IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

From Seed to Skin: Unveiling the Dermatoprotective Potential of Flaxseed Mucilage in Atopic Dermatitis Management

Imrongnaro[1], Dr Rupesh Kumar M[1,2], Namgyal Dolma1, Bhargavi V[1]
[1]Department of Pharmacology
[2]Department of Pharmacology, Faculty of Pharmacy
Al-Ameen College of Pharmacy, Bengaluru, Karnataka, India.

Abstract: *Linum usitatissimum L. (flaxseed) is a medicinal plant widely recognized for its nutritional value and therapeutic potential, particularly in dermatological applications. This review, titled "From Seed to Skin: Unveiling the Dermatoprotective Potential of Flaxseed Mucilage in Atopic Dermatitis Management," highlights the bioactive constituents of flaxseed and their significance in skin health, with special emphasis on flaxseed mucilage. Flaxseed contains omega-3 fatty acids, lignans such as secoisolariciresinol diglucoside (SDG), phenolic compounds, and flavonoids, which possess antioxidant, anti-inflammatory, antimicrobial, and wound-healing properties. Flaxseed mucilage, a water-soluble polysaccharide, forms a protective gel-like layer upon hydration, enhancing skin hydration and barrier integrity. Emerging evidence suggests that flaxseed-derived constituents can attenuate oxidative stress, modulate inflammatory pathways, and support tissue repair processes. Collectively, these pharmacological properties indicate that flaxseed mucilage represents a promising, natural, and cost-effective therapeutic candidate for the management of atopic dermatitis and other inflammatory skin disorders.*

Keywords: *Linum usitatissimum* L., Flaxseed mucilage, Atopic dermatitis, Anti-inflammatory, Wound healing, Skin barrier protection

I. INTRODUCTION

Linum usitatissimum L., widely known as flaxseed or linseed, is considered among the earliest plants to be domesticated by humans for agricultural use. It has been cultivated since ancient times for its dual importance as both a fibre-producing crop and an oil-yielding seed. Taxonomically, this plant is classified under the family Linaceae and is mainly grown in regions with moderate and cool climatic conditions across the globe. Over the years, flaxseed has found applications not only in traditional food systems but also in folk medicine and various industrial processes. Many of these traditional therapeutic claims are now being increasingly validated through contemporary scientific investigations, highlighting its growing importance in modern research. [1].

Flaxseed is considered a functional food owing to its dense nutrient profile and presence of various health-promoting plant bioactives. [2]. It typically contains 30–45% oil, 18–25% protein, and a considerable amount of dietary fiber [3,4,5]. One of the key active constituents present in flaxseed is α-linolenic acid (ALA), which is a type of plant-derived omega-3 fatty acid. It is widely studied for its beneficial effects on heart health and its ability to help reduce inflammatory responses in the body.[2,3]. Along with ALA, flaxseed contains exceptionally high levels of plant lignans, with secoisolariciresinol diglucoside (SDG) being the most predominant form present, which exhibits antioxidant, anticancer, and phytoestrogenic effects[3]. In addition, phenolic acids, flavonoids, proteins, cyanogenic glycosides, and other secondary metabolites further enhance its pharmacological potential[1,5].A wide range of studies has shown that flaxseed possesses a wide range of studies has shown that flaxseed possesses multiple biological activities, which include free-

DOI: 10.48175/IJARSCT-37833

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 6, Issue 3, July 2026 Impact Factor: 8.2

radical scavenging (antioxidant), reduction of inflammation (anti-inflammatory), inhibition of microbial growth (antimicrobial), blood glucose regulation (antidiabetic), protection of the cardiovascular system (cardioprotective), and prevention of cancer cell development (anticancer effects).[1,3,4]. However, it also contains certain antinutritional factors such as cyanogenic glycosides, compounds that may liberate hydrogen cyanide when they undergo enzymatic or chemical breakdown in the body. Despite this, proper processing and moderate consumption ensure its safety. Despite this, proper processing and moderate consumption ensure its safety[3]. Recent nutritional reviews highlight both the benefits and limitations of flaxseed intake, supporting its use as part of a balanced diet[8].

An important and industrially valuable component of flaxseed is its mucilage, a water-soluble polysaccharide located in the outer seed coat[6]. Flaxseed mucilage consists mainly of neutral arabinoxylan-rich fractions and acidic rhamnogalacturonan-type polysaccharides, which give it high molecular weight and strong viscosity characteristics[6]. When hydrated, it forms a gel-like structure with excellent water-binding ability and pseudoplastic behaviour [6,7]. These rheological properties make flaxseed mucilage a useful natural hydrocolloid, widely applied as a thickener, stabiliser, emulsifier, fat replacer, and texture modifier in food systems[6]. The isolation of flaxseed mucilage is most commonly carried out using water-based extraction techniques, where factors like temperature, pH level, duration of extraction, and the ratio of seed to water significantly influence both the overall yield and the resulting functional characteristics. [6]. Ziolkovska (2012) reported that extraction conditions significantly influence the rheological behaviour and structural characteristics of the mucilage system[7]. Therefore, optimising these parameters is essential to obtain mucilage with desirable physicochemical properties[6,7]. Beyond food applications, flaxseed oil and mucilage are also gaining attention in pharmaceutical and cosmetic formulations due to their moisturising, anti-inflammatory, and skin-protective effects[9]. Their incorporation into skincare and therapeutic products reflects the expanding industrial relevance of this plant[9].

Overall, flaxseed represents a highly versatile crop with nutritional, pharmacological, and industrial importance. Its rich chemical composition, well-established health benefits, and multifunctional mucilage continue to attract growing interest in the fields of food science, nutraceuticals, and biomedical research[1,9].

Chemical Composition and Structure

Flaxseed mucilage is a structurally complex heteropolysaccharide system composed primarily of two distinct portions, one being a neutral polysaccharide component and the other an acidic polysaccharide fraction[10,11].

The neutral fraction is mainly composed of arabinoxylans, with a backbone rich in xylose and arabinose side chains[10]. In contrast, the acidic fraction is made up of rhamnose, galactose, and galacturonic acid residues and is structurally similar to rhamnogalacturonan-type polymers[10].

These two fractions differ in molecular weight and degree of branching, which together contribute to the unique rheological and functional behaviour of flaxseed mucilage. Kučka et al. (2024) further reported that flaxseed mucilage consists of high molecular weight polysaccharides with strong water-holding and hydration capacity, making it highly valuable for various technological and functional applications[11].

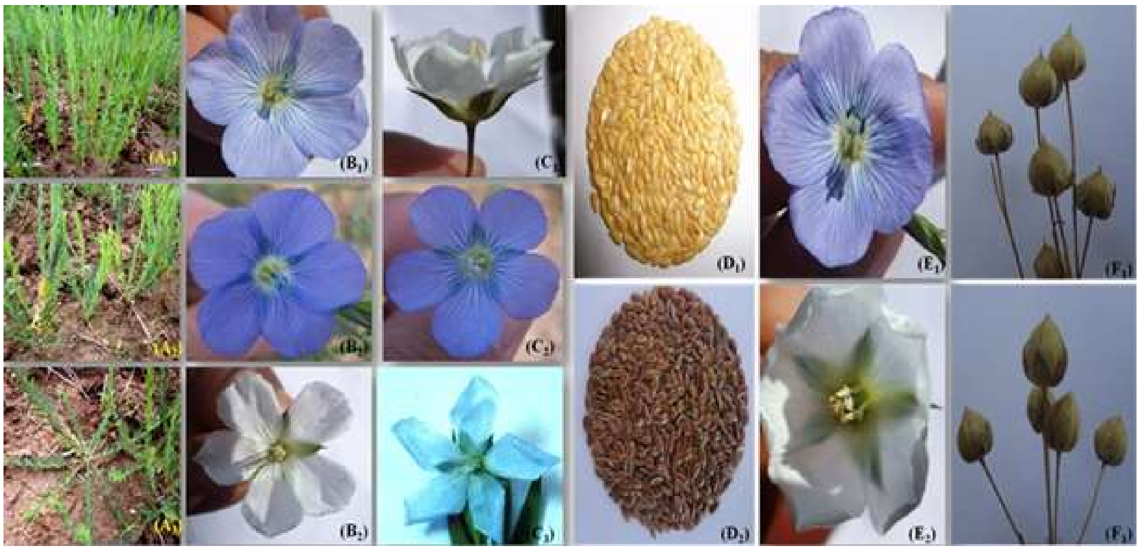
Extraction and Isolation of Flaxseed Mucilage

The extraction of flaxseed mucilage is mainly performed through aqueous methods. Among these, conventional hot water extraction is the most commonly used technique, where parameters like temperature, duration of extraction, pH level, and the ratio of seed to water, significantly affect both yield and physicochemical properties[6]. Generally, higher temperatures increase mucilage yield, although they may also alter its molecular structure and viscosity.

After extraction, the mucilage solution is separated from the solid seed residues through filtration or centrifugation and is usually precipitated using ethanol or other alcohols, followed by drying. In recent years, advanced extraction approaches such as ultrasound-based methods and microwave-assisted techniques have been explored to improve efficiency and reduce processing time. Additionally, extraction facilitated by enzymes has also been studied to improve yield and modify functional properties[10].

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

It has been reported that extraction conditions can influence the proportion of neutral and acidic fractions, which in turn affects viscosity and functional behaviour [10]. Overall, processing conditions play a significant role in influencing physicochemical as well as techno-functional properties of the extracted mucilage[11].



Functional and Rheological Properties

Flaxseed mucilage exhibits distinctive rheological properties, including high water-binding capacity, high viscosity at low concentrations, and pseudoplastic (shear-thinning) flow behaviour. demonstrated that flaxseed mucilage solutions show non-Newtonian flow behaviour and strong viscosity development, which is influenced by concentration, temperature, and ionic strength [12]

The neutral and acidic polysaccharide fractions contribute differently to viscosity and gel formation. The mucilage's ability to retain water and form viscous solutions makes it suitable as a thickener, stabiliser, emulsifier, and fat replacer in food systems. It further describes its application in bakery, dairy, beverage, and functional food formulations due to its moisture retention and texture-modifying properties.

It highlights the broad technological potential of flaxseed mucilage, emphasising its application as a natural hydrocolloid with promising applications in food innovation and clean-label product development. Additionally, its soluble fibre nature contributes to physiological benefits, including improved gastrointestinal function and potential cholesterol-lowering effects [11]

Flaxseed mucilage is a high-molecular-weight, structurally complex heteropolysaccharide composed of neutral arabinoxylan and acidic rhamnogalacturonan fractions.[10,11] Its extraction is mainly achieved through aqueous methods, with processing conditions significantly influencing yield and functionality.[11] The mucilage exhibits high viscosity, pseudoplastic behaviour, and excellent water-binding capacity, making it a valuable natural hydrocolloid for food applications.[13] Collectively, these studies demonstrate the significant technological and functional importance of flaxseed mucilage in food systems [6,11]

II. PLANT PROFILE [13]

Fig.1 Visual representation of *Linum usitatissimum* (flaxseed) highlighting its key morphological features. The images include different stages of plant growth (A_1–A_3), characteristic blue flowers (B_1–B_3), white flower variations (C_1–C_3), seeds in both yellow and brown forms (D_1–D_2), detailed views of the flower structure (E_1–E_2), and the mature seed capsules (F_1–F_2).

DOI: 10.48175/IJARSCT-37833

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

III. TAXONOMY [14]

Rank	Classification
Kingdom →Subkingdom	Plantae → Tracheobionta
Super division → Division	Spermatophyta → Magnoliophyta
Class → Order	Magnoliopsida → Malpighiales
Family	Linaceae
Genus	*Linum*
Species	*Linum usitatissimum* L.

Table 1 Taxonomical classification of *Linum usitatissimum* L.

IV. ETHNOPHARMACOLOGY

Linum usitatissimum L. (widely referred to as alsi or atasi) has been utilised in traditional medicinal systems like Ayurveda and Unani to help manage a broad range of both acute and chronic health conditions. In Ayurvedic practice, the seeds are described as demulcent, emollient, laxative, and anti-inflammatory, and are commonly used to treat constipation, gastritis, intestinal irritation, and urinary disorders. They are also considered beneficial in balancing aggravated Vata and promoting tissue nourishment and healing [15].

In Unani and traditional folk medicine, flaxseed is primarily used for respiratory ailments such as cough, bronchitis, and chest congestion, owing to its soothing and expectorant properties. External application of flaxseed pastes or poultice is traditionally recommended for wounds, burns, boils, abscesses, ulcers, eczema, and other inflammatory skin conditions, where it helps reduce inflammation, soften tissues, and accelerate healing. Additionally, it has been used to manage joint pain, swelling, arthritis, and other inflammatory disorders [16].

V. BOTANICAL DESCRIPTION [14]

Plant

Linum usitatissimum is a slender, upright annual herb that generally reaches a height of about 60 to 120 cm under suitable growing conditions. It is well adapted to temperate environments and can also be cultivated in moderately elevated regions, growing successfully at altitudes of up to around 1800 meters above sea level.

Flower

The plant bears small, fragile flowers that are most commonly blue in colour, although shades of bluish-violet or white may also be observed. These flowers are typically borne in terminal inflorescences. Each flower is about 1.5 to 2.5 cm wide and is composed of five separate petals, giving it a simple yet characteristic appearance.

Fruit

The fruit of linseed is a dry, rounded capsule that is relatively small in size, usually measuring between 5 and 9 mm in diameter. Internally, the capsule is divided into five sections, and each compartment contains two seeds, making it a multi-seeded structure.

Seeds

The seeds are tiny, flattened, and oval-shaped, with a sleek and glossy outer surface. Their length typically ranges from 4 to 7 mm, and individual seed weight may vary between approximately 3.5 and 11 mg. They possess a faint odour and develop a slightly oily and mucilaginous texture when exposed to moisture.

An increase in seed size and weight is often associated with a higher oil yield, which is an important trait for industrial and nutritional purposes. Structurally, the seed consists of an embryonic portion, a delicate nutritive tissue layer known as endosperm, and a pair of cotyledon structures, all enclosed within a protective outer covering known as the seed coat or spermoderm. Based on colour, flaxseeds are generally classified into two common types: brown and yellow.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

VI. GEOGRAPHY [17]

- **Distribution, Yield, Use:**

Geographical Distribution

Linseed is cultivated extensively across different parts of the world, particularly in temperate regions. Major areas of production include Europe, countries of the former Soviet region, China, India, North America, and Argentina. The crop is adaptable to a variety of soil types, although optimal growth is achieved with adequate moisture availability. Compared to fibre flax, linseed varieties are better suited to relatively warm climatic conditions with lower atmospheric humidity.

Yield Potential

The productivity of linseed varies depending on environmental conditions, agricultural practices, and the cultivar used. Under normal conditions, seed yield generally ranges between 5 and 20 quintals per hectare. Fibre yield, in varieties cultivated for fibre extraction, may vary from approximately 5 to 25 quintals per hectare. These variations are largely influenced by soil fertility, irrigation, and climatic factors.

Economic Uses

Linseed is considered a versatile crop with both industrial and nutritional importance. The seeds are primarily used for the extraction of oil, which finds applications in the manufacture of products such as paints, varnishes, linoleum, and also as an edible oil in certain regions. The by-product obtained after oil extraction, commonly known as oil cake, is widely used as a protein-rich animal feed.

In addition to industrial uses, linseed seeds are valued for their health benefits and are utilized in various dietary and medicinal preparations. The fibres obtained from the stem are used as raw materials in the textile industry for the production of linen and related products. Typically, linseed seeds contain about 38–45% oil, which is abundant in important fatty acids such as linoleic acid and α-linolenic acid, which contribute to its nutritional significance.

Fig. 2 Region of origin: ■ Region of cultivation: ■

Origin and Cultivation History

Flax is among the earliest domesticated crops known to human civilisation. Historical records suggest that its cultivation dates back approximately 6000 to 8000 years, with early evidence found in ancient Egyptian and Mesopotamian cultures. Over time, its cultivation spread to different parts of Europe during the early Stone Age period. The cultivated form of flax is thought to have originated from *Linum angustifolium*, a wild species found naturally in the Mediterranean basin as well as parts of Southwest Asia. Through continuous selection and domestication, various forms of flax have been developed to meet specific requirements such as oil production, fibre extraction, or combined utility.

Breeding and Improvement

Breeding strategies in linseed are primarily focused on enhancing both yield and quality parameters. For fibre production, desirable traits include tall plant height, minimal branching, and high fibre content. In contrast, oilseed varieties are typically shorter in stature, exhibit profuse flowering, and produce a higher number of seed capsules.

Recent breeding programs aim to develop improved cultivars that combine the advantages of both fibre and oil types. Emphasis is also placed on optimising seed characteristics such as size, oil percentage, and fatty acid composition to meet industrial and nutritional demands.

VII. BENEFITS OF FLAXSEED [18]

7.1. Cardiovascular Protection

Flaxseed serves as a rich dietary source of α-linolenic acid (ALA), a type of plant-derived omega-3 fatty acid that is essential for supporting and maintaining heart health. It helps lower blood cholesterol levels in the blood, aids in maintaining stable blood pressure, and ultimately reduces the likelihood of developing cardiovascular disorders.

7.2. Antioxidant Activity

Flaxseed contains a significant amount of lignans, particularly secoisolariciresinol diglucoside (SDG), which possess strong which exhibit potent free-radical scavenging activity. These bioactive compounds assist in reducing reactive oxygen species and offer protection against cellular damage caused by oxidative stress.

7.3. Anti-Cancer Potential

The lignans present in flaxseed are metabolized in the intestine into compounds known as enterolignans. These metabolites display estrogen-like effects and are thought to play a role in reducing the likelihood of cancers, including hormonal factors, such as breast and prostate cancer.

7.4. Digestive Health Support

Due to its high content of having a combination of soluble and insoluble dietary fibre, flaxseed promotes supports proper digestive function by facilitating regular bowel activity, helping to avoid constipation, and contributing to the maintenance of a healthy gastrointestinal system.

7.5. Blood Glucose Control

Flaxseed assists in maintaining stable blood glucose levels by delaying the rate at which glucose is absorbed into the bloodstream. The presence of soluble fibre and mucilage plays a key role in improving glycemic control, making it beneficial for individuals with diabetes.

7.6. Anti-Inflammatory Effects

The combined presence of the synergistic action of omega-3 fatty acids along with lignans contributes to the anti-inflammatory properties of flaxseed. These components help reduce inflammation, which is often associated with various chronic diseases.

7.7. Weight Management

The high fibre content in flaxseed promotes satiety, which can contribute to lowering total calorie consumption. This may support managing body weight and preventing overeating.

7.8. Skin and overall Health

The vital polyunsaturated fatty acids present in flaxseed contribute to preserving skin moisture levels and supporting the structural integrity of the skin barrier. In addition to supporting skin health, they also contribute to overall metabolic well-being.

VIII. AN OVERVIEW OF THE CHEMICAL CONSTITUENTS OF *LINUM* USITATISSIMUM L. [19,20]

Plant Part	**Chemical Constituents**	**Approximate Composition /Details**
Whole Seed	Oil (lipids)	30-45 % of seed weight
	Proteins	18-25%
	Dietary Fiber	20-28%
	Ash (minerals)	3-4%
Seed Oil (Fatty Acid Profile)	α- Linoleic acid (ALA, $\omega - 3$)	~50-60% of total fatty acids

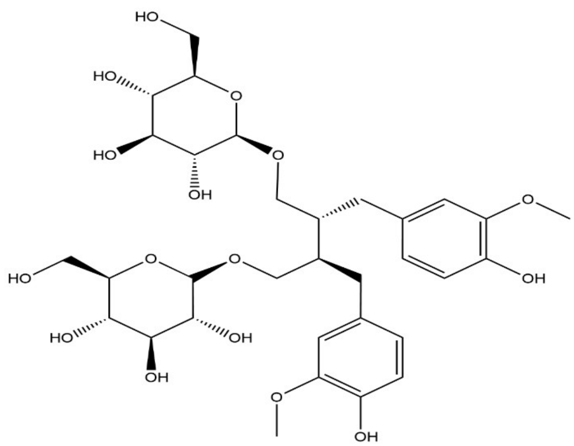
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

	Linoleic acid (omega-6 $\omega-6$)	~15-18%
	Oleic acid	~18-22%
	Palmitic acid	~5-7%
	Stearic acid	~3-5%
Bioactive Components Mentioned	Lignans (mainly SDG)	Principal phenolic compound
	Soluble and Insoluble Fibre	Includes mucilage polysaccharides

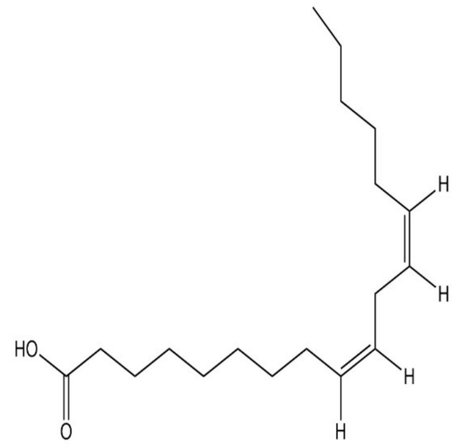
Chemical constituents of *Linum usitatissimum* L. Gum Mucilage [6]

Component Category	**Chemical Constituents Reported**	**Details Mentioned in Review**
Major Structural Type	Heteropolysaccharide	High molecular weight, water-soluble polysaccharide
Neutral Polysaccharide Fraction	Arabinoxylan	Major neutral fraction
	Arabinose	Monosaccharide unit
	Xylose	Monosaccharide unit
	Galactose	Monosaccharide unit
Acidic Polysaccharide Fraction	Pectic-like polysaccharides	Acidic fraction of mucilage
	Galacturonic acid	Major acidic sugar
	Rhamnose	Monosaccharide component
	Fucose	Monosaccharide component
Other Characteristics Mentioned	Neutral and acidic fractions are present in specific ratios.	Responsible for viscosity and functional properties

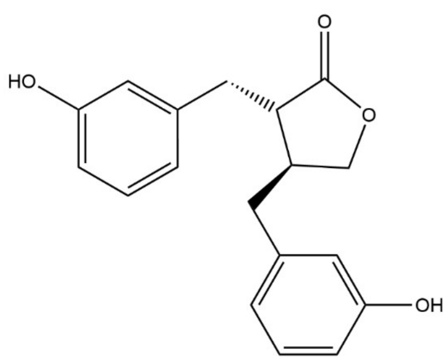
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2



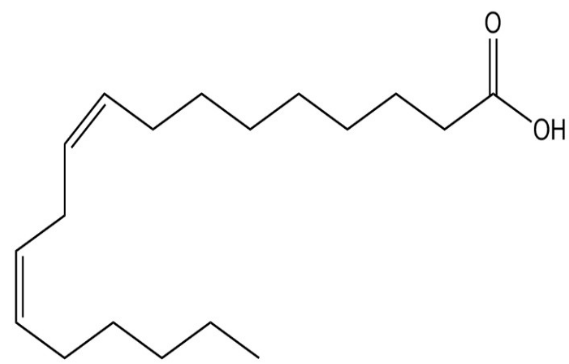
Secoisolariciresinol



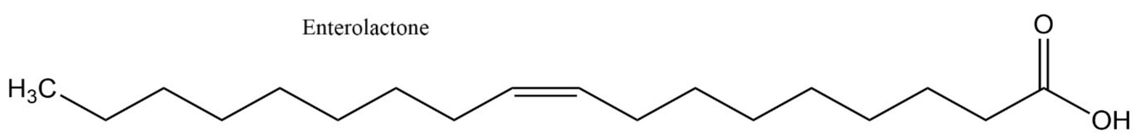
Linoleic acid



Enterolactone



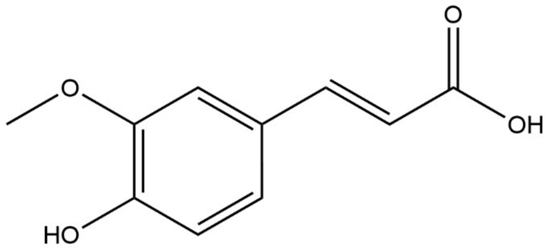
Lenoleic acid



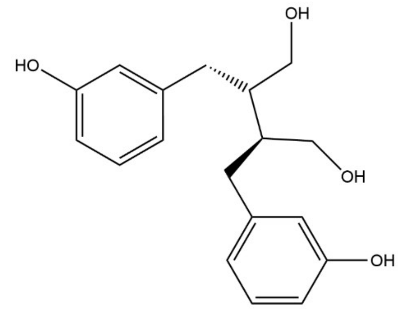
Oleic acid

DOI: 10.48175/IJARSCT-37833

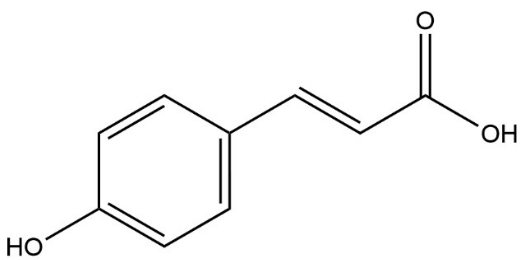
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2



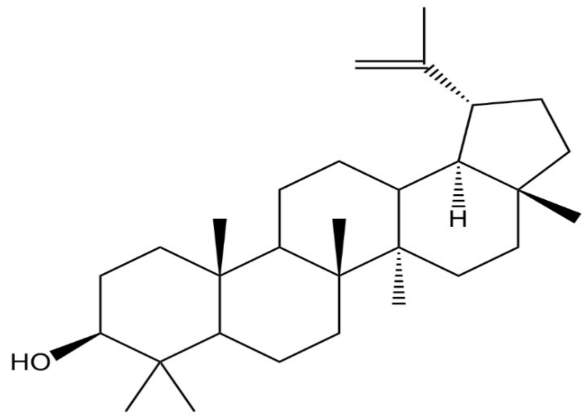
Ferulic acid



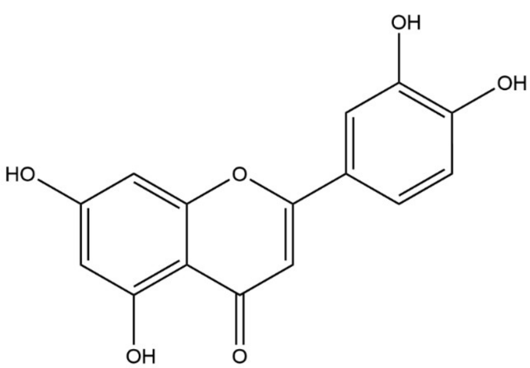
Enterodiol



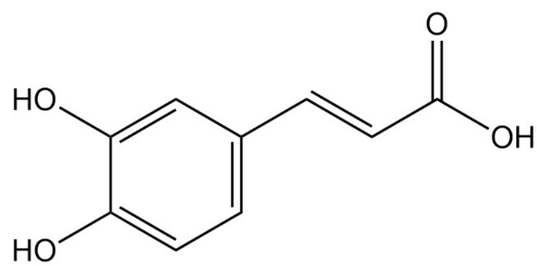
P-Coumaric acid



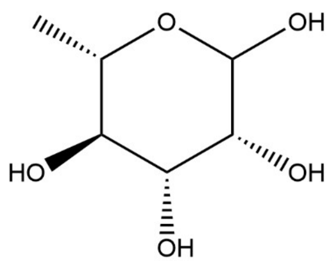
lupeol



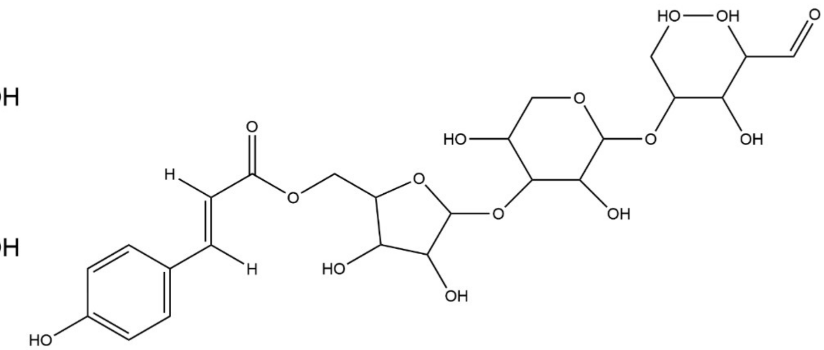
Luteolin



Caffeic acid



L-Rhamnose



Arabinoxylan

Fig. 3 Key phytochemical classes of *Linum usitatissimum* L. and its gum mucilage, together with their chemical structures.

IX. AN OVERVIEW OF THE BIOLOGICAL ACTIVITY OF *LINUM USITATISSIMUM* L.

9.1 Antioxidant activity

Flaxseed (*Linum usitatissimum L.*) is noted for its abundance of bioactive compounds, particularly lignans such as secoisolariciresinol diglucoside (SDG). These compounds play a significant role in antioxidant defence mechanisms by assisting in the removal of harmful free radicals and lowering oxidative damage within the body. This process involves the scavenging of reactive oxygen species (ROS), such as superoxide anions, hydroxyl radicals, and peroxyl radicals, which are known to cause cellular damage. Once consumed, flaxseed lignans are metabolised in the intestine into active forms like enterodiol and enterolactone. These metabolites exhibit enhanced antioxidant effects by inhibiting lipid peroxidation and safeguarding cells against oxidative damage. In addition to lignans, flaxseed oil contributes significantly to antioxidant defence as it is rich in omega-3 fatty acids. These fatty acids aid in reducing the generation of reactive oxygen species and are associated with beneficial effects against cardiovascular, inflammatory, and neurological disorders. The combined interaction of lignans together with omega-3 fatty acids and other phytochemicals results in a synergistic effect, making flaxseed an effective functional food for combating oxidative stress. This multi-component activity supports its contribution in lowering the risk of long-term disorders such as cancer, cardiovascular diseases, and neurodegenerative conditions. Flaxseed ethanol extract also demonstrates strong antioxidant potential, largely due to its rich composition of phenolic constituents such as lignans, phenolic acids, and flavonoids[21,22]. Laboratory studies have shown that the extract exhibits significant free radical scavenging ability, which increases with concentration. It also demonstrates strong reducing power, indicating its ability to donate electrons and inhibit oxidative reactions. The antioxidant effects of the extract are mediated through several mechanisms, including direct neutralisation of reactive free radicals, binding with pro-oxidant metal ions, and prevention of lipid peroxidation. These actions help protect vital cellular components like lipids, proteins, and DNA against oxidative injury. Since oxidative stress has a significant involvement in the onset of chronic inflammatory diseases and cancer, the antioxidant properties of flaxseed are considered highly beneficial. Overall, its ability to strengthen the body's intrinsic defence mechanisms and reduce oxidative damage highlights its therapeutic importance.[23]

9.2 Antitumor Activity

The antitumor potential of flaxseed ethanol extract was evaluated using human cancer cell line models, where the extract exhibited a pronounced antiproliferative effect. The study reported a significant reduction in cancer cell viability following treatment with the extract, indicating its cytotoxic and growth-inhibitory properties. Importantly, the extract

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 3, July 2026 Impact Factor: 8.2

demonstrated selective activity, exerting stronger effects on malignant cells while showing comparatively lower toxicity toward normal cells. Mechanistic investigations suggest that the antitumor activity of the flaxseed ethanol extract is mediated by triggering programmed cell death (apoptosis) and interfering with the normal progression of the cell cycle. The extract influences intracellular oxidative balance, leading to mitochondrial dysfunction and activation of apoptotic signaling pathways. Additionally, lignans and phenolic compounds present in flaxseed are known to modulate hormone-dependent pathways, which play a role in the noted anticancer activity. These observations emphasise the promising potential of flaxseed ethanol extract as a natural chemo preventive compound and support its possible role as an adjuvant in cancer therapy, especially in malignancies associated with oxidative stress and chronic inflammation. [24]

9.3 Anti-Inflammatory Activity

Flaxseed ethanol extract has shown notable anti-inflammatory effects by acting on multiple pathways involved in inflammation. It functions by decreasing the release of pro-inflammatory cytokines and restricting the activity of enzymes that promote and sustain inflammatory responses. One of the major mechanisms behind this effect is the suppression of the NF-κB signalling pathway, which acts as a central controller of genes involved in inflammatory responses. By inhibiting this pathway, the extract helps control the expression of various inflammatory mediators. In addition, flaxseed extract decreases the activity of important enzymes such as cyclooxygenase (COX) and inducible nitric oxide synthase (iNOS). This results in lowered formation of inflammatory mediators and reactive nitrogen species that contribute to tissue damage. The antioxidant characteristics of the extract further enhance its anti-inflammatory action. Limiting the production of reactive oxygen species (ROS), it helps prevent the activation of inflammation triggered by oxidative stress. Overall, flaxseed ethanol extract provides a combined effect by targeting both oxidative stress and inflammatory pathways. This makes it particularly useful in conditions where long-term inflammation and oxidative damage occur together.[24]

9.4 Wound Healing

Linum usitatissimum L. (flaxseed) has been reported to show significant wound-healing potential in experimentally induced wound models in rats, as reported in the study conducted by Farahpour et al. In this study, topical application of flaxseed formulations notably improved the rate of wound contraction and reduced the epithelialization period compared to untreated control groups. This indicates a faster closure of the wound and more rapid restoration of the skin surface. Histopathological analysis of the treated wound tissues further supported these findings. The flaxseed-treated groups showed well-formed granulation tissue with increased fibroblast activity, dense and well-organised collagen deposition, and enhanced re-epithelialization, all of which reflect better structural repair of the damaged skin. In addition, a higher level of angiogenesis was observed, evident from the development of new blood vessels within the wound area, which is essential in delivering oxygen and nutrients required for tissue regeneration. Another important observation was a reduction in inflammatory cell infiltration during the early phase of healing, suggesting that flaxseed helps regulate and shorten the inflammatory stage. This controlled inflammatory response may prevent delayed healing that is often associated with excessive or prolonged inflammation. These effects are believed to be due to the rich phytochemical profile of flaxseed, which includes lignans, flavonoids, phenolic compounds, and omega-3 fatty acids. Together, these constituents contribute to antioxidant and anti-inflammatory effects help in lowering oxidative stress at the wound site, and support collagen synthesis and tissue remodelling. Overall, the study highlights that Linum usitatissimum L. positively influences all major phases of wound healing—namely inflammation, proliferation, angiogenesis, and remodelling—thereby supporting its promise as a naturally derived therapeutic option for enhancing skin wound repair.[25]

9.5 Antibacterial Activity

The antibacterial potential of *Linum usitatissimum* L. (flaxseed) has been scientifically supported in the study conducted by Hussien and Aziz, where flaxseed extracts were evaluated for activity against disease-causing bacterial strains. The

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

observed antibacterial activity is mainly attributed to its diverse phytochemical composition, including phenolic compounds, flavonoids, lignans, fatty acids, and other bioactive secondary metabolites. Laboratory-based investigations demonstrated that flaxseed extracts formed distinct zones of inhibition when applied to both Gram-positive and Gram-negative bacteria, reflecting their capacity to hinder bacterial proliferation. However, Gram-positive bacteria were generally more susceptible to the extracts. This is likely due to variations in the bacterial cell wall architecture, as Gram-negative organisms possess an extra outer membrane that restricts the penetration of active compounds. Even so, the extracts still showed meaningful activity against certain Gram-negative strains, highlighting their broad antibacterial potential. The antibacterial action of *Linum usitatissimum* is closely related to its phytochemicals. Phenolic compounds and flavonoids can disrupt bacterial cell membranes, increase permeability, and interfere with essential enzymes, ultimately leading to bacterial cell damage and death. Unsaturated fatty acids may also contribute by integrating into bacterial membranes and disturbing their structural integrity. In addition, lignans and other polyphenols can inhibit bacterial adhesion and metabolic processes, further reducing microbial survival. Overall, the findings of Hussien and Aziz support the idea that flaxseed has genuine antibacterial potential. Along with its antioxidant and generally safe profile, *Linum usitatissimum* appears to be a promising natural candidate for developing plant-based antimicrobial agents. These results also help validate its traditional use in treating infections and suggest possible applications in pharmaceutical and nutraceutical products aimed at combating bacterial infections.[26]

9.6 Antimicrobial Activity

Linum usitatissimum L. (flaxseed) has been widely reviewed as a promising natural antimicrobial agent owing to its diverse phytochemical makeup and its capability to inhibit various pathogenic microorganisms. According to Fadzira et al., flaxseed shows significant antimicrobial effects across numerous bacterial and fungal species, supporting its traditional use in managing infections and inflammatory conditions. This antimicrobial effect is mainly linked to its active phytoconstituents such as lignans, phenolic acids, flavonoids, fatty acids, and polysaccharides. Flaxseed extracts and oils have been reported to exhibit activity against both Gram-positive and Gram-negative bacteria, with Gram-positive strains generally showing greater susceptibility. This difference is mainly attributed to the presence of an additional protective outer layer in Gram-negative bacteria, which makes it harder for antimicrobial compounds to enter. Even so, flaxseed preparations have still shown effectiveness against several clinically important Gram-negative pathogens, indicating a broad spectrum of activity. In addition to antibacterial effects, flaxseed also demonstrates antifungal properties against different fungal species. Phenolic compounds and unsaturated fatty acids help disrupt fungal cell membranes and interfere with essential cellular processes, thereby limiting fungal growth. This makes flaxseed particularly useful in managing skin and mucosal infections. At the mechanistic level, the antimicrobial action of Linum usitatissimum is multi-targeted. Phenolics and flavonoids disrupt microbial cell membranes, leading to increased permeability and leakage of intracellular components. Lignans may interfere with microbial enzymes and inhibit nucleic acid synthesis, while omega-3 fatty acids can alter membrane structure and fluidity by integrating into lipid bilayers. Together, these actions lead to strong inhibition of microbial growth and, in some cases, cell death. Fadzira et al. also highlight that the antimicrobial activity of flaxseed is further strengthened by its antioxidant as well as anti-inflammatory effects. By reducing oxidative damage and inflammatory responses, flaxseed helps create an environment that is less favourable for microbial survival while also supporting tissue repair. This combined action strengthens its overall therapeutic potential. Overall, the available evidence suggests that Linum usitatissimum L. has significant antimicrobial properties and may serve as a plant-based alternative or complementary option to conventional antimicrobial therapies. Its broad-spectrum activity and favourable safety characteristics make it a strong candidate for developing plant-based antimicrobial formulations.[27]

9.7 Antidiabetic Activity

The antidiabetic potential of Linum usitatissimum L. (flaxseed) has been demonstrated in in-vitro studies that explore its role in regulating key biochemical pathways involved in glucose metabolism. In the study by Alawlaqi et al., linseed extracts were evaluated for their effects on carbohydrate-digesting enzymes as well as their antioxidant activity—both of which are important in diabetes management. The findings indicated that flaxseed extract markedly suppressed the activity of α-amylase and α-glucosidase, the enzymes involved in converting complex carbohydrates into simple sugars. By slowing down these enzymes, flaxseed helps delay carbohydrate digestion, which in turn reduces the rise in blood glucose after meals and supports better glycemic control. This inhibitory effect was also found to be concentration-dependent, meaning higher doses of the extract produced stronger antidiabetic activity. This effect is mainly linked to the rich phytochemical content of flaxseed, which includes phenolic compounds, flavonoids, lignans, and dietary fiber. Phenolics and flavonoids can interact with digestive enzymes and reduce their activity, while lignans such as secoisolariciresinol diglucoside (SDG) may support glucose regulation through antioxidant effects and improved insulin sensitivity. In addition, the high fibre content in flaxseed can slow down glucose absorption in the intestine, helping to stabilise blood sugar levels. Another important aspect highlighted in the study is oxidative imbalance, which is strongly involved in the onset and advancement of diabetes and its associated complications. Flaxseed extract showed strong antioxidant activity, which helps reduce reactive oxygen species and protects pancreatic β-cells against oxidative injury. This protective action may aid in insulin release and enhance the body's sensitivity to insulin. Overall, the findings of Alawlaqi et al. suggest that Linum usitatissimum L. has promising antidiabetic potential through a combination of enzyme inhibition and antioxidant activity. These complementary mechanisms indicate that flaxseed may serve as a beneficial natural approach for aiding in the control and prevention of diabetes, especially when combined with proper diet and lifestyle measures.[28]

9.8 Anticancer Activity

The anticancer activity of Linum usitatissimum L., as reported by Merkher et al., extends beyond its well-known lignans and includes bioactive proteins and peptides identified within the flaxseed proteome. The study demonstrated that specific flaxseed protein fractions exert growth-inhibitory actions on cancer cell cultures, reducing tumour cell survival in a dose-dependent fashion while showing comparatively lower toxicity toward normal cells. Mechanistically, these protein components were found to induce apoptosis through modulation of mitochondrial pathways and disruption of cell cycle progression. Additionally, flaxseed-derived peptides influenced intracellular oxidative balance, promoting pro-apoptotic signalling and inhibiting survival pathways in malignant cells. These findings highlight that flaxseed proteins contribute substantially to its overall anticancer potential and support the role of Linum usitatissimum as a promising naturally derived reservoir of bioactive molecules for cancer prevention and adjunct therapy. The anticancer activity of Linum usitatissimum L., as described in the review, is attributed to its lignans, fiber, and polyunsaturated fatty acids, which inhibit tumour cell proliferation, modulate estrogen metabolism in hormone-dependent cancers, induce apoptosis, suppress angiogenesis, reduce inflammation, and disrupt key molecular signalling pathways involved in carcinogenesis, thereby reinforcing its importance in cancer prevention and supportive therapy.[23]

9.9 Anti-Ageing Activity

The anti-ageing activity of Linum usitatissimum L. was demonstrated in aged rat skin using a flaxseed oil–based nanoemulsion gel formulation. The study showed that topical application markedly lowered oxidative stress by reducing lipid peroxidation and boosting endogenous antioxidant enzyme activity. In addition, flaxseed oil suppressed pro-inflammatory mediators, thereby attenuating chronic inflammation associated with skin ageing. Histological analysis revealed improved dermal architecture, enhanced collagen fibre organisation, and restoration of skin thickness in treated animals. These effects are primarily attributed to the abundance of omega-3 fatty acids along with other bioactive constituents present in flaxseed oil, which collectively promote antioxidant defence, reduce inflammation, and support collagen synthesis, confirming its promise as a naturally derived anti-ageing option in dermatological applications. According to the review by Varma and Kandasubramanian, Linum usitatissimum L. exhibits notable anti-ageing activity primarily due to its high levels of lignans, omega-3 fatty acids, and antioxidant polyphenols. These bioactive compounds assist in lowering oxidative stress, limiting inflammatory responses, and protect dermal cells from premature ageing. Flaxseed also supports collagen preservation and improves skin hydration through its essential fatty acids, thereby improving skin elasticity and minimising the appearance of wrinkles. Collectively, these mechanisms highlight the significant promise of flaxseed as a naturally derived anti-ageing agent in nutraceutical and dermatological applications. [31]

9.10 Anti-Hyaluronidase Activity of Flaxseed

Hyaluronidase is an enzyme responsible for degrading hyaluronic acid, a key constituent of the extracellular matrix responsible for maintaining skin hydration, elasticity, and overall structural support. When hyaluronidase activity becomes excessive, it can contribute to inflammation, tissue breakdown, and faster skin ageing. According to Jayarama Naik and Madhusudhan, flaxseed lignans concentrate exhibited significant in vitro anti-hyaluronidase activity. The inhibitory effect was concentration-dependent, indicating that higher concentrations of lignan extract produced stronger enzyme inhibition. The study suggests that the phenolic structure of flaxseed lignans contributes to this activity by interacting with the enzyme and possibly interfering with its catalytic mechanism. The inhibition of hyaluronidase implies that flaxseed lignans may help preserve hyaluronic acid levels in tissues. This preservation is important for:

- Maintaining skin hydration
- Reducing inflammation
- Preventing extracellular matrix breakdown
- Supporting anti-ageing effects

The authors associated this enzyme inhibition with the antioxidant capacity of lignans, as oxidative stress is known to enhance enzymatic degradation processes. Therefore, flaxseed lignans may contribute to dermal protection through dual mechanisms: antioxidant action and direct enzyme inhibition.[32]

9.11 Anti-Elastase Activity of Flaxseed

Elastase is a protein-digesting enzyme that breaks down elastin, the key structural protein responsible for keeping the skin elastic and firm. When elastase activity becomes elevated, it can lead to reduced skin firmness, the formation of wrinkles, and damage to connective tissues. It is also linked to tissue damage during inflammatory conditions. The same study demonstrated that flaxseed lignans concentrate showed measurable anti-elastase activity in vitro. Similar to hyaluronidase inhibition, elastase inhibition was dose-dependent. The results indicated that lignan compounds from flaxseed can interfere with elastase activity, thereby reducing elastin degradation. The anti-elastase potential of flaxseed lignans may be attributed to:

- Their polyphenol-rich composition
- Ability to bind to enzyme active sites
- Free radical scavenging activity that reduces oxidative activation of proteases

  By inhibiting elastase, flaxseed lignans may:

- Protect the dermal elastic fibre
- Prevent premature skin ageing
- Reduce inflammatory tissue damage
- Improve skin structural stability[32]

9.12 Anti-Osteoporosis Effect of Flaxseed

Flaxseed oil shows protective effects on bone health and may help prevent osteoporosis, mainly owing to its abundant content of α-linolenic acid (ALA) along with other omega-3 fatty acids. Mechanisms reported: Reduction of bone resorption: Omega-3 fatty acids decrease osteoclast activity, thereby limiting bone breakdown. Improvement in bone mineral density (BMD): Supplementation with flaxseed oil has been associated with increased calcium retention and improved bone strength. Modulation of inflammatory mediators: Since chronic inflammation accelerates bone loss, the anti-inflammatory action of ALA indirectly supports bone health. Hormone-related support: Omega-3 fatty acids may help minimise post-menopausal bone loss by influencing prostaglandin metabolism.[33]

X. CONCLUSION

Flaxseed (*Linum usitatissimum* L.) has emerged as a scientifically important medicinal plant with considerable potential in dermatological research owing to its rich repertoire of bioactive constituents and multifunctional therapeutic properties. Among its various components, flaxseed mucilage has attracted particular interest because of its unique physicochemical characteristics, including excellent water-retention capacity, film-forming ability, and biocompatibility, which make it an attractive natural candidate for topical drug delivery and skin-care formulations. Current evidence indicates that the biological activities of flaxseed are mediated through the combined actions of omega-3 fatty acids, lignans, phenolic compounds, flavonoids, and polysaccharides. These constituents collectively contribute to antioxidant, anti-inflammatory, antimicrobial, wound-healing, and barrier-restorative effects, all of which are highly relevant to the pathophysiology of atopic dermatitis. By attenuating oxidative stress, regulating inflammatory signalling, preserving extracellular matrix integrity, enhancing skin hydration, and promoting tissue regeneration, flaxseed mucilage addresses several key mechanisms involved in chronic inflammatory skin disorders. Beyond its therapeutic efficacy, flaxseed mucilage offers additional advantages as a naturally derived, biodegradable, sustainable, and cost-effective biomaterial. Its favourable safety profile and versatile functional properties further support its incorporation into innovative pharmaceutical, cosmeceutical, and biomedical formulations. These characteristics position flaxseed mucilage as a promising alternative to synthetic excipients and an attractive ingredient for the development of next-generation dermatological products.Despite the encouraging findings reported in experimental and preclinical investigations, robust clinical evidence remains limited. Future research should therefore focus on well-designed clinical trials, standardisation of extraction techniques, optimisation of formulation strategies, pharmacokinetic evaluation, and comprehensive long-term safety assessments to facilitate successful clinical translation.

In summary, the collective body of evidence highlights flaxseed mucilage as a multifunctional natural biomaterial with substantial therapeutic promise for the management of atopic dermatitis and related inflammatory skin disorders. Continued interdisciplinary research is expected to strengthen its scientific validation and expand its application in modern dermatology, ultimately contributing to the development of safer, more effective, and environmentally sustainable skin-care therapies.

REFERENCES

1) Akter Y, Junaid M, Afrose SS, Nahrin A, Alam MS, Sharmin T, Akter R, Hosen SZ. A comprehensive review on *Linum usitatissimum* medicinal plant: its phytochemistry, pharmacology, and ethnomedicinal uses. Mini Reviews in Medicinal Chemistry. 2021 Nov 1;21(18):2801-34.

2) Kajla P, Sharma A, Sood DR. Flaxseed—a potential functional food source. Journal of food science and technology. 2015 Apr;52(4):1857-71.

3) Mueed A, Shibli S, Jahangir M, Jabbar S, Deng Z. A comprehensive review of flaxseed (*Linum usitatissimum* L.): health-affecting compounds, mechanism of toxicity, detoxification, anticancer and potential risk. Critical Reviews in Food Science and Nutrition. 2023 Dec 21;63(32):11081-104.

4) Noreen S, Tufail T, Ul Ain HB, Awuchi CG. Pharmacological, nutraceutical, and nutritional properties of flaxseed (*Linum usitatissimum*): An insight into its functionality and disease mitigation. Food Science & Nutrition. 2023 Nov;11(11):6820-9.

5) Koçak MZ. Phenolic compounds, fatty acid composition, and antioxidant activities of some flaxseed (*Linum usitatissimum* L.) varieties: A comprehensive analysis. Processes. 2024 Mar 29;12(4):689.

6) Puligundla P, Lim S. A review of extraction techniques and food applications of flaxseed mucilage. Foods. 2022 Jun 7;11(12):1677.

7). Laws of flaxseed mucilage extraction, Ziolkovska A, Food hydrocolloids, 2012 Jan 1;26(1):197 204.

8) Flaxseed in Diet: A Comprehensive Look at Pros and Cons, Duarte S et.al., Molecules, 2025 Mar

9). Development of skincare formulations using flaxseed oil and mucilage, There U et.al., Journal of Pharmacognosy and Phytochemistry, 2023;12(2):33-9.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

10) Shim YY, Gui B, Arnison PG, Wang Y, Reaney MJ. Flaxseed (*Linum usitatissimum* L.) bioactive compounds and peptide nomenclature: A review. Trends in food science & technology. 2014 Jul 1;38(1):5-20.

11). Kučka M, Harenčár Ľ, Ražná K, Nôžková J, Kowalczewski PŁ, Deyholos M, Dziedzic K, Rybicka I, Zembrzuska J, Kačániová M, Ivanišová E. Great potential of flaxseed mucilage. European Food Research and Technology. 2024 Mar;250(3):877-93.

12) Mazza G, Biliaderis CG. Functional properties of flax seed mucilage. Journal of food science. 1989 Sep;54(5):1302-5

13). Patial RA, Paul SA, Sharma DE, Sood VK, Kumar NI. Morphological characterization and genetic diversity of linseed (*Linum usitatissimum* L.). Journal of Oilseeds Research. 2019;36(1):8-16.

14). Badole SL, Zanwar AA, Bodhankar SL. Antihyperglycemic potential of secoisolaricinol diglucoside. Bioactive food as dietary interventions for diabetes: bioactive foods in chronic disease states. 2012 Oct 23;53.

15) Radadiya KV, Panara K, Acharya R. A comprehensive ethnopharmacological review on Linum usitatissimum Linn. (Atasi). Int. J. Botany Stu. 2023;8(2):47-54.

16) Ara R, Bhat WQ, Rather SA. Phytochemical, Ethnomedicinal, and Pharmacological Aspects of Alsi (*Linum usitatissimum* L.)–A Critical Study. Hippocratic Journal of Unani Medicine. 2025 Jul 1;20(3):95-103.

17) Schuchert W. Flax (*Linum usitatissimum* L.). Linaceae family. Adapted to HTML by Saedler R. LON-CAPA Plant Biology Resource [Internet]. [cited 2026 Feb 20]. Available from: https://share.google/v9Zq6AIG6zcQwRwl1

18). Jhala AJ, Hall LM. Flax (*Linum usitatissimum* L.): current uses and future applications. Aust. J. Basic Appl. Sci. 2010 Dec 8;4(9):4304-12.

19). Rubilar M, Gutiérrez C, Verdugo M, Shene C, Sineiro J. Flaxseed as a source of functional ingredients. Journal of soil science and plant nutrition. 2010 Jul;10(3):373-7.

20). SALEM MO, LAKWANI MA. Determination of Chemical Composition and Biological Activity of Flaxseed (*Linum usitatissimum*) Essential Oil. GENERAL COORDINATOR'S PREFACE. 2024:511.

21). Ravi, S. K., Kumari, R., & Thakur, M. (2021). Antioxidant properties of *Linum usitatissimum*: A review. Antioxidants, 10(12), 2001. https://doi.org/10.3390/antiox10122001

22). Touré A, Xueming X. Flaxseed lignans: source, biosynthesis, metabolism, antioxidant activity, bio-active components, and health benefits. Comprehensive reviews in food science and food safety. 2010 May;9(3):261-9.

23). Stepień AE, Trojniak J, Tabarkiewicz J. Anti-Oxidant and Anti-Cancer Properties of Flaxseed. International Journal of Molecular Sciences. 2025 Jan 30;26(3):1226.

24). Chera EI, Pop RM, Pârvu M, Sorițău O, Uifălean A, Cătoi FA, Cecan A, Negoescu AG, Achimaș-Cadariu P, Pârvu AE. Flaxseed ethanol extracts' antitumor, antioxidant, and anti-inflammatory potential. Antioxidants. 2022 Apr 30;11(5):892.

25). Wound healing activity of flaxseed *Linum usitatissimum* L. in rats Mohammad Reza Farahpour1 *, Human Taghikhani2, Mostafa Habibi3 and Mohammad Amin Zandieh

26). Hussien ZG, Aziz RA. Chemical composition and antibacterial activity of *Linum usitatissimum* L. (Flaxseed). Syst. Rev. Pharm. 2021;12(2):145-7.

27). Fadzir UA, Darnis DS, Mustafa BE, Mokhtar KI. *Linum usitatissimum* as an antimicrobial agent and a potential natural healer: A review. Archives of Orofacial Science. 2018 Dec 1;13(2).

28) Alawlaqi MM, Al-Rajhi AM, Abdelghany TM, Ganash M, Moawad H. Evaluation of biomedical applications for linseed extract: antimicrobial, antioxidant, anti-diabetic, and anti-inflammatory activities in vitro. Journal of Functional Biomaterials. 2023 May 28;14(6):300.

29) Merkher Y, Kontareva E, Alexandrova A, Javaraiah R, Pustovalova M, Leonov S. Anti-cancer properties of flaxseed proteome. Proteomes. 2023 Nov 16;11(4):37.

30) Ismail S, Ahmed-Farid OA, Metwally GF, Mansour D, Khattab A. Anti-aging effect of mustard and flax seed oils based nanoemulsion gel on aged rat skin through antioxidant and anti-inflammatory activity. Scientific African. 2024 Dec 1;26: e02369.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

31) Varma P, Kandasubramanian B. Exploring the antiaging properties of curcumin, flaxseed, and collagen: a comprehensive review. Chemistry Select. 2024 Dec;9(48): e202403395.
32) Jayarama Naik N, Madhusudhan B. In Vitro Free Radical Scavenging, Anti-Hyaluronidase and Anti-Elastase Potential of Flaxseed Lignans Concentrate. Int. J. Pure App. Biosci. 2018;6(6):172-9.
33) Al-Madhagy S, Ashmawy NS, Mamdouh A, Eldahshan OA, Farag MA. A comprehensive review of the health benefits of flaxseed oil in relation to its chemical composition and comparison with other omega-3-rich oils. European journal of medical research. 2023 Jul 18;28(1):240.