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A Review: Pharmacokinetics and Pharmacodynamics Studies of Chia Seed Derived Compounds

Mohd. Wasiullah[1], Piyush Yadav[2,*], Deepak Kumar Patel[3]

Abstract

Chia seeds (Salvia hispanica L.) have been historically valued by ancient civilizations and are increasingly being recognized for their powerful nutritional and therapeutic properties. Rich in omega-3 fatty acids, polyphenols, fiber, and essential minerals, chia seeds are gaining attention for their potential health benefits. This review examines the pharmacokinetics and pharmacodynamics of chia seed-derived compounds, with emphasis on their absorption, distribution, metabolism, and elimination processes, as well as their biological effects. Chia-derived omega-3 fatty acids, polyphenols, and fiber promote anti-inflammatory, antioxidant, cardiovascular, neuroprotective, and gastrointestinal benefits. Despite the promising results of clinical research, there are some issues, such as biological utilization and low restrictions on production. As functional foods, chia seeds offer significant potential for improving health and preventing chronic diseases, although further research is needed to fully optimize their therapeutic applications.

Keywords: Chia seeds, functional foods, *Salvia hispanica L,* bioactive compounds, Chia seed oil

INTRODUCTION

The word chia (*Salvia hispanica L.*) is derived from the Spanish word “chian” or “cane” which means “fat”. Mexico and Guatemala are recognized as the birthplace of chia, which has served as a significant element of the human diet for approximately 5,500 years. Since chia is an herbal plant, it was traditionally used by the Aztecs and Mayans to prepare traditional medicines, foods, and clothing. Chia seeds are oval and gray in color, featuring white and black spots, and measure approximately 2 millimeters (0.08 inches) in diameter. Chia is a seed oil, it is considered a source of omega-3 fatty acids, containing premium proteins, higher amounts of dietary fiber, vitamins, and minerals, and is a vital source of bioactive compounds and polyphenols. Chia contains a significant amount of omega-3poly unsaturated fatty acids, which can help prevent inflammation, increase cognitive performance, and minimize cholesterol levels in the human body. Chia contains saw health polyphenols derived from caffeic acid that acts as an antioxidant to protect the body from free radicals, aging, and chronic diseases. In addition, high levels of concentration of dietary fiber based on carbohydrates are present in chia, associated with reduced inflammation, cholesterol, and irregular intestinal function. Given its excellent phytochemical content and eminent nutritional and functional properties, chia is gaining importance worldwide. Since the recognition of its nutritional benefits, chia is now called “the seed of the 21st century”, “new gold” or “supernutrients”. Recent studies show that the components of chia seeds have a beneficial effect on improving the lipid profile of blood thanks to their hypotensive, hypoglycemic, antimicrobial, and immuno-stimulating properties.

***Author for Correspondence**
Piyush Yadav
E-mail: piyush6118@gmail.com

[1]Principal, Department of Pharmacy, Prasad Institute of Technology, Jaunpur, Uttar Pradesh, India
[2]Professor & Head, Department of Pharmaceutical Chemistry, Prasad Institute of Technology, Jaunpur, Uttar Pradesh, India
[3]Scholor, Department of Pharmacy, Prasad Institute of Technology, Jaunpur, Uttar Pradesh, India

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Beyond their nutritional value, compounds derived from chia seeds, such as phenolic acids, flavonoids, and other bioactive compounds have attracted attention for their potential therapeutic properties. This review focuses on the pharmacokinetics (how the body absorbs, distributes, metabolizes, and secretes chia-derived compounds) and pharmacodynamics (biological effects and mechanisms of action) of these compounds (Figure 1).

Figure 1. Chia seed.

PHYTOCHEMICAL PROFILE OF CHIA SEED DERIVED COMPOUND

The Chemical Composition of Chia Seeds Has Been Analyzed by Several Researchers

Macronutrients (Per 100 Grams of Chia Seeds)

1. *Calories:* 486 kcal.
2. *Carbohydrates:* 42.1 g.
3. *Dietary fiber:* 34.4 g (high fiber content).
4. *Sugars:* 0 g (practically sugar-free).
5. *Protein:* 16.5 g.
6. *Lipids:* 30.7 g.
7. *Omega-3 fatty acids:* 17.8 g (mainly ALA-alpha-linolenic acid).
8. *Omega-6 fatty acids:* 5.8 g.
9. *Unsaturated fat:* 2.3 g.
10. *Saturated fat:* 3.3 g.

Vitamins and Minerals

a. *Calcium:* 631 mg (important for bone health).
b. *Iron:* 7.7 mg (important for the transport of oxygen in the blood).
c. *Magnesium:* 335 mg (supports muscle and nerve function).
d. *Phosphorus:* 860 mg (important for bone health).
e. *Zinc:* 4.6 mg (important for immune function).
f. *Potassium:* 407 mg (contributes to fluid balance and muscle function).

Antioxidants

Chia Seeds Contain Several Antioxidant Compounds, Including

1. Flavonoids (such as quercetin, kaempferol and myricetin).
2. Caffeic acid.

Chlorogenic Acid

These antioxidants help neutralize free radicals in the body, potentially reducing inflammation and oxidative stress [1, 2].

Water Content

Chia seeds also absorb a significant amount of water and expand, creating a gel-like substance, which contributes to its fiber content and potential digestive benefits.

Fiber Content

The fiber content of chia seeds is also very high.

Chia seeds contain between 34 and 40 grams of fiber food per 100 g [3].

In this quantity, the insoluble fraction (IDF) accounts for approximately 85–93%, whereas the soluble fraction (SDF) constitutes between 7% and 15%. Their research indicated that a significant intake of fiber lowers the risk of coronary heart disease, type 2 diabetes, and certain types of cancer. Additionally, a high dietary fiber content in daily meals helps to diminish hunger later.

Chia seeds are also rich in minerals, including calcium, phosphorus, potassium, and magnesium, as well as a variety of vitamins, such as A, B, K, E, and D, with a particular emphasis on vitamins B1, B2, and niacin. For example – it is higher than in rice, barley, wheat, and oats.

The content of other minerals, such as magnesium, potassium, and phosphorus is also higher in chia than in other grains [4].

The Pharmacokinetics of Compounds Derived from Chia Seeds

Pharmacokinetics pertains to the processes of absorption, distribution, metabolism, and excretion of substances following their administration.

Since chia seeds contain various bioactive compounds, several compounds, including omega-3 fatty acids, polyphenols, and fiber-derived metabolites, have been studied for their pharmacokinetic properties [5, 6].

Absorption

The bioactive compounds in chia seeds, especially omega-3 fatty acids (ALA), polyphenols, and proteins, must first be absorbed into the bloodstream to exert their effects. Studies show that compounds derived from chia seeds are mainly absorbed in the small intestine, where the digestive processes break down the components of the seed.

Omega-3 Fatty Acids

ALA, the primary omega-3 fatty acid present in chia seeds, is taken up by the intestinal lining and transformed into long-chain omega-3 fatty acids, including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in small quantities. However, the bioavailability of ALA is limited by its low conversion efficiency in humans. This low conversion rate may affect the therapeutic potential of chia seeds as a source of long-chain omega-3.

Polyphenols

Polyphenolic compounds, such as flavonoids and phenolic acids, are absorbed from the intestinal tract and are readily available in plasma. They have relatively high bioavailability, especially after consuming ground chia seeds, which increase the surface area for digestion [7].

Protein

The absorption of protein from chia seeds is facilitated by digestive enzymes. Chia seed proteins, such as albumin and globulin, are absorbed in a similar way to other plant proteins, although the rate may be affected by the presence of dietary fiber.

Distribution

Once absorbed, the distribution of bioactive chia seed compounds sin the systemic circulation depends on their solubility, affinity for plasma proteins, and tissue binding.

Omega-3 Fatty Acids

ALA is incorporated into the phospholipid layers of cell membranes, which can affect the fluidity and function of cell membranes, particularly in brain and heart tissue. Long-chain omega-3 fatty acids

derived from ALA can be distributed throughout the body, with higher concentrations in tissues, such as the heart, liver, and brain.

Polyphenols

Polyphenols are distributed to various tissues, such as the liver, kidneys, and brain, following absorption, where they demonstrate antioxidant and anti-inflammatory properties. Polyphenols are known to bind to plasma proteins, which can extend their half-life and improve tissue penetration.

Metabolism

The metabolism of compounds derived from chia seeds occurs mainly in the liver, where enzymes metabolize omega-3 fatty acids and polyphenols.

Omega-3 Fatty Acids

After absorption, ALA undergoes metabolism to form EPA and DHA, although conversion rates vary greatly between individuals. The liver also processes ALA into various metabolites that may have direct or indirect effects on lipid metabolism and inflammation.

Polyphenols

Polyphenolic compounds are metabolized in the liver by phase I (oxidation) and phase II (conjugation). These metabolites are then excreted through the kidneys or bile. The metabolism of polyphenols can influence their bioactivity, as some metabolites can have stronger antioxidant or anti-inflammatory properties than the parent compounds.

Elimination

Compounds derived from chia seeds, especially polyphenols, and metabolites of omega-3 fatty acids, are mainly excreted through urine and feces. The half-life of ALA and its metabolites in the blood is generally shorter than that of long-chain omega-3s, resulting in a faster elimination process. After being conjugated in the liver, polyphenolic compounds are typically eliminated in the urine [8–12].

Pharmacodynamics of Compounds Derived from Chia Seeds

The study of pharmacodynamics focuses on how substances derived from chia seeds affect the body.

Anti-Inflammatory Effects

Omega 3 Fatty Acid (ALA)

Chia seed ALA has strong anti-inflammatory properties, mostly by blocking proinflammatory cytokines like TNF-α, IL-6, and IL-1β.

Polyphenols

Flavonoids and phenolic acids found in chia seeds have been shown to Inhibit COX-2 and reduce the production of nitric oxide (NO), which contributes to the inflammatory process.

Antioxidant Activity

Omega-3 Fatty Acids

By lowering oxidative stress and promoting the expression of antioxidant enzymes like catalase and superoxide dismutase (SOD), ALA demonstrates its antioxidant qualities.

Polyphenols

The antioxidant properties of polyphenol-rich seeds have been demonstrated to include the ability to scavenge free radicals, chelate metal ions, and decrease the production of reactive oxygen species (ROS).

CARDIOVASCULAR BENEFITS

Lipid Modulation

The metabolism of fats is significantly impacted by omega-3 fatty acids, particularly ALA. Research indicates that supplementing with chia seeds raises HDL cholesterol levels while lowering serum triglycerides, LDL cholesterol, and total cholesterol.

Blood Pressure and Arterial Stiffness

Clinical studies have shown that chia seeds can help reduce blood pressure and arterial stiffness, which are major risk factors for cardiovascular disease. A study by Nieman et al. (2012) showed that chia seed supplements action led to a reduction in systolic and diastolic blood pressure in hypertensive individuals [7].

NEUROPROTECTIVE EFFECTS

Cognitive Function

The omega-3 fatty acids in chia seeds, especially ALA, are essential for brain health. DHA, an essential part of neuronal membranes, can be produced from ALA. Animal studies suggest that omega-3 derived from chia seeds improves cognitive function, memory, and learning.

Neuroinflammation and Oxidative Stress

Chia-derived polyphenols can lower neuroinflammation and shield neurons from oxidative damage, two major causes of neurodegenerative diseases like Alzheimer's.

INTESTINAL HEALTH

Digestive Health

Chia seeds are rich in insoluble and insoluble fiber, which supports gastrointestinal health by increasing stool mass and improving bowel regularity in the gut, soluble fiber condenses into a gel-like substance that can aid in controlling digestion.

Prebiotic Effect

Chia seeds can also act as prebiotics, increasing the growth of beneficial microbiota and improving the function of the intestinal barrier, which is essential for overall metabolic health and immune function.

ANTI-CANCER POTENTIAL

Antiproliferative Effects

Studies have shown that polyphenolic compounds in chia seeds can exhibit anti-cancer properties by inhibiting the proliferation of cancer cells and promoting apoptosis. The antioxidant effects of chia seeds also help reduce oxidative damage to DNA, which can lead to cancer formation.

Clinical Studies of Chia Seeds

Several clinical studies have examined the health benefits of chia seed consumption, particularly in relation to metabolic health, cardiovascular function, and inflammation.

Cardiovascular Health

Chia seed supplementation (25 g daily) significantly decreased triglyceride levels and improved lipid profiles in participants with type 2 diabetes and hyperlipidemia.

Anti-Inflammatory Effects

In healthy adults, chia seed supplementation decreased levels of the inflammatory marker C-reactive protein (CRP), according to a clinical trial published in the Journal of Nutritional Biochemistry. This study confirmed the anti-inflammatory effects of chia seeds, mainly due to their high content to FALA (24).

Gut Health

In a study analyzing the effects of chia seed fiber on gastrointestinal health, participants who regularly consumed chia seeds experienced improved bowel regularity and a reduction in symptoms of constipation.

Type 2 Diabetes

In a randomized controlled trial, chia seeds have been shown to improve glycemic control and reduce fasting blood sugar in people with type 2 diabetes.

Obesity

Clinical evidence suggests that chia seed supplementation can help reduce body weight, probably due to its high fiber content, which promotes satiety and reduces calorie intake. One study showed a decrease in body fat percentage in overweight adults after consuming chia seeds for 12 weeks.

CHALLENGES

Challenges of Chia Production in Kenya

Compared to other countries near the equator, Kenya has the highest potential for chia production. Chia production has the potential to spread to new regions across Kenya due to its distinct growth characteristics and the fact that almost 20% of the country's land is arable. Chia production currently takes up less than 1% of the nation's arable land, indicating low utilization. Chia production is favored by the fact that most of the agricultural land is situated between 1000 and 2500 meters above sea level and receives 800 to 2000 mm of rainfall annually. The increasing demand for environmentally friendly and healthful food products will eventually be satisfied by China's production. Furthermore, chia production gives researchers and policymakers the chance to create technologies and policies that will boost and enhance production. A lack of certified seeds, inadequate agronomic practices, a lack of knowledge about the production process, and a lack of technically appropriate harvesting and post-harvest procedures are some of the reasons for the low production of chia per area. More than 80% of chia farmers reported experiencing challenges during the cultivation and production of chia, indicating that poor agronomic practices are one of the primary barriers to high chia production.

Numerous farmers nationwide have also reported crop failures or non-germinating seeds. According to a study carried out in Nyeri County, Kenya, 37% of farmers reported total crop failure, which explains why there is little chia cultivation in the country. There are not many extra services for chia production, which found that just 5.4% of farmers were given information on chia production by extension agents. The low proportion of extension officers to farmers, however, may be the cause of the small number of extension councils. Farmers also struggle with seed crushing, which has led to significant seed losses. Birds, rain, and wind are the usual causes of seed dispersal

Application of Chia Seed and Derived Compound

Functional foods have received a lot of attention lately due to the global shift to healthier lifestyles.

FOOD INDUSTRY

Several Studies Have Been Done on the Use of Chia Seed in the Food Industry

Chia seeds can be used in the food industry in a variety of ways, including whole, ground, flour, oil, and gel. According to the US Dietary Guidelines from 2000, chia could be used as a main food in limited amounts; it is advised to consume more than 48 grams per day. Chia seeds can be mixed or added to cereals, cookies, pasta, snacks, and sweet foods and supplements. These chia seeds can be used as an egg and fat substitute because of their hydrophilic qualities. In water, they can support twelve times their own weight. In baked goods, chia gel can be used as an alternative to eggs. Furthermore, recent research has demonstrated that chia seed mucilage can be applied as a functional coating with enhanced functional qualities.

Chia Gum

Because of their dietary fiber content, chia seeds are regarded as a raw material in the food industry. To regulate viscosity, stability, and structure, chewing gum can be separated from the dietary fiber fraction by adding water. Polysaccharide's suitability in the food and pharmaceutical industries is largely determined by its chemical composition, molecular structure, and derived properties like gel ability or thermal stability. Additionally, the rubber remains stable at elevated temperatures.

Chia Mucilage

Because of its water-holding capacity and viscosity, chia mucilage can be used in the food industry as an adhesive, binder, emulsifier, foam stabilizer, and suspending agent. According to recent research, chia seed mucilage can be applied as a functional coating with enhanced functional qualities. The chia mucilage films plasticized with varying glycerol concentrations showed a significant increase in water solubility

CONCLUSIONS

Chia seeds and their derived components possess a wide range of biological activities, including cardiovascular protection, anti-inflammatory effects, antioxidant activity, and potential metabolic regulation. Although the pharmacokinetic and pharmacodynamic profiles of chia seeds are promising, more research is needed to clarify their clinical relevance and optimize their use in therapeutic applications. As research progresses, chia seeds may become an important functional food with significant therapeutic potential for chronic disease.

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