

Flaxseed as an Inimitable Functional Food: A Comprehensive Review

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DOI: [10.36348/sb.2024.v10i04.002](https://doi.org/10.36348/sb.2024.v10i04.002)

| Received: 26.02.2024 | Accepted: 01.04.2024 | Published: 04.04.2024

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Abstract

Flaxseed, derived from the humble flax plant (*Linum usitatissimum* L.), has gained substantial recognition as a nutritional powerhouse in recent years. This abstract delves into the multifaceted attributes that make flaxseed an inimitable functional food for the human diet. With its rich history dating back to ancient civilizations, flaxseed has undergone a remarkable resurgence due to its exceptional health benefits. One of the standout features of flaxseed is its remarkable nutritional profile. It is renowned for being an excellent source of alpha-linolenic acid (ALA), a plant-based omega-3 fatty acid crucial for heart health. Furthermore, flaxseed is abundant in dietary fiber, lignans, and various essential vitamins and minerals, making it a versatile ingredient for promoting overall well-being. The advantages of flaxseed for health are numerous. It is known to reduce the risk of chronic diseases, including cardiovascular diseases, diabetes, and certain cancers. Its high fiber content aids in digestive health and weight management. Moreover, the lignans found in flaxseed exhibit powerful antioxidant properties, helping to combat oxidative stress and inflammation. Flaxseed's versatility extends to its culinary applications. It can be easily incorporated into a myriad of dishes, including smoothies, baked goods, and salads, enhancing both flavor and nutrition. In conclusion, flaxseed stands out as an inimitable functional food for the human diet, offering a potent combination of essential nutrients and health-promoting compounds. Incorporating this humble seed into daily nutrition holds the potential to transform health outcomes and contribute to a healthier, more vibrant future for individuals worldwide.

Keywords: Flaxseed, lignans, fiber, diabetes, and cardiovascular disorders.

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INTRODUCTION

Flaxseed, also referred to as typical linseed which belongs to the family Linaceae. In subcontinent languages, it may also refer to as Alsī, Aksebija & Jawas. A significant oilseed crop, flaxseed is employed in industrial, food, and fiber applications. Nearly every part of flaxseed crop is employed economically, either as-is or following processing. Flaxseed has been found flavor as nutty with texture of crispy (Dzuvor *et al.*, 2018). The both varieties have identical nutritional properties and the same amount of omega-3 fatty acids (FA). Solin, a type of yellow flax with a distinct oil composition and little omega-3 FA, is the exception (Campos *et al.*, 2019). As more health concerns were raised by consumers in the market of functional foods, flaxseed is getting more

attention as functional food. Because of its superior nutritional value, flaxseed has a lot of potential as a functional food. The seeds are high in omega-3 fatty acids such as α -linolenic acid, soluble & insoluble fibers, polyunsaturated fatty acids (PUFA) of short chains, lignans, antioxidants & proteins (Parikh *et al.*, 2019). Whole flaxseed, ground meal, and obtained oil or mucilage are all examples of edible flaxseed products. When making a variety of food items, like baked cereal goods, ready-to-eat (RTE) cereals, meat, fiber leather, muffins, toppings for salad, bread, extenders & spaghetti, these ingredients have been used as nutritional supplements (Raghuwanshi *et al.*, 2019).

The initial definition of functional foods (FFs)

came about in the early 1980 when Japanese ministry of health & welfare established the regulating framework for food that might have health related benefits. The foods may be considered as "functional" when it has favorable effects on a particular biological function that have dietary effects and are responsible for improvement of health and wellness or stop the onset of long-term diseases. As functional foods gain popularity on a global scale, consumers incorporate them into their regular meals. By 2020, estimations project that world marketplace for FFs and beverages would be valued to one hundred and eighty two billion dollars (Konstantinidi & Koutelidakis, 2019). Functional food (FFs) is sometimes termed as "healthy foods" or "natural pure products." Although there is not a single definition to define the functional foods, foods may only be termed as functional when, along with their common nutritional impact, they may demonstrate impressive positive impact on functions in an individual, leading to improved physical wellness and/or a reduced risk of chronic disease occurrence (Brown *et al.*, 2018). However, only in a few instances where strong scientific data supports their characteristics have nutritional & health claims regarding the probable impact of FFs on disease prevention been made. Additionally, research suggests that FFs may only help health when consumed in balanced diet, like Mediterranean diet (Ntrigiou *et al.*, 2019; Elmaliklis *et al.*, 2019).

Food contains small levels of bioactive compounds, and their effects on human health are continually being researched. According to epidemiological research, a high consumption of naturally occurring, functional foods that are high in functional chemicals, such as specific fruits & vegetables, is linked to a lower risk of long-term illnesses like cancer, type II diabetes, metabolic syndrome, cardiovascular disease, and obesity (Karasawa *et al.*, 2018; Konstantinidi and Koutelidakis, 2019).

This comprehensive review study is intended to investigate flaxseed as a unique functional food, covering its historical relevance, nutritional content, health advantages, bioavailability, culinary applications, safety concerns, and market dynamics. It provides a comprehensive resource for understanding the potential of flaxseed in enhancing health and well-being for researchers, healthcare professionals, and consumers. The review discusses its historical application, distinct nutritional profile, numerous health benefits, bioavailability enhancement strategies, practical dietary inclusion, safety guidelines, emerging research areas, and market trends. The research intends to provide significant insights into the diverse role of flaxseed as a functional food through this comprehensive examination.

1.1 NUTRITIONAL COMPOSITION

According to its physicochemical composition, flaxseed is a multi-component food item that contains oil, dietary fiber, protein, lignans, soluble polysaccharides, phenolic compounds, vitamins (A, C, D, & E), and minerals (P, K, Mg, Na, Cu, Fe, Zn, & Mn) (Nguyen *et al.*, 2019). Flaxseed has potential health benefits aside from nutrition, owing to 3 factors: firstly, its large amount of α -linolenic acid; 2nd, the high content of soluble & insoluble dietary fibers; and 3rd, its high content of lignans, which function as antioxidants and phytoestrogens. The chemical composition of flaxseed varies depending on the growing environment, genetics, analytical method, and processing circumstances (Raghuwanshi *et al.*, 2019).

α -linolenic acid is the main functional component of flaxseed. It serves as one of the sources of omega-3 FA in vegetarian diets (Katoch & Bhatia, 2021). The 55% of total lipids found in flaxseed are divided as almost 30% α -linolenic acid (ALA) & 17% linoleic acid (LA), while 19% are oleic acid, followed by 5% are palmitic acid and 3% are stearic acid, and, providing outstanding n-6: n-3 FA ratio of roughly i.e. 0.3:1 (Shahidi *et al.*, 2019). According to studies, linolenic acid is found in the highest concentration in flaxseed, followed by soybeans & mustard oil, while the linoleic acid, which can lead to a number of diseases, is found in large amounts in sunflower and safflower oils. Numerous clinical studies have demonstrated the huge potential of n-3 FA in the treatment or reduction of coronary cardiac disease, asthma, atherosclerosis, and rheumatoid arthritis (Yang *et al.*, 2023).

Plant lignans are believed to be present in large quantities in flaxseed. High amounts of lignans, a type of phytoestrogen, can be found in plants high in fiber, legumes, grains, fruits, alcoholic beverages, and vegetables. The amount of lignans in flaxseed is 75–800 times greater than that in grains, legumes, cereals, fruits, & vegetables. Secoisolaricresinol diglucoside (SDG) is the main lignan in flaxseed (Zhang *et al.*, 2022). Flaxseed lignan is a functional food that contains valuable bioactive compounds found in plant based diets. Protein Flaxseed has a typical protein concentration of 20%-30%, with roughly globulins (80%) & glutelin (20%). The cotyledons contain majority of the protein content (De Silva & Alcorn, 2019). Flaxseed protein has an amino acid sequence comparable to soybean protein and has no gluten, making it nutritious plant proteins food. The protein found in flaxseed contain high levels of arginine, aspartic acid, and glutamic acid, but low levels of lysine. Increased antioxidant levels caused by high cysteine & methionine content reduce the risk of cancer. Protein content is affected by processing conditions such as dehulling and defatting. When compared to casein and soy protein, flaxseed protein is more effective at lowering plasma cholesterol and triglycerides (Bhandari *et al.*, 2020).

Only 1g of carbohydrates (sugars and starches)

are present in 100 g of flaxseed. As a result, flaxseed adds very low amount to total carbohydrate intake. Polysaccharides of flax are made up of 2 major components: neutral arabinoxylan (75%), and acidic Rhamnogalacturonan (25%) (Safdar *et al.*, 2019). The lipid content of flaxseed varies between 37 and 45 g/100 g of the seed, according to different studies. The majority of seed oil, approximately 75% of it, is stored in cotyledons. Triacylglycerol, phospholipids, and free fatty acids make up 98% of the composition of flaxseed oil (Raghuwanshi *et al.*, 2019). Both soluble as well as insoluble dietary fiber are abundant in flaxseeds. It has 35–45% fiber, of which 2/3 are insoluble and 1/3 are

soluble. The fibers that are insoluble are lignin, cellulose, and hemicellulose. The majority of the fiber that is soluble in flaxseed believed to be mucilage from the seed coat. The presence of polysaccharides in the seed coat is responsible for flaxseed's high water binding capacity (Katoch & Bhatia, 2021). Flaxseed fiber is beneficial in decreasing blood glucose levels. Vitamins and minerals Flaxseed is high in minerals, particularly phosphorus, magnesium, and calcium, and has a low salt content. It also has trace levels of both water-soluble and fat-soluble vitamins. Vitamin E is found in the form of -tocopherol. Flaxseed lacks vitamin C (Goyal *et al.*, 2014).

Table-1: Nutritional composition of flaxseed per 100g

Nutrients	Amount per 100 g of edible flaxseed
Moisture (g)	6.5
Protein (N × 6.25) (g)	20.3
Fat (g)	37.1
Minerals (g)	2.4
Crude fiber (g)	4.8
Total dietary fiber (g)	24.5
Carbohydrates (g)	28.9
Energy (kcal)	530
Potassium (mg)	750
Calcium (mg)	170
Phosphorous (mg)	370
Iron (mg)	2.7
Vitamin A (µg)	30
Vitamin E (mg)	0.6
Thiamine (B1) (mg)	0.23
Riboflavin (B2) (mg)	0.07
Niacin (mg)	1.0
Pyridoxine (mg)	0.61
Pantothenic acid	0.57
Biotin (µg)	0.6
Folic acid (µg)	112

1.2 FLAXSEED AND ITS DIETARY USE

The primary bioactive compound of flaxseed may include α -linolenic acid, fiber & lignans. The four most popular flaxseed products for consumption by humans are the whole seed, its oil, powder, and partially defatted flaxseed (Parikh *et al.*, 2018). New on the market is flax "milk" (Pizzey Ingredients, Canada). In place of "milks" like almond milk, flax milk is made with finely ground flaxseed mixed with purified water & other small amount of ingredients. Due to its lack of lactose or cholesterol, flax milk is a fantastic substitute for dairy milk due of its high ALA content. It is safe for those with soy, nut, or gluten allergies and promises additional health advantages than almond milk (Parikh *et al.*, 2019).

However, no matter how delicious a food is for the general populace to eat, most people won't eat it if it doesn't have the right taste, texture, look, color, and aroma. Concerning flaxseed are a number of characteristics that could negatively affect the flavor

profile of the seed. The two most important are the potential for oxidation to turn flaxseed's extraordinarily high omega-3 FA into rancidity and its bitterness. ALA is present in high concentrations, making it particularly susceptible to oxidation. Oxidation and consequent rancidity will produce off flavors and a musty aroma, which will be disapproved in taste testing. Flaxseed's high concentration of secoisolariciresinol diglucoside (SDG), an antioxidant, is very helpful in preventing oxidation (Mueed *et al.*, 2022). It might be appropriate for usage in a variety of cuisines. In research trials, flaxseed has been added to snack bars, bagels, muffins, bread, tea biscuits, buns, cinnamon rolls, and spaghetti with success (Ursoniu *et al.*, 2016; Bekhit *et al.*, 2018). Flaxseed was added to foods intended for human consumption at levels ranging from 5% to 28% (by weight) of the total ingredients before baking. Daily flaxseed consumption has varied between 40 and 50 g (Zhang *et al.*, 2023).

The stability of the flaxseed may be impacted by each of these several dietary matrices. Flaxseed food processing, storage period, temperature, and flaxseed variety (milled vs. whole vs. oil of flaxseed) will all have an impact on the product's stability. When flaxseed is milled, ground, or crushed, the dense seed coat is destroyed, subjecting the ALA & SDG to oxidation. It's possible that using milled flaxseed in baked foods will stop ALA & SDG from deteriorating. Additionally, longer storage times and cooler storage temperatures, especially for flax oil, will increase the retention of ALA and SDG (Edel *et al.*, 2015).

The presence of flaxseed components that can impair the bioavailability of crucial nutrients has recently drawn a great deal of attention. Linatine, phytic acids, Protease inhibitors, & glycosides that are cyanogenic are among the compounds found in flaxseed. However, no unfavorable impacts of these ingredients have been identified in studies involving humans. It's possible that the amounts of these substances provided by dietary flaxseed are less than what's necessary to trigger any biological reactions. However, it is wise to take the stated problem into consideration. Techniques for plant bio-

breeding or food processing could be utilized to lower concentration of these substances in flaxseed (Parikh *et al.*, 2019; Dzuovor *et al.*, 2018).

1.3 HEALTH BENEFITS OF FLAXSEED

Many nations have used linseed (*Linum usitatissimum* L.), as a food and medicinal. The flax plant, an annual herb, is where flaxseed is obtained. It has been utilized as flour, oil, and seeds, among other things. Due to the numerous bioactive chemicals it contains, flaxseed and flaxseed oil are regarded as healthful foods. A plant food called flaxseed offers fiber, good fats, and antioxidants (Lee *et al.*, 2021). These days, flaxseed is offered as oil, seeds, pills and powder. Dietary supplements with linseed fiber & whole flaxseed are consumed to lower cholesterol, diabetes, heart disease, cancer, and other illnesses' risks as well as constipation (Shim *et al.*, 2014). Fiber, lignans, protein content, antioxidant & polyunsaturated FA such as ALA are among the bioactive substances in flaxseed (Rubilar *et al.*, 2010). These nutrients may improve human health and reduce the chance of developing a variety of diseases. The health benefits of flaxseed are illustrated in the Figure.

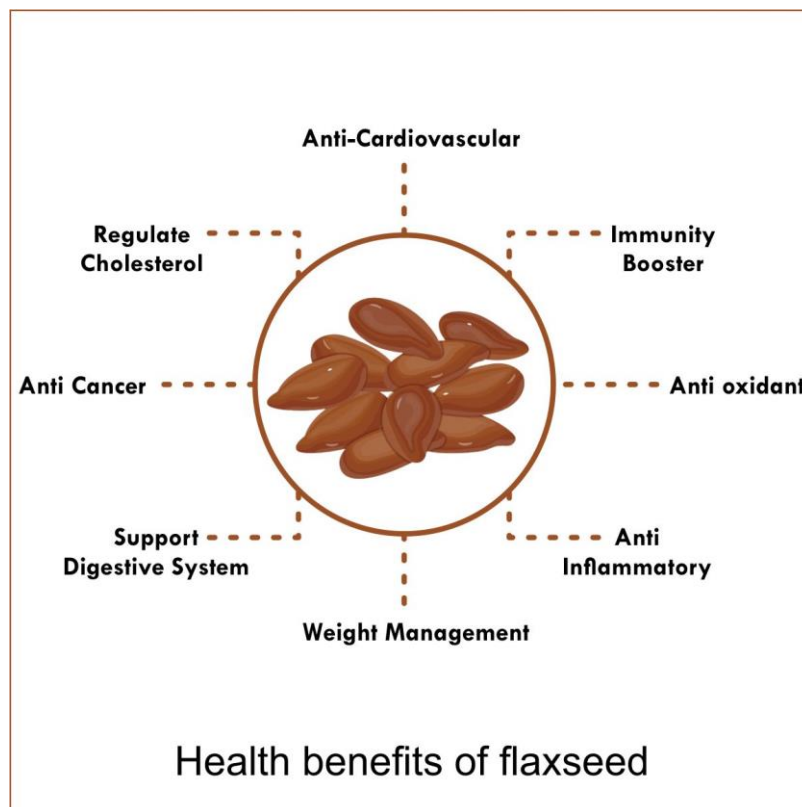


Figure-1: Illustration of the health benefits of flaxseed or linseed

1.3.1 Flaxseed oil in cardiovascular diseases

Cardiovascular disease, one of the heart and blood vessel illnesses, has been recognized as one of the major global health threats (Tang *et al.*, 2021). Recent research has demonstrated the potency of flax oil to lower risk of cardiovascular diseases (CVD).

Inflammation and hypercholesterolemia are significant risk factors for the emergence of CVD. According to Tzang *et al.*, (2009), flaxseed oil has a hypocholesterolemic effect, although butter and other oils (coconut oil) do not have. Triacylglycerol and cholesterol concentrations in the feces were higher in the

flaxseed oil group. A type of disease known as atherosclerosis is brought on by the deposit and buildup of lipids in the walls of blood cells. Numerous variables, including interleukin 1-b, hypercholesterolemia, tumor necrosis factor, eicosanoids, platelet-activating factor, and reactive oxygen species, have been implicated in the creation and development of atherosclerosis (Han *et al.*, 2018). A different study found that fiber in flaxseed can significantly reduce cholesterol levels, in part by encouraging the elimination of fat in the stools (Kristensen *et al.*, 2012). Additionally, soluble flaxseed fiber might entice bile to minimize fat absorption and boost elimination (Tse *et al.*, 2022).

1.3.2 Digestive health support:

Flaxseed is a beneficial food source that is well-known for promoting digestive health. This is mostly because of the significant amount of soluble and insoluble fiber it contains, which has numerous health benefits for the digestive system. The capacity of flaxseed to support digestive health is among its most thoroughly researched advantages. The gastrointestinal tract's lining is protected and inflammation is reduced by ALA. It has been demonstrated by Plissonneau *et al.*, (2022) that flaxseed is advantageous for persons with Crohn's disease & other digestive system related diseases. Although for people with normal digestive system, dietary fiber supports healthy gut flora. The fiber aids in clumping wastes and is supposed to purge contaminants from the digestive tract. Healthy gut bacteria can eat and live on complex carbs, like those in linseed gum. Due to its high soluble & insoluble fiber content, flaxseed is a widely recognized all-natural therapy for constipation. Edible flaxseed is consumed as a dietary supplement to support regular bowel motions.

1.3.3 Lower cancer risk

The unchecked development and proliferation of aberrant cells within the body characterizes cancer, a complex and sometimes fatal disease. Through a process known as metastasis, these aberrant cells, which are sometimes referred to as cancer cells, can invade nearby tissues and migrate to other areas of the body. A lower risk of colon cancer has been linked to a high-fiber diet that includes flaxseed. Fiber supports colon health and may help with colorectal cancer prevention. Flaxseed may also help lower the risks of developing certain cancers, such as breast, prostate, ovarian, and colon cancer. Flaxseed consumption (30 g/day) may slow the growth of tumors and also reduce chances of the breast cancer (Calado *et al.*, 2018). Gut bacteria convert the lignans in flaxseed into the mammalian lignans that are enterolactone & enterodiols. These substances have metabolic reactions actions similar to estrogen (Chang *et al.*, 2019). Dietary phytoestrogens may lower the chance of causing of breast cancer & issues related to low and unstable estrogen levels in females. The lignans found in linseed may also reduce the chances of developing the endometriosis & ovarian cancer for comparable reasons.

Sources of omega-6 and omega-3 fatty acids, such as fats from maize oil or flaxseed oil with a natural or enriched greater concentration, respectively, play a significant effect in suppressing the formation of chemically caused tumors in experimental animals and lowering the risk of colon cancer beginning (McGrowder *et al.*, 2020).

1.3.4 Flaxseed oil in liver health:

The liver, which is the body's main metabolic organ and is easily harmed by a variety of inflammatory substances like viruses, bacteria, alcohol, endotoxins, etc. Through the suppression of inflammatory signaling pathways, flaxseed oil exhibits hepatoprotective properties. According to Wang *et al.*, (2018) research, flaxseed oil may lower interleukin-6, tumor necrosis factor-alpha, and cyclooxygenase expression levels. According to Zhang *et al.*, (2017), mice with abnormally increased levels of aspartate aminotransferase and alanine aminotransferase may benefit from eating flaxseed oil. It is hypothesized that the anti-inflammatory properties of dietary flaxseed oil and its capacity to regulate gut flora could help treat alcoholic liver disease. According to a different study by Wang *et al.*, (2016), dietary flaxseed oil reduced the elevation of plasma endotoxin levels and slowed the inflammation brought on by endotoxin. Another study found that flaxseed oil showed remarkable protective effects against mercuric chloride-mediated liver cytotoxicity (AlRamadneh *et al.*, 2022).

1.3.5 Healthy skin and hair:

Hair and skin health are important indications of general wellbeing. A balanced diet full of vitamins, minerals, and fluids is crucial for keeping them healthy. Omega-3 FA & antioxidants included in the flax may help to maintain young appearance and better skin and hair by lowering inflammation. There have also been reports that flaxseed oil and gum formulations can reduce hair loss. Particularly, the abundance of B vitamins and omega-3 FA in flax helps lessen dryness & flakiness of skin. Flaxseed oil use reduces inflammation, which helps to alleviate a number of dry skin disorders like psoriasis, acne, & atopic dermatitis. Linseed oil may have a stronger impact on dry type skin than roasted whole flaxseed does on inflammation. An important factor in promoting healthy hair is flaxseed. α -linolenic acid (ALA), a particularly abundant omega-3 fatty acid in it, gives the hair follicles the nourishment they require. These fatty acids work to fortify hair strands, lessen brittleness, and fight dryness to produce softer, easier-to-manage hair (Kolekar *et al.*, 2021). Flaxseed is a high source of lignans, a type of antioxidant, & omega-3 FA, both of which have great advantages for the health of the skin. Flaxseed's omega-3s assist in preserving skin's moisture, minimizing dryness, and fostering a glowing, healthy complexion. Additionally, by lowering redness and irritation, its anti-inflammatory characteristics can treat skin diseases like acne, eczema, and psoriasis (There *et al.*, 2023).

1.3.6 Weight loss:

Weight loss is the deliberate reduction of a person's body weight, frequently with the intention of enhancing one's health, beauty, or general well-being. Consuming flaxseed has been shown to be useful in encouraging weight loss in several randomized studies. Additionally, it can aid in reducing cravings and preserving steady energy levels throughout the day because of its capacity to control blood sugar levels (Zhao *et al.*, 2023). Another study found that patients' weight might be dramatically reduced by dieting while using flaxseed oil or sunflower seed oil. Additionally, giving the patients flaxseed oil considerably reduced their waist circumference (Akrami *et al.*, 2018).

CONCLUSION

In conclusion, this comprehensive research reveals flaxseed's exceptional potential as a distinguished functional food. Its historical significance, combined with its unique nutritional content, which includes important omega-3 fatty acids, protein, dietary fibre, minerals, and antioxidants, highlights its importance in boosting general health. The wide range of health advantages, from cardiovascular and gastrointestinal health to metabolic health, cognitive function, and even possible applications in specific medical disorders, highlights flaxseed's adaptability as a dietary component.

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