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# Linseed: A Versatile Crop Integrating Nutrition, Oil Production and Natural Fibre for Sustainable Agriculture

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## Abstract

Linseed (*Linum usitatissimum* L.) or flaxseed, is an ancient cultivated crop known for its versatile applications in food, oil and industrial products. Its seeds are rich in oil (35–46%), proteins, dietary fibre and bioactive compounds like lignans and flavonoids, which enhance its functional properties. Linseed oil is valued for its high alpha-linolenic acid (ALA) content, linked to lower risks of cardiovascular diseases, cancer and inflammation. Additionally, linseed's by-products, such as seedcake, fibres and shives have significant industrial uses and contribute to food preservation and pharmaceuticals. Cultivating linseed supports sustainable agriculture due to its adaptability and low input needs, making it a promising crop for enhancing agricultural diversification and rural economic growth amid rising demand for eco-friendly products.

## Introduction

Linseed (*Linum usitatissimum* L.) or flaxseed, is an ancient crop noted for its diverse applications in food, oil and fibre production. The oil derived from flaxseeds is praised for its high omega-3 fatty acids, particularly alpha-linolenic acid, which is essential for human health and chronic disease prevention. Biochemical studies have revealed numerous bioactive compounds within linseed oil that have nutritional, cosmetic and pharmaceutical benefits. Besides oil, linseed yields valuable by-products such as seedcakes, fibres and shives, which hold increasing industrial importance. Recent advances in analytical techniques have identified beneficial compounds in these by-products, including phenylpropanoids, terpenoids and lignocellulosic biomass, known for their antibacterial, antifungal, anticancer and anti-inflammatory properties. This diversification broadens linseed's industrial applications, extending to functional foods, nutraceuticals, polymer composites, biofuels and pharmaceuticals. Furthermore, linseed cultivation promotes sustainable farming practices due to its adaptability to various agro-climatic conditions and minimal input requirements, making it fit for small and marginal farmers. India is a major linseed producer,

primarily in rainfed areas across numerous states. With increasing global interest in healthy diets, plant-based nutrition, and sustainable materials, linseed is re-emerging as a highly valuable crop with significant agricultural and industrial potential.

**Origin and Distribution**

Linseed is believed to have originated in the Middle East and later spread to Europe and other regions of the world through domestication and cultivation. Over time, selective breeding resulted in the development of two main forms of the crop: oilseed flax (linseed) and fibre flax. These two forms differ significantly in their morphological characteristics and production objectives. Oilseed flax plants are usually shorter and more branched, while fibre flax plants are taller and less branched to facilitate the production of long and strong fibres (Green & Marshall, 1984; Singh *et al*., 2011).

Today, linseed is cultivated in many parts of the world including Canada, Russia, China, India and several European countries. Canada is currently one of the leading producers and exporters of linseed, followed by Russia and Kazakhstan (FAO, 2018). In India, the crop is mainly grown in states such as Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Bihar, Rajasthan and Maharashtra, mostly under rainfed conditions (ICAR, 2020).

**Nutritional and Biochemical Composition of Linseed**

Linseed seeds are highly nutritious and contain a balanced composition of oil, proteins, carbohydrates, dietary fibre and minerals. The seeds generally contain 35–46% oil, 20–25% protein, and about 25–30% carbohydrates, making them an excellent source of energy and nutrients (Kajla *et al*., 2015; Goyal *et al*., 2014).

One of the most important components of linseed oil is alpha-linolenic acid (ALA), an essential omega-3 fatty acid that plays a vital role in human health. In addition, linseed seeds contain several biologically active compounds, including lignans, phenolic acids, flavonoids and dietary fibre, which contribute to their functional and medicinal properties (Oomah, 2001; Goyal *et al*., 2014).

Among these compounds, Secoisolariciresinol Diglucoside (SDG) is the most abundant lignan present in flaxseed. This compound exhibits strong antioxidant activity and has been associated with reduced risk of cardiovascular diseases, hormonal disorders and certain types of cancer (Adlercreutz, 2007; Kajla *et al*., 2015).

**Linseed Oil and Its Applications**

Linseed oil is one of the most valuable products derived from flax seeds and has extensive applications in both food and industrial sectors. Due to its high content of polyunsaturated fatty acids, especially omega-3 fatty acids, linseed oil is widely recommended as a health-promoting dietary supplement (Goyal *et al*., 2014).

In the pharmaceutical and cosmetic industries, linseed oil is used in skin-care products, therapeutic formulations and nutraceutical supplements due to its anti-inflammatory and antioxidant properties (Kajla *et al*., 2015).

**Seedcake (Linseed Expeller) and Its Industrial Importance**

The residue remaining after oil extraction from flax seeds is known as linseed seedcake or expeller. This by-product is rich in proteins, lignans and phenolic compounds and therefore has considerable economic value. Linseed seedcake extracts contain compounds such as ferulic acid, caffeic acid and coumaric acid, which possess strong antioxidant and antimicrobial properties (Zuk *et al*., 2015).

Furthermore, linseed seedcake has been used to prevent lipid oxidation in meat products, thereby improving the shelf life and nutritional quality of processed foods (Kajla *et al*., 2015).

**Fibre Production and Industrial Uses**

Flax fibre obtained from the stem of the plant is one of the strongest natural fibres available. Traditionally, flax fibres were used to produce linen textiles, ropes and fabrics. However, in recent years, new industrial applications of flax fibre have emerged. These fibres offer an environmentally friendly alternative to synthetic fibres such as glass and carbon fibres.

Additionally, flax-based fabrics have shown promising results in biomedical applications such as wound dressings and tissue engineering, as they exhibit good compatibility with human cells and low cytotoxicity (Zuk *et al*., 2015).

**Shives and Their Bioactive Properties**

Shives are the woody inner portions of the flax stem that remain after fibre extraction. These materials were once considered agricultural waste but are now recognized as valuable sources of lignocellulosic biomass and bioactive compounds.

Linseed shives consist mainly of cellulose, hemicellulose, lignin and phenolic compounds. They also contain substances such as vanillin and ferulic acid, which have antioxidant and antimicrobial properties (Zuk *et al*., 2015).

Because of these beneficial properties, shives are being investigated for use in biofuel production, biodegradable materials, mushroom cultivation and pharmaceutical products. Their utilization contributes to the development of a circular bioeconomy and sustainable resource management.

**Multipurpose Applications of Linseed**

The linseed plant demonstrates exceptional versatility because nearly every component of the plant can be utilized for various purposes. Seeds are used for food and oil production, fibres are used in textiles and industrial composites, seedcakes are utilized in animal feed and pharmaceutical products and shives are used as raw materials for bioenergy and construction materials.

This comprehensive utilization makes linseed an important crop for sustainable agriculture and value-added product development. The development of innovative products from linseed biomass has the potential to increase farmers' income while reducing agricultural waste (Kajla *et al*., 2015; Zuk *et al*., 2015).

**Future Prospects of Linseed Cultivation**

Recent advances in plant biotechnology and genomics have opened new possibilities for improving linseed productivity and quality. The sequencing of the flax genome has facilitated research on crop improvement, enabling scientists to develop varieties with improved oil composition, disease resistance, and fibre quality (Wang et al., 2012).

Moreover, growing global demand for functional foods, plant-based omega-3 fatty acids and natural fibres is expected to enhance the commercial importance of linseed in the future. With appropriate research support, improved varieties and better agronomic practices, linseed cultivation can significantly contribute to sustainable agricultural systems and rural economic development.

**Conclusion**

Linseed (*Linum usitatissimum* L.) is a highly versatile crop that offers a unique combination of food, oil, fibre and industrial raw materials. Its seeds provide nutritionally rich oil containing essential omega-3 fatty acids, proteins and antioxidants that contribute significantly to human health. In addition to its dietary importance, linseed oil has extensive industrial applications in paints, coatings, cosmetics and pharmaceutical products.

The by-products of linseed processing, including seedcake and shives, are also valuable resources containing bioactive compounds with antimicrobial, antioxidant, and medicinal properties. Furthermore, flax fibres represent an environmentally friendly alternative to synthetic materials and are increasingly used in textiles, construction materials, and automobile components. The complete utilization of the linseed plant demonstrates its potential to support sustainable agriculture, reduce waste, and generate value-added products for multiple industries. With increasing global demand for functional foods and eco-friendly materials, linseed cultivation is expected to regain its importance in modern agriculture (Kajla *et al.,* 2015; Zuk *et al.,* 2015).

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