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A COMPREHENSIVE REVIEW ON PHARMACOLOGICAL ACTIVITIES, NUTRACEUTICAL SIGNIFICANCE AND EXTRACTION APPROACHES OF CHIA SEEDS

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ABSTRACT

Chia seeds (*Salvia hispanica L.*), belonging to the family Lamiaceae, have gained significant global attention as a functional and nutraceutical food owing to their exceptional nutritional composition and wide pharmacological potential. Traditionally used by ancient civilizations such as the Aztecs and Mayans as a source of energy and vitality, chia has re-emerged as a modern “superfood.” The seeds are rich in proteins, omega-3 fatty acids (particularly α-linolenic acid), dietary fibers, antioxidants, and essential minerals including calcium, magnesium, and phosphorus. These bioactive constituents contribute to a broad spectrum of health benefits, including cardioprotective, antidiabetic, anti-inflammatory, antioxidant, and weight management effects.

In recent years, chia has become an integral part of nutraceutical formulations and functional food applications, serving as a natural remedy for metabolic disorders and oxidative stress. The review comprehensively discusses the botanical and phytochemical profiles, nutraceutical significance, and diverse pharmacological activities of chia seeds. It also emphasizes recent advancements in extraction methodologies such as cold pressing, Soxhlet, maceration, ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), enzyme-assisted extraction (EAE), and supercritical fluid extraction (SFE). Each method offers distinct advantages concerning yield, purity, and bioactive preservation.

This review highlights chia’s potential as a sustainable plant-based resource for the development of health-promoting nutraceuticals and pharmaceuticals. Understanding its phytochemical diversity and optimizing extraction techniques can further enhance the therapeutic and commercial value of chia seeds in global health and nutrition sectors.

KEYWORDS:

Salvia hispanica L., Chia seeds, Nutraceuticals, Omega-3 fatty acids, Antioxidant activity, Functional food, Extraction methods, Pharmacological effects, Polyphenols, α-linolenic acid.

INTRODUCTION:

In recent decades, there has been a remarkable shift in the global perspective toward health, wellness, and disease prevention. The traditional concept of food being merely a source of energy and nutrients has evolved into a more holistic view that recognizes the potential of certain foods to promote health and prevent diseases. These foods are known as functional foods. Functional foods are those that provide health benefits beyond their basic nutritional value, owing to the presence of bioactive components such as polyphenols, flavonoids, dietary fibers, and omega fatty acids.

The term nutraceutical, derived from "nutrition" and "pharmaceutical," refers to substances that are derived from food sources and provide both nutritional and therapeutic effects. Nutraceuticals can range from isolated nutrients, dietary supplements, and herbal products to specific diets that have physiological benefits or protect against chronic diseases such as diabetes, cardiovascular disorders, cancer, and neurodegenerative diseases. Unlike conventional pharmaceuticals, nutraceuticals are often consumed as part of a daily diet and are considered safer with fewer side effects.

Table 1: Comparison between Functional Foods and Nutraceuticals

Parameter	Functional Foods	Nutraceuticals
Definition	Foods that provide health benefits beyond basic nutrition.	Bioactive substances derived from food sources that offer medical or health benefits.
Form	Conventional foods such as cereals, dairy, fruits, and beverages.	Capsules, powders, tablets, or concentrated extracts.
Purpose	To promote general health and prevent diseases.	To manage or prevent specific diseases and health conditions.
Consumption Mode	Consumed as part of the daily diet.	Often consumed as supplements.
Regulatory Category	Classified as foods.	Falls between food and pharmaceutical categories.
Examples	Yogurt with probiotics, fortified milk, green tea.	Omega-3 capsules, herbal extracts, antioxidants supplements.

Chia Seeds (*Salvia hispanica* L.)

Botanical Source, Family, and Distribution

Chia seeds are obtained from the plant Salvia hispanica L., which belongs to the family Lamiaceae (the mint family). The plant is an annual herb native to Central and South America, particularly Mexico and Guatemala, where it has been cultivated for centuries. Salvia hispanica is herbaceous plant that grows up to 1–1.5 meters in height, with opposite leaves, small blue or purple flowers, and oval-shaped seeds. The seeds are tiny (approximately 2 mm in diameter) and come in colors ranging from black to white or gray, with a characteristic glossy appearance.

Currently, chia cultivation has expanded beyond its native regions to several parts of the world, including Australia, Argentina, Bolivia, Peru, and India, due to growing commercial demand. The plant thrives in warm, tropical, and subtropical climates and requires well-drained soil for optimal growth. Its adaptability to diverse environmental conditions has made chia a valuable crop for both agricultural and nutraceutical industries.

Figure 1: Chia Seeds

Historical Background and Traditional Uses

Historically, chia seeds were a **staple food of ancient civilizations**, especially the Aztecs and Mayans, who valued them for their nutritional and medicinal properties. The term “chia” itself is derived from the ancient Mayan word meaning “strength,” reflecting its traditional use as an energy-boosting food. Ancient warriors consumed chia seeds before battles and long journeys to enhance stamina and endurance.

In traditional medicine, chia was used to relieve joint pain, improve digestion, and maintain hydration. It was also believed to promote heart health and enhance mental clarity. Over time, chia seeds lost prominence following the colonization of the Americas but were rediscovered in the late 20th century as scientific interest in plant-based functional foods grew. Today, chia has regained global recognition as a “superfood,” widely incorporated into smoothies, baked goods, cereals, and dietary supplements.

Table 2: Botanical Profile of Chia Plant (*Salvia hispanica* L.)

Characteristic	Description
Scientific Name	*Salvia hispanica* L.
Family	Lamiaceae (Mint family)
Common Name	Chia
Plant Type	Annual herb
Height	1–1.5 meters
Leaves	Opposite, serrated, 4–8 cm long
Flowers	Blue to purple, small, borne in clusters
Seeds	Oval, smooth, 1.5–2 mm in size; color varies from black to white
Native Region	Central and South America (Mexico, Guatemala)
Major Cultivating Countries	Mexico, Argentina, Bolivia, Australia, India
Preferred Climate	Warm tropical to subtropical with well-drained soil

Increasing Scientific and Commercial Interest in Chia

The resurgence of chia in modern times is largely attributed to the increasing number of scientific studies highlighting its diverse pharmacological and nutritional benefits. Chia seeds are considered a rich source of α-linolenic acid (ALA), a type of omega-3 fatty acid known to support cardiovascular and brain health. They are also packed with antioxidants, dietary fibers, proteins, and essential minerals such as calcium, magnesium, and phosphorus.

Due to this remarkable composition, chia is increasingly being explored as a functional ingredient in nutraceuticals and health-promoting foods. Research has demonstrated its beneficial effects in managing hyperlipidemia, diabetes, oxidative stress, and inflammatory conditions. Consequently, the chia seed industry has witnessed tremendous commercial growth, with products ranging from chia-based beverages and puddings to capsules and fortified foods available in the market.

Table 3: Nutritional Composition of Chia Seeds

Component	Approximate Content (% w/w)	Physiological Role
Protein	16–20%	Muscle development, enzyme synthesis
Dietary Fiber	30–34%	Improves digestion, lowers cholesterol
Lipids (Fat)	30–33%	Source of omega-3 fatty acids (ALA)
Carbohydrates	25–30%	Provides energy
Calcium	500–600 mg/100 g	Bone health
Phosphorus	700–800 mg/100 g	Energy metabolism
Magnesium	300–400 mg/100 g	Nerve and muscle function
Potassium	400–500 mg/100 g	Maintains fluid balance
Antioxidants (Polyphenols)	—	Protects against oxidative stress

Role in Modern Diet and Therapeutic Use

In the context of modern health challenges—such as obesity, diabetes, and cardiovascular disorders—chia seeds offer a natural, dietary-based approach to prevention and management. Their high soluble fiber content aids in regulating blood sugar levels, improving satiety, and reducing cholesterol. The presence of antioxidants like caffeic acid and quercetin helps combat oxidative stress, which is a key factor in aging and chronic diseases.

Furthermore, the versatility of chia allows it to be incorporated into a variety of food preparations without compromising taste or texture. Its ability to absorb water and form a gel-like consistency makes it suitable for low-calorie and gluten-free diets. Given these diverse applications and health benefits, the scientific exploration of chia's pharmacological activities and extraction methods is of immense significance to both the nutraceutical and pharmaceutical industries.

Table 4: Traditional and Modern Uses of Chia Seeds

Type of Use	Application/Benefit	Remarks
Traditional Use (Aztec & Mayan Era)	Energy booster for warriors, ritual food, digestion aid	Used as staple food and medicine
Folk Medicine	Relief from joint pain, improved hydration, digestive support	Consumed as seed or mixed with water
Modern Nutraceutical Use	Weight management, cardiovascular protection, diabetes control	Formulated into health supplements
Functional Food Application	Added to bakery products, beverages, smoothies, cereals	Improves nutritional value
Cosmetic Use	Ingredient in natural moisturizers and anti-aging creams	Due to antioxidant and omega-3 content

BOTANICAL AND PHYTOCHEMICAL PROFILE

Botanical Description

Scientific Classification

Salvia hispanica L., commonly known as chia, belongs to the family Lamiaceae (mint family). It is a flowering herbaceous plant cultivated primarily for its seeds, which are renowned for their exceptional nutritional and medicinal properties. The scientific classification of chia is given below.

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Lamiaceae
Genus	*Salvia*
Species	*Salvia hispanica* L.
Common Name	Chia
Origin	Central and Southern Mexico, Guatemala

The plant is an annual herb that grows up to 1–1.2 meters tall, bearing opposite leaves and small white or purple flowers arranged in terminal racemes.

Morphological Features of Plant and Seeds

The chia plant is upright and branched, with quadrangular stems typical of the mint family. The leaves are opposite, serrated, and ovate, measuring about 4–8 cm long and 3–5 cm wide. The flowers are small, bilabiate, and form dense spikes at the terminal ends of branches.

The chia seeds are small, oval, and about 2 mm in length. They have a smooth and shiny surface with mottled colors varying from black, white, brown to gray. When soaked in water, the seeds form a gel-like mucilaginous coat, a result of soluble fiber (mainly mucilage polysaccharides) present in the seed coat. This property plays a key role in their hydrophilic nature, making them valuable for food and nutraceutical applications.

Morphologically, chia seeds consist of three layers:

- **Seed coat (testa)** – rich in mucilage and phenolic compounds.
- **Endosperm** – contains lipids and storage proteins.
- **Embryo** – rich in polyunsaturated fatty acids and enzymes.

Cultivation and Harvesting

Geographical Distribution

Chia (*Salvia hispanica L.*) is native to Central and Southern Mexico and Guatemala, but it is now cultivated widely in Latin America, Australia, the United States, and parts of India. In India, chia cultivation is gaining popularity in states such as Madhya Pradesh, Rajasthan, and Karnataka, where the climate suits its growth.

It thrives best in temperate and subtropical climates with well-drained soils and moderate rainfall. The plant requires a frost-free environment and grows well at altitudes up to 2,500 meters above sea level**.**

Region	Major Producing Countries	Cultivation Conditions
Central America	Mexico, Guatemala	Warm, semi-arid conditions
South America	Bolivia, Argentina, Peru	Moderate rainfall, loamy soil
Asia	India, Thailand	Tropical to subtropical regions
Australia	Western & Southern regions	Temperate dry climates

Agronomic Conditions

Chia grows best in well-drained sandy loam or clay-loam soils with a pH between 6 and 8. It requires 12–14 hours of daylight for proper flowering, which is why it is considered a short-day plant.

Temperature: Optimal range is 16–26°C.

Rainfall: Moderate (400–600 mm annually).

Sowing time: Late Spring or early summer.

Harvesting period: Around 120–150 days after sowing, when the leaves begin to dry and seeds mature.

Yield: Average yield is 500–1000 kg/ha under favorable conditions.

The harvested seeds are cleaned, dried, and stored in airtight containers to prevent oxidative rancidity due to their high oil content.

Chemical Composition

Chia seeds are considered a nutrient-dense functional food, rich in macronutrients, micronutrients, and bioactive phytochemicals. Their balanced nutritional profile contributes to both nutraceutical and pharmacological value.

Macronutrient Composition

Chia seeds are an excellent source of proteins, carbohydrates, and lipids.

Proteins (15–25%): High in essential amino acids such as leucine, lysine, and valine.

Carbohydrates (30–40%): Primarily in the form of dietary fibers (both soluble and insoluble).

Lipids (30–33%): Rich in polyunsaturated fatty acids, particularly omega-3 α-linolenic acid (ALA) and omega-6 linoleic acid (LA).

The ratio of omega-6 to omega-3 (≈0.3:1) makes chia unique among plant seeds.

Nutrient Component	Approximate Content (% by weight)
Protein	15–25
Lipids (fats)	30–33
Carbohydrates	26–41
Dietary Fiber	18–30
Moisture	6–8
Ash	4–5

Micronutrient Composition

Chia seeds are rich in minerals and vitamins, which contribute to their health-promoting potential. They are an excellent source of calcium, magnesium, potassium, phosphorus, and zinc, with moderate amounts of iron and copper.

Mineral/Vitamin	Approximate Value (mg/100 g)
Calcium	631
Magnesium	335
Potassium	407
Phosphorus	860
Iron	7.7
Zinc	4.6
Vitamin B1 (Thiamine)	0.62
Vitamin B3 (Niacin)	8.83

These micronutrients contribute to bone health**,** metabolic regulation, and antioxidant defense.

Phytochemical Composition

Chia seeds contain a wide range of bioactive compounds, which contribute to their pharmacological activities such as antioxidant, anti-inflammatory, antidiabetic, and cardioprotective effects. The major phytochemicals include:

Phenolic compounds: Caffeic acid, chlorogenic acid, quercetin, kaempferol, and rosmarinic acid.

Flavonoids: Myricetin, apigenin, and luteolin, known for strong antioxidant properties.

Omega-3 fatty acids: Predominantly alpha-linolenic acid (ALA), beneficial for cardiovascular and brain health.

Fibers: Both soluble and insoluble, aiding in gut health and reducing cholesterol levels.

Mucilage polysaccharides: Responsible for water retention and gel formation, useful in digestion and sustained energy release.

Phytochemical Group	Representative Compounds	Pharmacological Role
Phenolics	Caffeic acid, chlorogenic acid	Antioxidant, anti-inflammatory
Flavonoids	Quercetin, apigenin, kaempferol	Antioxidant, cardioprotective
Fatty Acids	ALA, LA	Hypolipidemic, anti-inflammatory
Polysaccharides	Mucilage, fiber	Laxative, satiety enhancer
Sterols & Tocopherols	β-sitosterol, α-tocopherol	Lipid regulation, antioxidant

NUTRACEUTICAL SIGNIFICANCE OF CHIA SEEDS

Role as a Functional Food

High Omega-3 Content

Chia seeds (*Salvia hispanica L.*) are widely recognized as one of the richest plant-based sources of alpha-linolenic acid (ALA), an essential omega-3 fatty acid. Approximately 60–65% of the total oil content in chia seeds consists of ALA. Omega-3 fatty acids are essential for maintaining cardiovascular health, reducing inflammation, and supporting brain function. Unlike fish oils, chia provides a vegan and sustainable alternative for omega-3 intake, making it an ideal component of functional foods and nutraceutical formulations.

The presence of ALA in chia seeds contributes to lowering blood cholesterol and triglyceride levels, improving the ratio of HDL to LDL cholesterol. Regular inclusion of chia in the diet has shown positive effects in reducing the risk of atherosclerosis and other lipid-associated disorders.

Nutrient	Content (%)	Physiological Role
Alpha-linolenic acid (ALA)	60–65	Cardiovascular protection
Linoleic acid	20–25	Maintains skin barrier function
Oleic acid	8–10	Anti-inflammatory effects

Antioxidant and Fiber-Rich Nature

Chia seeds are also an excellent source of natural antioxidants, including chlorogenic acid, caffeic acid, quercetin, and kaempferol. These compounds neutralize free radicals, preventing oxidative stress and cellular damage. The total phenolic content contributes to their strong antioxidant capacity, which helps in reducing the progression of chronic diseases such as diabetes, cancer, and cardiovascular disorders.

Moreover, chia is rich in soluble and insoluble dietary fibers (34–40%), which promote gastrointestinal health and regulate bowel movements. The mucilaginous layer that forms when chia seeds are soaked in water aids digestion, slows glucose absorption, and contributes to prolonged satiety.

Health Benefits

Cardiovascular Health

Chia seeds have been scientifically proven to improve cardiovascular parameters through their lipid-lowering, anti-inflammatory, and vasodilatory properties. The omega-3 fatty acids in chia reduce serum triglycerides, lower blood pressure, and prevent platelet aggregation. Polyphenolic compounds also reduce oxidative damage to cardiac tissues, thereby improving vascular function and reducing the risk of coronary heart disease.

Glycemic Control

Chia seeds play a beneficial role in glucose regulation due to their high fiber content and slow digestibility. The viscous gel formed by soluble fiber in the gastrointestinal tract delays carbohydrate absorption, leading to lower postprandial glucose levels. Studies have demonstrated that regular chia supplementation improves insulin sensitivity and reduces glycosylated hemoglobin (HbA1c) in diabetic individuals. Hence, chia seeds serve as a natural dietary intervention for type 2 diabetes management.

Anti-Inflammatory and Antioxidant Effects

The bioactive compounds in chia, such as quercetin and caffeic acid, inhibit pro-inflammatory cytokines like TNF-α and IL-6. This contributes to the suppression of chronic inflammatory responses. Additionally, the antioxidants prevent lipid peroxidation and enhance the activity of endogenous enzymes such as superoxide dismutase (SOD) and catalase. These combined effects make chia an effective natural anti-inflammatory and antioxidant nutraceutical.

Weight Management and Digestive Health

Chia seeds promote weight management due to their high fiber and protein content, which induce a feeling of fullness and reduce overall calorie intake. When hydrated, chia seeds expand in the stomach, suppressing appetite and prolonging satiety. The soluble fibers aid in maintaining gut microbiota balance, improving digestion, and preventing constipation. Moreover, chia seeds are gluten-free, making them suitable for individuals with celiac disease or gluten intolerance.

Comparative Studies

Different extraction techniques vary in yield, purity, and bioactive content**.** Comparative studies of chia seed extracts show:

Method	Target Compounds	Yield (%)	Advantages	Limitations
Cold Pressing	Lipids, omega-3	25–30	Preserves bioactivity	Lower yield
Soxhlet	Lipids, phenolics	28–32	High yield	Heat may degrade sensitive compounds
Maceration	Phenolics, flavonoids	12–18	Simple, preserves heat-sensitive compounds	Time-consuming, low efficiency
UAE	Phenolics, flavonoids	20–25	Fast, solvent-efficient	Requires ultrasonic equipment
MAE	Phenolics, oils	22–30	Rapid, efficient	Risk of thermal degradation
SFE (CO_2)	Lipids, omega-3	30–33	High purity, solvent-free	Expensive equipment
EAE	Polysaccharides, phenolics	18–22	Mild conditions, higher bioactive recovery	Enzyme cost

CONCLUSION

Chia seeds (*Salvia hispanica L.*) represent a remarkable example of a traditional food rediscovered for its multifaceted nutritional and therapeutic potential. Their rich content of omega-3 fatty acids, dietary fibers, proteins, and polyphenolic compounds endows them with potent health-promoting properties, including antioxidant, cardioprotective, antidiabetic, and anti-inflammatory effects. The seeds not only play a vital role in functional foods and nutraceutical formulations but also serve as a sustainable source of essential nutrients for both preventive and therapeutic applications.

Furthermore, the optimization of extraction techniques is crucial for maximizing the yield and stability of bioactive compounds. Modern green extraction methods such as ultrasound-assisted, microwave-assisted, enzyme-assisted, and supercritical CO_2 extraction have shown promise in enhancing efficiency and preserving phytochemical integrity.

In conclusion, chia seeds possess immense potential as a nutraceutical resource that bridges the gap between food and medicine. Continued scientific exploration, clinical validation, and technological innovation in extraction and formulation will further strengthen chia's role in promoting human health and combating lifestyle-related diseases.

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