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Review Article

Therapeutic Potential and Nutritional Phytochemical Profile of Flax Seeds

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Abstract

Linum usitatissimum or flax or linseed which is commonly used in large numbers to obtain seeds and fibres. Over the past decades, flax seeds have attracted growing interest of scientists because of the presence of a wide range of phytochemicals as well as the range of pharmacological effects. This review has given a detailed account of the pharmacognostic properties, phytochemical compounds as well as pharmacological prospects of flax seeds. The microscopic, organoleptic and macroscopic characteristics of pharmacognostics that are so crucial to pharmacogenetics and quality assurance of raw material are observed in detail through the pharmacogenetics study in detail. Phytochemical studies have identified several kinds of bioactive compounds in the plant, which are lignans (especially secoisolariciresinol diglucoside), omega-3 fatty acids (alpha-linolenic acid), flavonoids, alkaloids, and mucilage, that play a role in the therapeutic action of the plant. Detailed pharmacognostic studies highlight the macroscopic, microscopic, and organoleptic features vital for the standardization and quality control of raw material. Several types of bioactive compounds, including lignans (in particular, secoisolariciresinol diglucoside), omega-3 fatty acids (alpha-linolenic acid), flavonoids, alkaloids, and mucilage, have been identified in phytochemical studies to play a role in the therapeutic action of the plant. Pharmacological studies demonstrate heterogeneity of a variety of biological activities such as antioxidant, anti-inflammatory, hypolipidemic, antidiabetic, anticancer, and cardioprotective effects, many of which are supported by in vitro and in vivo research. This is an in-depth review aiming at relating traditional knowledge to modern pharmacological research, and this will become a single source to research scholars, health professionals, and the pharmaceutical industry.

Keywords: *Linum usitatissimum*; Microscopy; Functional Foods; Flavonoids; Cardioprotective; Lignans

Introduction

Flax seeds, also known as *Linum usitatissimum*, have been grown for centuries and play a significant role in traditional medicine and modern medicine. They have traditionally been a popular Ayurvedic, Unani and folklore laxative, anti-inflammatory, and soothing ingredient [1]. With time, an increasing number of people have been interested in their rich phytochemical composition and variety of health benefits, which have entered the realms of nutrition and biomedical studies.

Nowadays, flax seeds are becoming popular as a functional food and nutraceutical, and due to their effectiveness in supporting digestive, metabolic, and cardiovascular health [2,57].

Pharmacognostically, the flax seeds have the typical macroscopic and microscopic properties of mucilaginous seed coat, oily endosperm and lens-shaped structure with help of which they are easily identified and standardized [3]. They owe its medicinal properties to an extensive variety of bioactive compounds, including flavonoids, alkaloids, polysaccharides, lignans (especially secoisolariciresinol diglucoside), and omega-3 fatty acids, especially alpha-linolenic acid (ALA) [4]. Modern methods of analyses have given a chance to comprehensively profile these phytochemicals and therefore clarified their functions in regulating inflammation, oxidative stress and lipid metabolism among other biological functions. It has been shown that flax seeds have a wide range of biological effects which include hypolipidemic, antidiabetic, antioxidant, anticancer and cardioprotective effects according to *in vitro* and *in vivo* studies [5,6]. It is believed that such therapeutic effects are caused mainly by the synergistic effect of phenolic compounds and omega-3 fatty acids, which makes flax seeds a promising source of plant-based medicines and preventive health interventions.

Hence, this review sets out to present an in-depth review of the pharmacognostic, phytochemical, and pharmacological characteristics of flax seeds and the potential of this natural therapeutic agent as a multifaceted agent as well as emphasizing the need to conduct more research on it.

Pharmacognosy of flax seeds (*Linum usitatissimum*)

Macroscopically, the flax seeds are tiny, flat, oval-shaped seeds, which are normally brown or golden and have a length range of 47 mm. They are smooth and glossy with the endosperm and embryo being covered by a thick seed coat that protects them, consisting of mucilage-producing cells that become swollen when exposed to water and that explains the large proportion of mucilage. The coat involves the use of parenchymatous cells, several layers of palisade cells, and an outer epidermis, which individually control the absorption of water and protection [9]. The endosperm has protein bodies which are endowed with essential amino acids and oil bodies in which lipids are stored mostly 10 -linolenic acid (ALA) [10]. Also, sclerenchymatous fibers give them mechanical strength and durability. Organoleptic characteristics are the plain though useful means of identification, flax seeds have a nutty taste with a slight tincture of bitterness, a slight characteristic smell and smooth, oily consistency, which turns mucilaginous when moist [11]. In order to provide quality control and determine adulteration in industrial or commercial samples, standard pharmacognostic parameters are used which include extractive values, moisture content and ash values [12]. These broad pharmacognostic evaluations are important in the validation of the flax seeds, batch-to-batch reproducibility, and for use in future phytochemical and pharmacological studies.

Phytochemistry of flax seeds (*Linum usitatissimum*)

Flax seed mainly contains dietary fibers, proteins, lignans, omega-3 fatty acids, and phenolic compounds. The most common bioactive polyphenols in flax seeds are lignans especially secoisolariciresinol diglucoside (SDG). SDG is a strong antioxidant phytoestrogen that has been widely investigated due to its effects in minimizing cardiovascular diseases and hormone-related cancers [13,14]. A second significant component is alpha-linolenic acid (ALA) an essential omega-3 fatty acid that makes up 50-60 percent of the total fatty acid content of flax seed oil. Flax seeds are also a good source of dietary fiber, soluble mucilage, and insoluble fibers that are very important as they render benefits in digestive health and glycemic control [17]. Moreover, flax seeds are also a good source of flavonoids, phenolic acids and alkaloids in smaller but

significant quantities, which have synergistic effects of strengthening antioxidants and anti-inflammatory. Their proteins and amino acids also add to the nutritional value and to pharmacological efficacy [18]. As spectroscopic and chromatographic methods have advanced, these phytochemicals can now be characterized and quantified more precisely, enhancing our knowledge of their biological functions, interactions, and bioavailability.

Pharmacology of flax seeds (*Linum usitatissimum*)

The major bioactive constituents of flax seeds are alpha-linolenic acid (ALA), lignans (especially secoisolariciresinol diglucoside, SDG), and soluble fiber, which are the components of the flax seed-based functional foods and pharmacology. ALA, an essential omega-3 fatty acid, undergoes partial bioconversion in the human body to produce **eicosapentaenoic acid (EPA)** and **docosahexaenoic acid (DHA).** These long-chain metabolites are crucial for the synthesis of **anti-inflammatory eicosanoids** and play a vital role in the **regulation of cell membrane fluidity**, thereby contributing to multiple therapeutic benefits associated with flax seed consumption [19,20]. Lignans, being phytoestrogens, structurally resemble endogenous estrogens and exert weak estrogen receptor agonist/antagonist activity, thereby influencing hormonal signaling pathways [21]. Soluble fibers, primarily mucilage, enhance gut health by modulating the microbiome, slowing carbohydrate absorption, and promoting cholesterol excretion through bile acid sequestration [22,25].

From a cardiometabolic perspective, flaxseed demonstrates lipid-lowering, antihypertensive, and antithrombotic pharmacology. ALA reduces serum triglycerides, improves endothelial nitric oxide bioavailability, and decreases platelet aggregation, collectively reducing atherosclerotic risk [19,20,22]. SDG and its metabolites, enterodiol and enterolactone, generated via gut microbiota metabolism, act as potent antioxidants and modulators of estrogen metabolism [21,24]. These compounds reduce low-density lipoprotein (LDL) oxidation, attenuate C-reactive protein (CRP) levels, and improve vascular compliance [23,24]. Meanwhile, the soluble fiber fraction delays gastric emptying, enhances satiety, lowers postprandial glucose, and improves insulin sensitivity, highlighting the character of flaxseed in obesity and type 2 diabetes mellitus management [25,26].

Beyond cardiometabolic health, flaxseed exhibits oncological and neuroprotective pharmacology. Lignans act as selective estrogen receptor modulators (SERMs), thereby attenuating the growth of hormone-dependent tumors such as breast and prostate cancers [21,23]. Experimental evidence suggests that flaxseed intake downregulates tumor cell proliferation, promotes apoptosis, and interferes with growth factor-mediated signaling [23,24]. Additionally, the anti-inflammatory and membrane-stabilizing effects of ALA confer neuroprotection, reducing risks of cognitive decline and neurodegenerative diseases [20]. Collectively, these mechanisms emphasize flaxseed as a dietary agent with pharmacological relevance across cardiovascular, endocrine, oncological, and neurological domains, warranting its identification as a therapeutic adjunct in long-term disease prevention and management.

Uses of flax seed (*Linum usitatissimum*)

Nutritional uses

- **Abundant in omega-3 fatty acids (ALA):** Flaxseed provides ~50–60% α-linolenic acid, a plant-based omega-3 important for cardiovascular health [27].
- **High dietary fibre:** Contains ~28–35% fibre (soluble and insoluble), improving bowel function and digestion [28].
- **Plant protein source**: Supplies 20–30% protein, useful in vegetarian/vegan diets though limited in lysine [29].
- **Vitamins and minerals:** Contributes vitamin E, B-complex, calcium, magnesium, potassium, and phosphorus [30].

Therapeutic/Health Uses

- **Cholesterol lowering:** Regular intake of ground flaxseed reduces total and LDL cholesterol, supporting cardiovascular health [31].

- **Blood pressure regulation**: Flaxseed consumption is linked with modest reductions in systolic and diastolic blood pressure [32].
- **Blood sugar control:** Improves fasting glucose and insulin sensitivity in diabetic patients [33].
- **Anti-inflammatory effects:** ALA and lignans reduce inflammation, beneficial in arthritis and chronic conditions [34].
- **Cancer risk reduction:** Lignans exert estrogen-modulating and antioxidant effects, reducing risk of breast, prostate, and colon cancers [35].
- **Weight management:** Fibre increases satiety, lowering overall energy intake [36].
- **Digestive health:** Acts as a mild laxative and improves gut microbiota [37].
- **Menopausal support:** Lignans reduce hot flashes and improve quality of life in postmenopausal women [38].

Culinary uses

- **As a food ingredient:** Ground flaxseed is added to cereals, smoothies, soups, salads, and porridges [39].
- **In baking:** Incorporated into breads, muffins, cookies for nutrition and texture [40].
- **Vegan egg substitute:** Flaxseed mixed with water forms a gel ("flax egg") used as a binder in vegan recipes [41].

Industrial uses

- **Linseed oil production:** Flaxseed oil is processed for paints, varnishes, and linoleum flooring [42].
- **Animal feed:** Flaxseed meal is used to enrich animal diets with omega-3 fatty acids [43].
- **Cosmetics:** Flaxseed oil is incorporated in moisturizers, soaps, and hair care products due to emollient properties [44].

Figure 1: Flax seeds.

Contraindications of flax seed (*Linum usitatissimum*)

Flaxseed (*Linum usitatissimum*) is widely recognized for its health-promoting properties, including lipid-lowering, glycemic control, and anti-inflammatory effects. However, despite its potential benefits, certain populations may need to exercise caution due to contraindications associated with its consumption. The high fiber content of flaxseed, both soluble and insoluble, may exacerbate gastrointestinal conditions such as irritable bowel syndrome, inflammatory bowel disease, or intestinal obstruction, particularly in individuals with pre-existing gastrointestinal motility disorders. Additionally, flaxseed contains cyanogenic glycosides, which can release small amounts of cyanide, potentially posing a risk if consumed in extremely high amounts, although typical dietary intake is considered safe [45,46].

Flaxseed may also influence hormonal activity due to its phytoestrogenic compounds, particularly lignans, which exhibit estrogen-like activity. Consequently, individuals with estrogen-sensitive conditions, such as breast, ovarian, or endometrial cancers, should exercise caution and seek medical advice before incorporating flaxseed supplements into their diet. Animal studies and limited clini-

cal reports suggest that excessive intake of lignans could potentially modulate estrogen receptor activity and interfere with endocrine therapy, though evidence in humans remains limited and inconclusive [47,48]. This Highlights the need for personalized assessment when recommending flaxseed supplementation in populations at risk of hormone-sensitive pathologies.

Furthermore, flaxseed may interact with certain medications, potentially reducing their efficacy or altering pharmacokinetics. For instance, the high fiber content may obstruct with the absorption of oral medications, including anticoagulants, antidiabetic agents, and lipid-lowering drugs, thereby requiring careful timing of administration. Additionally, due to its mild anticoagulant effect, flaxseed supplementation may increase the risk of bleeding in Individuals taking antithrombotic or antiplatelet therapy [49,50]. Therefore, healthcare providers should evaluate individual risk factors, pre-existing conditions, and concomitant medication use when advising on flaxseed consumption to prevent adverse outcomes.

Interactions of flax seed (*Linum usitatissimum*)

Flaxseed (*Linum usitatissimum*), a nutrient-dense functional food, has gained widespread attention due to its high content of a-linolenic acid (ALA), lignans (particularly secoisolariciresinol diglucoside or SDG), and soluble dietary fiber. These bioactive compounds contribute to its hypocholesterolemic, anti-inflammatory, and antioxidative effects. However, flaxseed can interact with pharmaceuticals and physiological systems, primarily through its modulation of cytochrome P450 enzymes and hormone metabolism. For instance, SDG and its mammalian lignan metabolites (enterodiol and enterolactone) exhibit phytoestrogenic activity by binding to estrogen receptors, potentially influencing the metabolism or efficacy of estrogen-dependent medications or conditions such as hormone replacement therapy and breast cancer treatments [51,52].

Dietary flaxseed also influences gastrointestinal function, which may alter the pharmacokinetics of orally administered drugs. Its high mucilage fiber content can delay gastric emptying and reduce intestinal absorption, possibly affecting the bioavailability of medications such as acetaminophen or carbamazepine [53]. Additionally, the bulking action of the fiber may hinder the absorption of minerals such as calcium, iron, and zinc; however, long-term research shows that this effect would be negligible with normal dietary intakes. Particularly, because ALA may have an additional influence on platelet function and clotting time, care should be used when taking flaxseed with anticoagulants or antiplatelet medications [54].

Because flaxseed contains lignan, interactions with the endocrine system are very important. Depending on the hormonal environment, these substances may have estrogenic or anti-estrogenic effects, which may have effects on hormone-sensitive malignancies as well as reproductive health. Flaxseed supplementation has been associated with **modest alterations in circulating estrogen levels and sex hormone-binding globulin (SHBG) concentrations** in postmenopausal women, suggesting possible implications for conditions such as **endometriosis and hormone-responsive cancers** [55,56]. These complex interactions underscore the importance of evaluating flaxseed not only as a **nutritional supplement** but also as a **physiologically active agent** capable of influencing the **safety and efficacy of conventional pharmacological therapies**.

Conclusion

Flax seeds (***Linum usitatissimum***) represent an important natural resource with a well-established **pharmacognostic profilae, rich phytochemical composition, and diverse pharmacological activities.** Detailed morphological and microscopic characterization enables accurate identification and quality assurance, ensuring consistency in therapeutic applications. Phytochemically, flax seeds are abundant in **lignans, omega-3 fatty acids, flavonoids, and polysaccharides,** which act synergistically to support a wide range of health benefits. Pharmacological evidence demonstrates their potential in mitigating **oxidative stress, inflammation, metabolic disorders, cardiovascular diseases, and cancer**, thereby reinforcing their role as both a **functional food** and a source of **plant-based therapeutics**. Despite promising findings, further

mechanistic studies and well-designed clinical trials are required to validate these effects and optimize therapeutic use. This review synthesizes current knowledge, bridging traditional insights with modern scientific evidence, and encourages continued research toward integrating flax seeds into contemporary healthcare and pharmaceutical practice.

Conflict of Interest

Authors state there is no conflict of interest.

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