 85-94%, complemented by a smaller portion of soluble fiber at 7-16%. Moreover, these seeds are a rich source of polyunsaturated fatty acids (PUFAs), particularly alpha-linolenic acid (ALA), constituting approximately 60% of their total fatty acid content. Additionally, chia seeds contribute 18-24% plant protein, featuring a diverse amino acid profile. In essence, incorporating chia seeds into any diet proves to be an excellent choice, providing a broad spectrum of essential nutrients (Vera-Cespedes et al., 2023; Bermejo et al., 2023; Anand et al., 2024).

Chia seeds emerge as a favorable dietary option for individuals with celiac disease, given their gluten-free nature. Beyond that, they deliver a wealth of essential vitamins (B1, B2, niacin) and minerals (phosphorus, calcium, potassium, magnesium). Chia seeds also shine as a source of various phytochemicals, including gallic acids, caffeic acids, chlorogenic acids, cinnamic acids, ferulic acids, quercetin, kaempferol, epicatechin, rutin, apigenin, p-coumaric acid, daidzein, glycitin, genistein, and genistin (Clara et al., 2020; Fernandes et al., 2021; Selvi et al., 2022). Please refer to Table 1 for a detailed breakdown of their chemical composition.

Table 1. Chemical composition of chia seed (USDA, 2020)

| Component | Quantity (100g) | Component | Quantity (100g) |
|---|---|---|---|
| Energy (kcal) | 569 | Carbohydrate (g) | 40.62 |
| Protein (g) | 15.62 | Fat (g) | 31.25 |
| Dietary fiber (g) | 34.4 | Ca (mg) | 625 |
| Fe (mg) | 7.5 | Mg (mg) | 335 |
| P (mg) | 860 | K (mg) | 406 |
| Na (mg) | 16 | Zn (mg) | 4,5 |
| Vitamin C (mg) | 15 | Vitamin $B_1$ (mg) | 0.62 |
| Vitamin $B_2$ (mg) | 0.2 | Vitamin $B_3$ (mg) | 8.8 |
| Vitamin A (IU) | 54 | Vitamin E (α-tocopherol) | 0.5 |

## EFFECTS OF CHIA SEED ON HEALTH

### Phenolic Compounds and Antioxidant Effects

Chia seeds are renowned for their notable antioxidant properties, attributed to various compounds such as tocopherols, plant sterols, carotenoids, and polyphenolic compounds. Analytical techniques like UHPLC (Ultra-High-Performance Liquid Chromatography), HPLC (High-Performance Liquid Chromatography), and UPLC (Ultra-Performance Liquid Chromatography) are commonly employed to investigate these compounds. Researchers use these techniques to study specific compounds such as caffeic acid, ferulic acid, chlorogenic acid,

rosmarinic acid, and flavonoids in chia seeds (Masood et al., 2022; Bermejo et al., 2023).
These compounds demonstrate a diverse range of biological activities, encompassing antioxidant, anti-aging, anti-hypertensive, anti-carcinogenic, and anti-inflammatory effects. It's noteworthy that the performance of these compounds may vary, influenced by factors such as genetic diversity, cultivation conditions, and overall variability among chia seed samples (Gallo et al., 2020; Grauso et al., 2023). Earlier studies have identified flavonoids and tocopherols as the primary antioxidants in chia seeds, underscoring their role in contributing to the beneficial effects associated with the consumption of chia seeds (Alcântara et al., 2019; Tutunchi et al., 2020; Grancieri et al., 2021). Studies have shown that due to its high antioxidant capacity and phenolic compounds, it may offer protection against chronic diseases such as cardiovascular diseases, diabetes, and various types of cancer (e.g. prostate, colon, breast) (Wang et al., 2021; Dickens et al., 2023).

**Effect on Body Composition and Obesity**
Obesity primarily results from lifestyle changes, characterized by excessive food intake surpassing physiological needs and decreased physical activity. Effective management involves lifestyle adjustments, emphasizing dietary strategies with a focus on polyunsaturated fatty acids (PUFAs). Features associated with obesity, such as dyslipidemia, hypertension, and insulin resistance, contribute to metabolic syndrome, increasing susceptibility to diseases like cardiovascular disease, diabetes, and cancer (Enes et al., 2020; Fernandes et al., 2023). The inclusion of alpha-linolenic acid (ALA) in the diet is crucial for long-term weight management success. Plant proteins exhibit an inverse association with obesity onset and progression, impacting satiety regulation, thermogenesis, energy utilization, and changes in body composition (Khalid et al., 2023; Barrea et al., 2023).

Chia seeds, renowned for their exceptional nutritional properties, serve as valuable sources of vegetable protein and essential PUFAs. They contain angiotensin-converting enzyme inhibitors, showcasing antioxidant and anticholesterolemic properties, as well as potentially bioactive peptides. The incorporation of chia seeds into the diet is considered significant for managing obesity due to their nutritional richness (Medina-Urrutia et al., 2020; Grancieri et al., 2021). While animal studies have explored the impact of chia seed consumption on obesity, limited human-focused research exists. Chia seeds present a viable dietary option for weight management initiatives, given their substantial content of protein, fat (especially ALA), fiber, and essential vitamins and minerals, leading to a reduction in body weight (Khalid et al., 2023; Agarwal et al., 2023).

Regular consumption of vegetable oils rich in ALA contributes to the accumulation of omega-3 fatty acids and PUFAs in the plasma, liver, and adipose tissue of mice. A balanced diet rich in ALA and low in fructose and sucrose is crucial for optimal health (El-Dreny et al., 2023; Omran et al., 2023). Diets high in fructose or sucrose negatively impact antioxidant capacity, enzyme activities, and visceral adiposity. The addition of chia seed oil to the daily diet has shown positive effects on blood parameters in individuals, as suggested by various studies (Enes et al., 2020; Ivanovski et al., 2019).

In a meta-analysis on chia seeds and obesity, it was found that chia seeds can improve blood glucose metabolism and reduce obesity by inducing phosphorylation of insulin receptor substrate (IRS) and translocation of glucose transporter type 4 (GLUT-4) to the plasma membrane, as well as lowering serum fasting insulin levels. The studies included in this research propose that *chia seeds* can improve insulin sensitivity in cases of obesity by regulating the phosphorylation of AMPK and IRS-1. This, in turn, enhances GLUT-4 translocation and increases the activity of hexokinase and glucose 6-phosphate enzymes (Enes et al., 2020).

**Effects on Cardiovascular Diseases (CVD) and Blood Lipid Levels**
A cardiovascular risk factor is a measurable characteristic causally linked to an elevated risk of

cardiovascular disease (CVD). These risk factors are traditionally categorized as modifiable or non-modifiable. Modifiable factors, subject to behavioral changes, include tobacco use, hypertension, diabetes mellitus (DM), hypercholesterolemia, physical inactivity, and obesity. Diet, a crucial modifiable factor, can be adjusted to mitigate CVD risk. Numerous studies advocate for the consistent intake of omega-3 fatty acids as a preventive measure for CVD, encompassing conditions like atherosclerosis and thrombosis (Khalid et al., 2023; Roohi, 2020; Dickens et al., 2023).

While scientific attention often centers on fish oils rich in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) for CVD prevention, the precursor alpha-linolenic acid (ALA) has received less focus. Chia seeds have recently gained popularity as a prominent plant-based source of ALA oil. Historically consumed by indigenous populations in Mexico and Guatemala, chia has garnered attention for its high ALA content and antioxidant properties, making it a valuable addition to the daily diet (Amin et al., 2023; Kaur et al., 2024). Enes et al. (2020) suggest that incorporating chia seeds into the diet has the potential to regulate blood cholesterol levels and establish a favorable fatty acid profile, given their oil content ranging between 25% and 40%. While empirical data on the effects of chia seeds on CVD risk factors is limited, existing research, including studies by Rabail et al. (2021) and Han et al. (2020), suggests beneficial effects, particularly in mitigating oxidative stress and hyperlipidemia in mice fed a high-fat diet.

**The Impact of Type 2 Diabetes on Blood Glucose Levels**

Diabetes, a prevalent chronic metabolic disorder affecting 10.5% of the global population in 2021, is expected to impact 783 million individuals by 2024, with over 90% of cases attributed to Type 2 Diabetes Mellitus (T2DM), often linked to an unhealthy lifestyle (Einarson et al., 2018; Dal Canto et al., 2019).

Strategies for preventing and managing T2DM include emphasizing food sources rich in polyphenolic compounds and antioxidants (Wang et al., 2021; Alwosais et al., 2021). Incorporating chia seeds into dietary patterns, known for their legumes, protein, and omega-3 fatty acids, shows promise in managing body weight and related comorbidities associated with diabetes. Research indicates that chia seed consumption is associated with reduced postprandial blood glucose levels and an increased satiety index, with no significant differences in glycaemic parameters compared to control groups (Alwosais et al., 2021; Wang et al., 2021). Additionally, studies highlight chia seed's ability to impede rapid carbohydrate release, mitigating blood glucose level increases (Kulczyński et al., 2019; de Abreu Silva et al., 2021).

Chia seed supplementation may regulate overeating, reduce postprandial glycaemia, and suppress appetite (Alwosais et al., 2021; Dal Canto et al., 2019). Notably, ground chia demonstrates potential in reducing postprandial glycaemia, while studies comparing flaxseed and chia seed supplements show both effectively lowering postprandial glucose levels, with no significant difference between the two after 120 minutes (Juangco et al., 2022; Dickens et al., 2023).

Recognized for their protein content, total fiber, and alpha-linolenic acid (ALA), chia seeds have gained popularity as a functional food. Evidence supports their significant role in weight loss, appetite suppression, and potential therapeutic benefits in managing T2DM and improving obesity-related risk factors (Alwosais et al., 2021; Juangco et al., 2022; Grancieri et al., 2022).

**Effects on Celiac Disease**

Urbanization, globalization, and economic progress have led to a rise in the prevalence of diseases such as obesity, diabetes, cardiovascular disease (CVD), stroke, hypertension, and certain cancers, making individuals more susceptible to these diseases. Consumer awareness and interest in the health-promoting properties of specific foods or bioactive components in foods have

significantly surged in recent years (Di Marco et al., 2020; Fırtın et al., 2020). Food not only provides essential nutrients and satisfies hunger, but also plays a crucial role in preventing diet-related diseases and enhancing the physical and mental well-being of consumers. This trend creates opportunities for innovative approaches in nutrition, such as the development of nutritious foods. Chia seeds have been extensively researched for their potential applications in various sectors to enhance individual and community well-being (Din et al., 2021; Ghafoor et al., 2020).

The global gluten-free industry has experienced significant growth due to the increasing prevalence of gluten-related diseases, such as non-celiac gluten sensitivity, wheat allergy, and celiac disease (Di Marco et al., 2020; Maidana et al., 2020). The rise in gluten-free diets is not solely due to the prevalence of gluten-related diseases. It is also influenced by consumer preferences for healthier and more nutritious products, which promotes the acceptance of gluten-free diets (Roohi, 2020). Gluten-free products are highly effective in addressing gluten-related disorders. It is worth noting that concerns have been raised about their nutritional value, as they tend to be high in sodium, fat, and sugar, while lacking essential minerals and fiber when compared to conventional counterparts (Rabail et al., 2021). However, it is important to remember that gluten-free products are still a viable option for those with gluten-related disorders.

In response to the increasing demand for gluten-free foods, substantial research efforts have focused on developing novel gluten-free products. However, improving the sensory attributes, technological properties, and bioactive composition of gluten-free products remains a challenge for food scientists and technologists, particularly in maintaining baking quality due to the viscosity and elasticity of these products. The challenge is to create products that are safe, acceptable, affordable, and compliant with FDA guidelines. Maize and rice are widely acknowledged as primary staples in formulating gluten-free foods. Ongoing efforts to identify alternative ingredients for gluten-free products are fueled by the presence of bioactive compounds in cereals (Alwosais et al., 2021; Din et al., 2021).

The increased utilization of chia seeds in various industries can be attributed to their viscosity, nutritious phytochemical composition, dietary fiber, omega-3 content, antioxidant capacity, and therapeutic potential. Incorporating chia seeds into food products, especially in creating gluten-free options, holds promise for benefiting individuals diagnosed with celiac disease. Chia seeds have demonstrated inhibitory properties against cholinesterase (ChE) activity, suggesting a potential preventive measure against neurodegenerative diseases (Din et al., 2021; Ghafoor et al., 2020; FaragAllah et al., 2023).

**Chia Seed Recommended Consumption Amount**

The United States Dietary Guidelines Advisory Committee (DGAC) recommends that adults should aim for an average daily consumption of 2.1 grams of chia seeds, with a maximum allowable intake of 12.9 grams, roughly equivalent to one spoonful. For children aged 1.5 to 4.5 years, the recommended average is 1.1 grams per day, with a maximum intake of 3.2 grams per day. Similarly, children aged 4.5 to 19 years should not exceed 4.3 grams per day. Recent revisions by the EFSA NDA Panel suggest a generally safe daily intake of chia seeds at around 50 grams (EFSA Panel on Nutrition, 2023).

Allergenic effects of chia seeds have been investigated in two case studies, indicating potential allergic reactions in individuals with pre-existing allergies to peanuts and sesame seeds upon chia seed consumption. Based on available human studies and an extensive literature review, a daily consumption of 50 grams of chia seeds is considered safe in terms of toxicity. Studies primarily focus on investigating potential beneficial effects, and the administration of chia seeds at a dose of 7.5 grams per kilogram of body weight has shown no toxicological effects. The EFSA Panel on Nutrition (2019) has not

identified significant safety issues based on available toxicological studies.

## CONCLUSION

In conclusion, a thorough examination of the subject matter emphasizes the importance of chia seeds, a botanical species with a rich historical legacy, celebrated for its outstanding nutritional composition and potential therapeutic attributes. In recent times, chia seeds have gained significant popularity as a highly favored food, owing to their diverse beneficial effects on human physiological processes. Noteworthy for their elevated levels of fiber, omega-3 fatty acids, and protein, chia seeds offer a comprehensive profile of essential amino acids. Additionally, they serve as a plentiful source of minerals, vitamins, and bioactive compounds, including polyphenols and tocopherols, contributing to their considerable antioxidant properties. Recent studies unequivocally demonstrate the potential effectiveness of chia seeds in addressing prevalent global health issues such as obesity, diabetes, and hypertension. The increasing popularity of chia seeds in the food, nutraceutical, and cosmetic industries is driven not only by their significant chemical composition and biological activity but also by their widespread availability. Acknowledged as a valuable raw material, chia seeds find extensive application in the food industry due to their beneficial properties for human health. To facilitate broader human consumption, the establishment of standardized protocols for the extraction and determination of effective doses of chia seeds, rooted in robust scientific evidence, becomes imperative. This need persists despite existing epidemiological and experimental studies supporting the medicinal use of chia seeds. The implementation of such protocols would contribute to ensuring consistent quality and efficacy in various applications of chia seeds, fostering their widespread and safe utilization.

## AUTHOR CONTRIBUTION

Hilal Doğan Güney: Design, analysis and/or interpretation, literature review, manuscript writing; Pınar Göbel: Idea/concept, supervision/counselling, manuscript writing, critical review

## CONFLICT OF INTEREST DECLARATION

There is no financial conflict of interest with any institution, organisation, person related to the article and there is no conflict of interest between the authors.

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