

Nutritional Composition, Bioactive Compounds and Food Applications of Lotus Seeds (*Nelumbo nucifera*): A Review

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Abstract

The scientific field shows increasing interest in *Nelumbo nucifera* seeds because they are prominent components of Asian diets and traditional medicine systems. According to research these seeds have 62–68% carbohydrates along with 16–21% proteins and a constant 2.0–2.9% fat. Lotus seeds offer two types of vital minerals for human structure while providing vital vitamins along with necessary mineral nutrients that include phosphorus magnesium and potassium and riboflavin along with thiamine. Moreover, their nutritional benefits stem from significant antioxidant compounds like alkaloids and flavonoids. The bioactive elements found in lotus seeds exhibit anti-inflammatory together with anti-cancer and hypoglycemic properties that help prevent chronic illnesses. Food science and technology incorporates different uses of lotus seeds as ingredients. The seeds appear both as the primary edible form and as raw materials for creating lotus seed paste which becomes essential in dessert-making. Current food processing technologies now utilize lotus seeds in functional foods and nutraceutical products to optimize their health-promoting components. The research examines nutritional properties and bioactive compounds of lotus seed together with its applications in food production. The document contains research synthesis that demonstrates how lotus seeds function as functional food elements and supports wellness at the same time but suggests new research applications in food technology and science.

Keywords: lotus seeds; nutritional composition; bioactive compounds; functional foods; applications

1.Introduction

The *Nelumbo nucifera* plant occupies an essential position in aquatic perennials since it delivers significant medicinal properties along with nutritional characteristics alongside traditional cultural importance. Lotus seeds grew in Australia and Asia before serving cultures for many centuries so people consider them significant in both Buddhist and Hindu beliefs because they symbolize spiritual purity and enlightenment. Studies showed that Chinese Indians Japanese and other nations include seeds in desserts and soups¹. Throughout these cultures cook chefs embrace lotus seeds because these ingredients show versatility in many culinary preparations. The macro- and micronutrients present in lotus seeds supply significant nutritional concentration along with vital compounds of essential nutritional elements. Statistics indicate that lotus seeds contain 64% carbohydrates paired with 15% protein content along with 2% fat in their typical composition. The nutritional composition of lotus seeds contains B vitamins and minerals including thiamine and manganese and phosphorus. Moreover, these seeds present high levels of B vitamins². The nutritional characteristics in lotus seeds support both metabolic power generation and system operation sustaining functions which makes them important dietary ingredients.

Bioactive compounds and nutritional mix found in Lotus seeds enable therapeutic functions to act effectively. The antioxidants present in lotus seeds come from their composition of alkaloids and flavonoids. Anti-inflammatory properties together with hypoglycemic and anti-cancer effects exist in lotus seeds thanks to their stored compounds. Lotus seeds benefit human health because their health properties allow them to function as functional food ingredients that help prevent undesirable diseases. Food technology utilizes lotus seeds in the development of nonstandard applications as per. The current technological food processing capabilities permit lotus seeds to integrate with functional foods and nutraceutical products. Both traditional Asian pastry products and baking industries depend on lotus seed paste for their main ingredients but use lotus seed flour in their formulation process. Because of their flavorless characteristics and nutritional benefits lotus seeds function as food additives to enhance the nutritional value of multiple food products. The survey conducts an advanced investigation of *Nelumbo nucifera* seed (Figure 1) dietary elements and bioactive compounds throughout their biological properties and their utilization in food processing operations. Sourced research data converge in

the study to demonstrate the health-supporting attributes of lotus seeds during food ingredient applications. The research investigates the application of technological innovation to lotus seed processing alongside its use in food

production. To enhance health-promoting foods in the food industry food science specialists should comprehend the main components of these food development fields.



Figure 1: Lotus Seed (*Nelumbo nucifera*).

2. Nutritional Composition of Lotus Seeds

Macronutrient Composition: The food article *Nelumbo nucifera* offers many health benefits through its nutritious content which includes carbohydrates together with proteins and fats. Dried lotus seeds provide 64% carbohydrates by weight thus serving as the main energy source for human metabolism. Human body requires both starches and sugars as carbohydrates because they serve essential metabolic and health-related purposes³. Every 100 grams of Lotus seeds contain 15% protein along with essential amino acids phenylalanine, tyrosine, leucine and lysine that fulfill important functions in muscle repair and metabolic operations and enzyme operation⁴. The fat composition of lotus seeds totals about 2 grams per 100 grams thus supporting the dietary needs of people who limit their consumption of fats. The majority of fats in anchovies consist of unsaturated fatty acids that support heart health [5].

Micronutrient Composition: The nutritional value of lotus seeds consists of vital vitamins and minerals in addition to being an exceptional source. The B-complex vitamins in lotus seeds include 53% of the daily required thiamin (B1) and 11.5% of riboflavin (B2) with 48% of vitamin B6 content per 100 grams⁶. These vitamins support energy metabolism and brain health and nervous system function. The folate amount in lotus seeds surpasses 104 micrograms of folate in each 100 grams which provides 26% of daily human need for essential functions including DNA synthesis, cell division and fetal development⁷. Manganese in minerals reaches 100% of the recommended daily allowance (RDA) per 100 grams as it acts as a co-factor for antioxidant enzymes⁸. Every serving of grape juice contains 1,368 mg of potassium as well as phosphorus (626 mg), magnesium (210 mg), calcium (163 mg) and iron (3.5 mg) which correspond to 36% RDA, 62% RDA, 50% RDA, 13%

RDA and 20% RDA respectively to support muscle function and bone health as well as oxygen transport and nerve function⁹.

Phytochemicals and Antioxidants: Bioactive ingredients inside lotus seeds exist together with flavonoids, alkaloids, polysaccharides and phenolic acids and help the seeds maintain antioxidant and therapeutic abilities. Flavonoids together with alkaloids within lotus seeds serve as fundamental compounds that minimize stress from oxidation while decreasing inflammatory response and combating both cardiovascular conditions and cancer development¹⁰. Scientific research has shown that the bioactive agents within lotus seeds possess three key health benefits: anti-inflammatory capacity and anticancer properties and blood sugar control functions¹¹.

Comparative Analysis and Nutritional Benefits: Compared to other commonly consumed seeds and nuts, lotus seeds are notably lower in fat and higher in essential amino acids. For instance, lotus seeds contain only 2 grams of fat per 100 grams, whereas almonds contain 50 grams of fat per 100 grams, making lotus seeds a preferred option for those reducing fat intake⁵. Their high protein content and complete amino acid profile make them comparable to some animal-based proteins, making them an excellent alternative protein source for plant-based diets. The nutritional values in lotus seeds can vary because of environmental conditions together with processing methods as well as storage conditions. Soil quality together with climatic factors and farming practices influence the nutritional elements present in lotus seeds in various regions according to Chouaibi et al. (2012)¹². Drying and roasting and boiling procedures during processing minimize the availability of vitamins and minerals³. Low humidity storage combined with temperature control represents an essential factor that avoids nutrient breakdown and secures nutritional value (Figure 2).

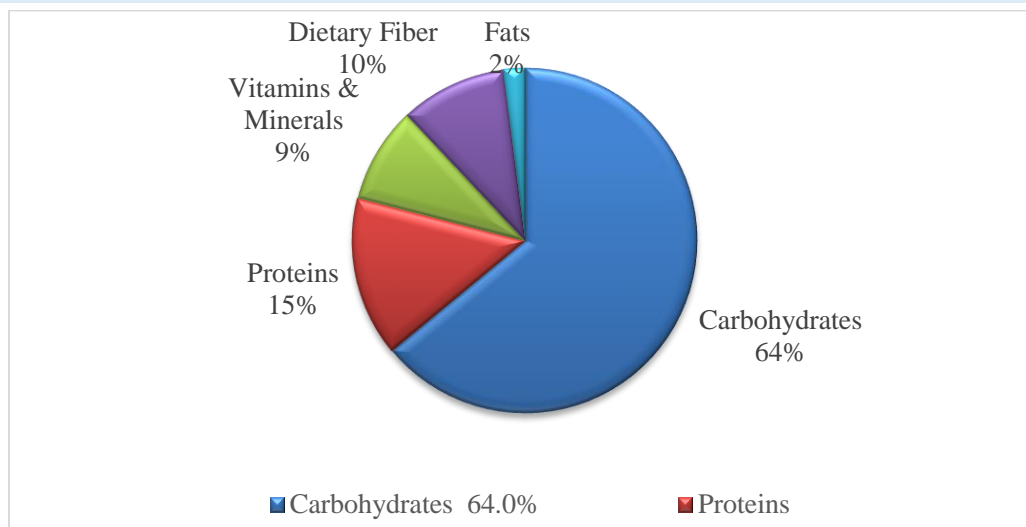


Figure 2: Nutritional Composition of Lotus Seeds per 100g.

3. Bioactive Compounds in Lotus Seeds: The therapeutic benefits of *Nelumbo nucifera* plant seeds come from various bioactive compounds that provide both therapeutic advantages along with nutritional qualities¹⁰. Health benefits from Lotus seeds (*Nelumbo nucifera*) result from their active compounds of alkaloids and flavonoids together with polysaccharides and phenolic acids.

3.1 Alkaloids: Pharmacological activities of nitrogen-containing compounds known as alkaloids comprise multiple therapeutic effects¹¹. Scientific studies have determined multiple crucial alkaloids present in lotus seeds.

Neferine: Exhibits antioxidant and anti-inflammatory properties, contributing to cardiovascular health.

Nuciferine: Known for its sedative and antipsychotic effects, it also aids in lipid metabolism.

Liensinine: Possesses antiarrhythmic and neuroprotective activities.

These alkaloids collectively enhance the medicinal value of lotus seeds, making them beneficial for various therapeutic applications.

3.2 Flavonoids: Flavonoids present in lotus seeds act as outstanding antioxidants through their polyphenolic compounds. The natural antioxidant compounds within lotus seeds aid in radical-free cancellation and stress levels reduction. The participation in this activity leads individuals to experience reduced risk factors for heart disease together with cancer and other chronic illnesses¹³.

3.3 Polysaccharides: The health-promoting properties of the human body stem from the polysaccharides found in Lotus seeds which serve as primary bioactive elements. The use of lotus seeds exists simultaneously as a supplement for nutrition as well as medical therapy. Studies show that polysaccharides activate multiple health benefits which include antioxidant action and immunological response and anti-inflammatory effects¹⁴.

3.4 Phenolic Acids: The antioxidant qualities of lotus seeds result from their phenolic acid content which includes gallic acid together with chlorogenic acid according to Chen et al. (2019)¹⁵. The compounds assist in eliminating free radicals which protects the body from the damaging effects of reactive oxygen molecules.

Compound Class	Specific Compounds	Reported Biological Activities
Alkaloids	Neferine, Nuciferine, Liensinine	Antioxidant, anti-inflammatory, sedative, antipsychotic, antiarrhythmic, neuroprotective
Flavonoids	Catechins, Quercetin, Isoquercetin	Antioxidant, anti-inflammatory, anticancer
Polysaccharides	Lotus seed polysaccharides	Antioxidant, immunomodulatory, antiinflammatory
Phenolic Acids	Gallic acid, Chlorogenic acid	Antioxidant, antimicrobial

Table 1: Bioactive Compounds Identified in Lotus Seeds.

The information in table 1 is compiled from various studies on the bioactive compounds present in lotus seeds. The therapeutic worth of lotus seeds becomes stronger because each seed contains various bioactive compounds. Lotus seeds acquire medical value as people use their bioactive compounds either through adding them to food ingredients or creating functional nutrition products.

4. Biological Activities of Lotus Seed Compounds: A wide range of biological activities contributes to the therapeutic properties found in therapeutic compounds contained in Lotus seeds (*Nelumbo nucifera*). These activities possess five distinct therapeutic biological functions which include antioxidant properties while combining anti-inflammatory and antimicrobial

effects and displaying neuroprotective as well as antidiabetic and cardioprotective together with anticancer effects.

4.1 Antioxidant Properties: The antioxidant mechanisms of lotus seeds derive from their flavonoids and phenolic acids bioactive substances. Upon absorption by compounds antioxidant radicals reduce oxidative stress to protect cells from damage. Proof through multiple scientific research has revealed that lotus seed extracts fight oxidative stress making them suitable for medical treatment of stress-related diseases¹⁶.

4.2 Anti-Inflammatory Effects: The research demonstrates that lotus seeds operate as anti-inflammatory elements that prevent inflammatory components from developing¹⁷. Plentiful alkaloids and flavonoids in Lotus

seeds demonstrate how they could manage inflammatory conditions through their effect on inflammatory pathways.

4.3 Antimicrobial Activity: The antimicrobial properties of lotus seeds derive mainly from phenolic compounds exhibiting inhibitory properties toward bacterial and fungal pathogens of multiple types. Research shows that lotus seeds demonstrate their potential as both food preservation additives and antibacterial treatments according to Youssef et al. (2021)18.

4.4 Neuroprotective Benefits: Research shows that the compounds neferine and liensinine in lotus seeds act as neuroprotective agents according to Zeng, et al., (2017)19. The protective neuronal compounds in these alkaloids shield brain cells from harm and apoptotic damage which implies that they could block the development of Parkinson's and Alzheimer's diseases.

4.5 Antidiabetic Effects: Research by professionals shows that lotus seeds act as antidiabetic agents because they help maintain insulin function and enhance how the human body processes glucose. The diabetes management effects of bioactive polysaccharides in lotus seeds make them stand as functional food possibilities for diabetes regulation20.

4.6 Cardioprotective Effects: The protective effects for heart health emerge from lotus seeds because these seeds combine anti-inflammatory substances with antioxidants to reduce heart tissue inflammation and stress. The cardiovascular system benefits from both neferine alkaloids and additional factors found in lotus seeds21.

4.7 Anticancer Properties: Studies established that lotus seed extracts show anticancer properties by causing cell death mechanisms that block cancer cell multiplication. Bioactive compounds such as alkaloids and flavonoids produce most of the cancer-fighting effects that lotus seeds exhibit indicating their worth as cancer-fighters22.

Various biological actions of lotus seed compounds demonstrate both food ingredient value and medicinal potential. Consuming loquat seeds in dietary meals and prepared health-based products provide medical advantages against chronic illnesses.

5.1 Traditional & Cultural Applications of Lotus Seeds: Since ancient times Asian cultures have used Lotus seeds (*Nelumbo nucifera*) in their traditional practices because they find them useful for both cooking and medicine. Traditional applications demonstrate how the cultural heritage of the floating water plant *Nelumbo nucifera* appears through Lotus seeds (*Nelumbo nucifera*).

Culinary Uses: In traditional Asian cuisine, lotus seeds are utilized in various forms:

Lotus Seed Paste: People use dried lotus seeds to make sweet paste which they use as filling in Chinese pastries designed as mooncakes and steamed buns. The desired texture of this paste derives from its smooth consistency which comes with a gentle sweetness according to Liu et al. (2018)14.

Soups and Congees: The inclusion of lotus seeds as food ingredients results in soups and rice congee with enhanced nutrition along with mild nuttiness but this addition also elevates the dietary benefits. Chinese nourishing recipes use cooking methods to merge lotus seeds with red beans and jujubes.

Snacks: People in certain cultures prepare snacks through roasting and caramelizing lotus seeds. Lotus seeds can be prepared as crystals function as a traditional Chinese food during festive times.

Medicinal Uses: Traditional Chinese Medicine (TCM) together with Ayurveda classifies lotus seeds as therapeutic elements in their medical traditions.

Digestive Health: People consider Lotus seeds to possess spleen-enhancing digestive properties which support the treatment of diarrhea and inadequately active appetite.

Renal Health: In TCM, they are used to reinforce kidney function and manage conditions like leukorrhea and spermatorrhea.

Mental Calmness: Lotus seeds are also used to nourish the heart and calm the mind, addressing issues such as palpitations and insomnia23.

5.2 Industrial & Functional Food Applications of Lotus Seeds (2D Approach): With advancements in food processing and a growing interest in functional foods, lotus seeds have found new applications in the modern food industry.

Food Processing Innovations: The unique properties of lotus seeds have led to their incorporation into various processed foods:

Lotus Seed Flour: Dried lotus seeds become flour through grinding processes which makes them applicable for baking and making confections. The gluten-free flour serves as an ingredient for baking cake, cookies and noodles to support health-conscious consumers together with individuals who are sensitive to gluten24.

Starch Extraction: Food manufacturers obtain highly coherent Lotus seed starch from its micronized granule form and elevated amylose composition to use as a stabilizer and thickener in various food products25.

Functional Foods and Nutraceuticals: The health-promoting components of lotus seeds have paved the way for their inclusion in functional foods and nutraceuticals:

Dietary Supplements: The manufacture of supplements starts with bioactive compound-rich extracts which contain flavonoids and polysaccharides for delivering antioxidant and anti-inflammatory benefits to consumers.

Fortified Foods: The addition of lotus seed derivatives to breakfast cereals and energy bars creates nutritious food products that provide health advantages to consumers26.

Application	Description
Traditional Culinary Uses	- Lotus Seed Paste: Filling for pastries. Soups and Congees: Added for flavor and nutrition. Snacks: Roasted or caramelized.
Traditional Medicinal Uses	- Digestive Aid: Strengthens spleen. Renal Tonic: Supports kidney health. Calming Agent: Alleviates insomnia.
Industrial Applications	- Lotus Seed Flour: Used in gluten-free baking. Starch Extraction: Employed as a food stabilizer.
Functional Foods	- Dietary Supplements: Source of antioxidants. Fortified Foods: Enhanced nutritional products.

Table 2: Traditional and Industrial Applications of Lotus Seeds.

The data shown in this table 2 originates from multiple research investigations of lotus seed applications. Lotus seeds have transitioned from traditional dietary uses to modern industrial purposes which demonstrate their diverse character and sustained valuable role in cooking and healthcare.

5.3 Future Innovations and Biotechnology in Lotus Seed-Based Foods

Development of Novel Food Products: The advancement of new lotus seed-based food products depends heavily on biotechnology to meet demands from modern consumers. Fermentation methods allowed scientists to develop functional beverages through the production of probiotic drinks that promote gut health and suit consumers seeking plant-based alternatives according to Chen et al. (2024)²⁷. Enzymatic processing of lotus seeds enables the production of lactose-free dairy substitutes for people following vegan diets. Manufacturers use fortification to improve the nutritional content of dairy alternatives thus making them equivalent to traditional dairy products.

Bioprocessing Techniques to Enhance Nutritional Value: Scientists conduct research on advanced bioprocessing methods to boost nutrient bioavailability and performance within lotus seeds. The process of germination activates enzymes that reduce antinutritional compounds and enhances both vitamins and amino acids and bioactive compounds accessibility during sprouting. Lotus seeds become more health promoting for humans through the sprouting process according to Liu et al. (2024)¹⁴. Through enzyme-based reactions complex carbohydrates and proteins get converted into simpler digestible substances. Enzymatic hydrolysis stands as a valuable method for creating lotus seed-derived ingredients which become easily absorbable among those who have special dietary requirements such as older adults along with people who suffer from digestive problems.

Exploration of Prebiotic Potential: Modern research demonstrates that lotus seeds function as prebiotics because they maintain gut microbiota health. Resistant starch happens to be one of the main components that escapes small intestine digestion to become a food supply for gut bacteria that provide benefits. Short-chain fatty acids (SCFAs) get produced by fermentation to improve gut health while enhancing calcium and magnesium uptake and strengthening immune responses²⁷. Prebiotic effects are demonstrated by oligosaccharides extracted from lotus seeds because they stimulate beneficial bacteria's growth in the digestive system. Such compounds can be added to functional foods alongside dietary supplements to provide digestive health benefits to consumers⁶.

Genetic Engineering for Trait Enhancement: The field of genetic engineering develops new methods to enhance lotus seed nutritional values combined with higher yields and better environmental adaptability. The analysis of metabolic compounds has revealed crucial health-benefiting compounds including flavonoids and alkaloids present in lotus seeds. Scientists working with lotus seed metabolic pathways can create better varieties by enhancing antioxidant contents together with bioactive compound levels²⁷. The studies focus on developing lotus plants with enhanced stress resistance. Researchers modify lotus plant genes to develop varieties which become more resilient against environmental stress factors that include drought along with pests and limited nutrient availability. These enhancements would lead to improved seed yields coupled with better seed quality that supports the development of sustainable agriculture practices.

Sustainable Production Practices: Through biotechnological advances innovative sustainable production methods can be developed that become the basis for environmentally friendly resource-efficient methods for processing lotus seeds. The valorization of waste by-products from lotus seed processing leads to creating usable bioactive extracts to produce nutraceuticals and

cosmetic and food products. Scientists are now exploring techniques to grow genetically improved lotus varieties which need minimal amounts of water and pesticides and require reduced quantities of fertilizers. The sustainable farming methods match global sustainability requirements thus minimizing environmental impact and preserving lotus seed production quality. Biotechnological progress enables the advancement of lotus seed food innovation which produces nutritious food that maintains sustainability and presents multiple functional food options. The functional food industry shows promise to integrate lotus seeds as a vital component because researchers continue to explore their potential²⁸⁻²⁹.

Conclusion

Traditional and modern food practices use *Nelumbo nucifera* seeds (lotus seeds) due to their diverse bioactive compounds together with their nutritional benefits. The nutritive value of food lotus seeds consists of vitamins and minerals alongside carbohydrates and protein contents and fats. Various health advantages emerge from lotus seed bioactive compounds such as alkaloids and flavonoids and polysaccharides because they possess antioxidant abilities and anti-inflammatory properties and show hypoglycemic effects. In Asian cultural traditions lotus seeds play a significant role as traditional ingredients that appear in preparations for both lotus seed paste and soups as well as snacks. The medical applications of Lotus seeds involve the treatment of both skin conditions and cancer manifestations and inflammatory responses. Research in food science employs the functional aspects of lotus seeds for producing gluten-free flour products and starch compounds and nutraceutical ingredients for industrial production applications. The advent of biotechnology has allowed the discovery of numerous means to enhance the existing and expected uses of lotus seeds. The combination of fermentation with enzymatic techniques allows eco-friendly manufacturing of new food products that include probiotic drinks and dairy-free alternative beverages. The health benefits of human intestine received attention when investigators demonstrated prebiotic properties in lotus seed polysaccharide compounds. Scientific genetic manipulation enables plant breeders to improve lotus plants in terms of nutritional content and producer lifespan for environmentally friendly farming. The wide product spectrum of lotus seed uses proves both their nutritional food value and their functional properties in industrial products. Researchers expect new discoveries that will lead to better functional foods for promoting health through their development.

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