



The functional and bioactive properties of flaxseed (*Linum usitatissimum* L.): A comprehensive review

Tanusri Patra¹, Somy Mary Mathew², Juhi Kumari³, Shweta Parida^{4*}

¹ Research Scholar, Department of Food and Nutrition, Swami Vivekananda University, Barrackpore, West Bengal, India

² Assistant Professor, Department of Food Technology and Quality Assurance, Cochin Arts and Science College, Mankakkadavu, Kakkanad, Ernakulam, Kerala, India

³ Professional Diploma in Nutrition and Diet Planning, FSTN Exploration Foundation, West Bengal, India

⁴ Assistant Professor and Head, Department of Food Science and Technology, School of CIST, KISS-DU, Bhubaneswar, Odisha, India

Abstract

Flaxseed (*Linum usitatissimum* L.), traditionally recognized for its versatile industrial uses, has emerged as a premier functional food and nutraceutical powerhouse. This review compiles current scientific literature regarding the specific functional ingredients locked within flaxseed—namely alpha-linolenic acid (ALA), lignans, dietary fibres, and unique proteins—and explores their structural and physiological impacts. The hydrocolloids within flaxseed function efficiently as thickening and emulsifying agents in food matrices, while its core bioactive components exhibit profound therapeutic capabilities. Clinical and experimental data demonstrate that regular flaxseed consumption addresses various non-communicable diseases by improving lipid profiles, lowering blood pressure, attenuating insulin resistance, and displaying potent antioxidant and anti-inflammatory properties.

Keywords: Flaxseed, human health, nutrition, dietary fibre, antioxidant, bioactive properties

Introduction

Flaxseed, an ancient oilseed crop belonging to the *Linaceae* family, has experienced a global resurgence in interest over recent decades due to its exceptional nutritional and structural profile (Kaur *et al.*, 2018) [4]. Its scientific name, *Linum usitatissimum*, translates literally to "extremely beneficial"—a description validated by contemporary food science (Shahada *et al.*, 2024) [8].

While traditionally cultivated for oil and fibre, flaxseed is now thoroughly classified as a "superfood" or major functional food (Nowak & Jeziorek, 2023) [6]. It spans a unique sweet spot in food processing, offering excellent technical properties (such as gelling, foaming, and emulsification) alongside structural bioactive compounds that directly counter chronic diseases like cardiovascular disorders, type 2 diabetes, obesity, and cancer (Dzuvoor *et al.*, 2018; Kaur *et al.*, 2018) [1, 4].

Technological & Techno-Functional Properties

The techno-functional profile of flaxseed is dictated primarily by its hydrocolloid fractions, which include both soluble mucilage (flaxseed gum) and structural proteins (Lorenc *et al.*, 2022) [5].

Emulsification, Thickening, and Gelling

Flaxseed gum is an exceptional water-soluble dietary fibre located in the outer seed coat. This polysaccharides-rich gum possesses high water-binding capacity, making it a highly effective thickening and gelling agent in food systems (Lorenc *et al.*, 2022) [5]. When introduced to fluid systems, it alters rheological dynamics, establishing stable structures helpful in low-fat dressings, dairy alternatives, and gluten-free baking.

Foaming and Interfacial Stabilization

The protein fraction of flaxseed, which typically accounts for 20% to 30% of the seed's total mass, is divided into two primary structural categories: albumins and globulins (Goyal *et al.*, 2014) [2].

- **Albumins:** exhibit a superior capacity for emulsion-forming due to their flexible, surface-active nature at fluid interfaces (Lorenc *et al.*, 2022) [5].
- **Globulins:** (specifically linin and conlinin) feature structural attributes that allow them to perform optimally as foaming agents, trapping air efficiently within matrices like meringues or baked goods (Lorenc *et al.*, 2022; Goyal *et al.*, 2014) [2, 5].

Bioactive Composition and Physiological Functionality

The true value of flaxseed as a therapeutic dietary entity lies in its trio of major functional ingredients: polyunsaturated fatty acids, plant lignans, and complex dietary fibres.

Alpha-Linolenic Acid (ALA) and Lipid Mechanics

Flaxseed serves as one of the richest plant-based reservoirs of lipid nutrition, with oil yields yielding high percentages of polyunsaturated fatty acids (Panaite *et al.*, 2017) [7]. Specifically, α -linolenic acid (ALA), an essential ω -3 fatty acid, constitutes roughly 39% to 60% of the total fatty acid blueprint (Goyal *et al.*, 2014) [2].

- **Cardiovascular Defense:** ALA functions as a critical metabolic precursor to long-chain ω -3 polyunsaturated fatty acids in the human body (Panaite *et al.*, 2017) [7]. It actively helps control the onset of atherosclerosis, mitigates blood platelet aggregation, and improves the overall systemic lipid profile by downregulating low-density lipoproteins (LDL) without altering high-density lipoproteins (HDL) (Dzuvoor *et al.*, 2018; Kajla *et al.*, 2014) [1, 3].

- **Anti-Inflammatory Pathways:** ALA exerts anti-inflammatory, anti-thrombotic, and anti-arrhythmic effects by countering pro-inflammatory cytokines, which directly aids individuals suffering from asthma, rheumatoid arthritis, and chronic renal deterioration (Dzuvor *et al.*, 2018; Kajla *et al.*, 2014; Kaur *et al.*, 2018) ^[1, 3, 4].

Secoisolariciresinol Diglucoside (SDG) and Lignan Phytoestrogens

Flaxseed is widely acknowledged as the premier botanical source of plant lignans (Panaite *et al.*, 2017) ^[7]. The primary lignan present is secoisolariciresinol diglucoside (SDG) (Kaur *et al.*, 2018) ^[4].

- **Antioxidant and Anticarcinogenic Impact:** SDG serves as a precursor to mammalian lignans, exhibiting robust antioxidant capabilities that suppress oxygen radical production (Panaite *et al.*, 2017) ^[7]. This specific function minimizes oxidative stress and blocks tumor angiogenesis and proliferation, establishing a strong protective barrier against hormone-dependent malignancies, such as breast, prostate, and colon cancers (Dzuvor *et al.*, 2018; Kaur *et al.*, 2018) ^[1, 4].

Dietary Fibre and Glycemic Modulation

Flaxseed features a substantial total dietary fibre load, typically close to 25% to 35% of its total weight, maintaining a ratio of approximately one-third soluble fibre to two-thirds insoluble fibre (Kajla *et al.*, 2014; Ursoniu *et al.*, 2019) ^[3, 9].

- **Metabolic and Gastrointestinal Health:** The non-starch soluble dietary fibres slow down stomach emptying and delay nutrient absorption within the small intestine (Kaur *et al.*, 2018) ^[4]. Clinical interventions indicate that consuming small daily doses of flaxseed powder (15 to 20 g) drastically drops postprandial blood glucose and improves insulin sensitivity index values, making it an excellent dietary tool for managing type 2 diabetes and obesity (Nowak & Jeziorek, 2023; Kaur *et al.*, 2018) ^[4, 6]. Furthermore, the insoluble fraction aids in smooth intestinal motility and remedies chronic constipation (Nowak & Jeziorek, 2023; Kaur *et al.*, 2018) ^[4, 6].

Nutritional Matrix and Antimicrobial Potential

Beyond its primary trio of bioactives, the broader macro- and micro-nutrient distribution within flaxseed reinforces its role in health maintenance.

Table 1: Key Nutritional Components and Functional Health Benefits of Chia Seeds (*Salvia hispanica L.*)

Nutrient Component	Functional Highlight
Proteins & Amino Acids	Rich in arginine, aspartic acid, and glutamic acid; high cysteine and methionine contents provide cellular antioxidant defense (Kajla <i>et al.</i> , 2014) ^[3] .
Minerals	Abundant in phosphorus, magnesium, and calcium, with exceptionally low sodium levels (Kajla <i>et al.</i> , 2014) ^[3] .
Potassium	High concentration (5600–9200 mg/kg), which helps counter stroke incidence and free-radical production (Kajla <i>et al.</i> , 2014) ^[3] .
Tocopherols (\$\gamma\$-tocopherol)	Potent fat-soluble antioxidant that protects cellular components from lipid peroxidation and lowers cardiovascular risks (Kajla <i>et al.</i> , 2014) ^[3] .

Furthermore, isolated flaxseed proteins and peptides have documented specialized biological traits, including verified antifungal actions against pathogenic strains such as *Alternaria solani*, *Candida albicans*, and *Aspergillus flavus* (Kajla *et al.*, 2014) ^[3].

Conclusion

Flaxseed proves to be a highly versatile functional raw material, blending technical processing utility with extensive clinical benefits. Its physical hydrocolloids serve as excellent clean-label thickening and stabilization agents for food formulations, while its dense payloads of alpha-linolenic acid, SDG lignans, and dietary fibre provide strong protection against cardiovascular, metabolic, and oncological disorders. Continued research into the structural extraction of these components promises to expand its footprint across both the global functional food sector and natural pharmaceuticals.

References

1. Dzuvor CKO, Taylor JT, Acquah C, Pan S, Agyei D. Bioprocessing of Functional Ingredients from Flaxseed. *Molecules*,2018;23(10):2444.
2. Goyal A, Sharma V, Upadhyay N, Gill S, Sihag M. Flax and flaxseed oil: an ancient medicine & modern functional food. *Journal of Food Science and Technology*,2014;51(9):1633-1653.

3. Kajla P, Sharma A, Sood DR. Flaxseed—a potential functional food source. *Journal of Food Science and Technology*,2014;52(4):1857-1871.
4. Kaur P, Waghmare R, Kumar V, Rasane P, Kaur S, Gat Y. Recent advances in utilization of flaxseed as potential source for value addition. *OCL*,2018;25(3):A304.
5. Lorenc F, Jarošová M, Bedrníček J, Smetana P, Bárta J. Structural Characterization and Functional Properties of Flaxseed Hydrocolloids and Their Application. *Foods*,2022;11(15):2304.
6. Nowak W, Jeziorek M. The Role of Flaxseed in Improving Human Health. *Healthcare*,2023;11(3):395.
7. Panaite T, Ropota M, Turcu R, Olteanu M, Corbu AR, Nour V. Flaxseeds: Nutritional Potential and Bioactive Compounds. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Food Science and Technology*,2017;74(2):65.
8. Shahada C, Morya S, Awuchi CG. A narrative review on nutraceutical, food and industrial applications of flaxseed (*Linum usitatissimum*. L). *Cogent Food & Agriculture*, 2024, 10(1).
9. Ursoniu S, Sahebkar A, Serban MC, Pinzaru I, Dehelean C, Noveanu L, *et al.* A systematic review and meta-analysis of clinical trials investigating the effects of flaxseed supplementation on plasma C-reactive protein concentrations. *Archives of Medical Science*,2019;15(1):12-22.