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Flaxseed properties and its application in food industry: A Review

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Abstract
Flaxseed with a high medicinal and functional value can easily be used in energy food processing as a functional ingredient**.** Flaxseed (*Linum usitassimum*) is a special functional food with an exceptional mix of important polyunsaturated fatty acids, omega 3 alpha linolenic acid, omega 6 linolenic acid (LA), In view of such functional and medicinal qualities of flaxseed, serious efforts have been made to produce a energy rich foods. Nutraceuticals and functional foods have heath-enhancing and therapeutic properties that are believed to enhance human health to prevent and control various forms of life-threatening disorders. The risk of heart disease, obesity, diabetics, colon and intestinal cancer, etc. is increased due to changing life patterns and faulty eating habits. Flaxseeds are a good source of fiber, vitamins, essential amino acids and minerals, and possess good antioxidant properties and some bioactive compounds.

Keywords: Flaxseed, nutritional value, bioactive compound, health benefit, functional food.

Introduction
Flax (*Linum usitatissimum* L.) is a native plant in the areas of Mediterranean and Western Asia, and has been grown since ancient times. The flaxseed is considered to be rich in nutrients and phytochemicals. Flaxseed emerges as one of the most important sources of phytochemicals in the functional food arena. In addition to being one of the best sources of a-linolenic acid oil and lignans, flaxseed is an important source of high-quality protein and soluble fibre, and as a source of phenolic compounds has significant potential. Flax lignan is also a source of valuable biologically active components found in plant foods, such as phytochemicals.

Flaxseeds have nutritional characteristics and are a rich source of α-3 fatty acids: α-linolenic cid (ALA), polyunsaturated fatty acids in the short chain (PUFA), soluble and insoluble fibers, phytoestrogen lignans (secoisolariciresinol diglycoside-SDG), proteins and a number of antioxidants. Flaxseed is a multicomponent system of bioactive plant substances such as fat, protein, dietary fiber, soluble polysaccharides, lignans, phenolic compounds, vitamins (A, C, F and E) and minerals (P, Mg, K, Na, Fe, Cu, Mn and Zn) according to its physicochemical composition (Ivanova *et al*., 2012) [42].

The protein content of flaxseed ranges from 20 to 30%, constituting around 80% globulins (linin and conlinin) and 20% glutelin. Flaxseed has a profile of amino acids similar to soybean, which contains no gluten. Although the existence of restricting amino acid-lysine does not allow flax protein to be a total protein (Hall *et al*., 2006) [35].

Flaxseed contains high concentrations of proteins such as arginine, aspartic acid, and glutamic acid, and small quantities of lysine, methionine, and cystine (Ganorkar and Jain, 2013). Flaxseed is filled with lignans and α-linolenic acid (ALA). It also has significant amounts of dietary fibers (Anon, 2003) [2]. Flaxseeds have greater levels of polyunsaturated fatty acid and lower saturated fatty acid content.

In addition to nutrition, flaxseed has potential health benefits, primarily due to three reasons: first, because of its high content of α-isease, hypertension, atherosclerosis, diabetes, cancer, arthritis and osteoporosis, autoimmune and neurological disorders. Flaxseed oil is thought to offer mental and physical stamina through the fight against exhaustion and the regulation of aging processes. In addition to improving vascular function, flaxseed has also been reported to act as an antiarrhythmic, anti-atherogenic, and anti-inflammatory agent (Gogus and Smith, 2010) [31].

Nutritional Value of flaxseed

Flaxseed has emerged as an alternative among functional foods Clear source of alpha-linolenic acid, lignans, high-quality protein, soluble fibre, and phenolic compounds are functional foods (Oomah 2001) [61, 62, 63]. Flaxseed Composition (Morris 2007; Gopalan *et al*. 2004; Payne (2000) [32, 55, 65]. Flaxseed's chemical composition depends on increasing environmental conditions, genetics, and processing factors (Morris 2007) [55].

Table 1: Nutritional Value of flaxseed

Nutrients	Nutritional Composition Value Per (100gm)	Reference
Moisture (g)	6.5	Morris 2007; Gopalan *et al*. 2004; Payne 2000 [55, 32, 65]
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	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	
Pyridoxine (mg)	0.61	
Pantothenic acid	0.57	
Biotin (µg)	0.6	
Folic acid (µg)	112	

Flax is high in dietary fibre, protein and fat. An study of brown Canadian flax averaged 41% fat, 20% protein, 28% total dietary fiber, 7.7% moisture and 3.4% ash, which is the mineral-rich residue left after samples were burned (Morris, 2003) [54, 56].

The richest source of phytoestrogens (lignans) is flaxseed. The volume of diglycoside secoisolariciresinol (SDG) ranges from 77 to 209 mg SDG / tbsp. Of flaxseed whole (Morris 2007; Toure and Xueming 2010) [55]. Flaxseed contains very low carbohydrate levels (1 g/100 g), and thus adds very little to the overall intake of carbohydrates (Morris 2007) [55].

Flaxseeds contain a good amount of phenolic compounds. These phenolic compounds are well known for anticancer ananti-oxidative properties. Basically, flaxseeds have three different types of phenolic compounds–phenolic acids, flavonoids and lignans. Ferulic acid (10.9 mg / g), chlorogenic aci (7.5 mg / g), gallic acid (2.8 mg / g) are significant phenolic acids found in defatte flaxseed. Other phenolic acids include low-quantity p-coumaric acid glucosides, glucosides of hydroxycinnamic acid and 4-hydroxybenzoic acid (Beejmohun *et al*., 2007; Mazza 2008) [4, 51]. The main flavonoids present in flaxseeds are Flavone Cand Flavone O-glycosides (Mazza 2008) [51].

Flaxseed for Functional food

Flaxseed is classified as a functional food due to the inclusion of three key bioactive components alpha-linolenic acid, lignans, and dietary fibre. Functional or nutraceuticals are foods which, in addition to essential nutritional properties in the food, claim to have health-promoting or disease-preventing properties. Many safety claims have been established for whole flax seed, flax meal and milled flax. Although a complete assessment of flax research as a Functional Food is outside the scope of this article and addressed to readers (Bloedon, L.T. and P. O. Szapary, 2004; Fitzpatrick, K., 2007) [7, 25].

Table 2: Health Benefit From flaxseed

Component	Health benefit	References
Omega 3-fatty acids	• Anti-ulcer activity anti-secretory effect • Reno-protection in lupus nephritis anti-atherogenic effect • CVD prevention • Decrease blodd pressure	Dugani *et al*. [23] Kaitwah *et al*. [43] Clark *et al*. (2001) [12] Dupasquier *et al*. (2007) [24] Rodriguez-Leyva *et al*. (2010) [74] Harper *et al*. (2006) [36, 37] Caligiuri *et al*. (2012) [8]
Dietary fibres	• Hunger suppression • Decrease total cholesterol in blood	Ibbrugger *et al*. (2012) [41]
Proteins	• Neurodegenerative disease prevention • Control blood pression • Influence on hypertriglyceridemia • Influence on diabete mellitus • Anti-hypertensive properties	Omoni and Aluko (2006) [60] Maramble *et al*. (2008) [49] Bhatena *et al*. (2002) [5] Velasquez *et al*. (2003) [90] Oomah *et al*. (2001) [61, 62, 63]
Lignans	• Control on hypertension • Protection against cancer and diabetes • Control on dyslipidemia • Reduce breast cancer growth • Effects on postmenopausal women symptons	Prasad (1998) [68] Adolphe *et al*. (2010) [1] Flower *et al*. (2013) [26] Saggar *et al*. (2010) [76] Strugeon *et al*. (2008) [85] Simbalista *et al*. (2010) [81] Nowak *et al*. (2007) [58] Dew *et al*. (2013) [21]

Alpha-linolenic acid

Alpha-linolenic acid is the principal functional component of flaxseed. It serves as a primary source of omega-3 fatty acid in vegetarian diets (Riediger *et al*. 2009). It is rich in both alpha-linolenic acid (ALA) and linolenic acid (LA) essential fatty acids. Fatty acids are called necessary

because both are needed by the body, but the body can't synthesize them, so they need to be supplied in the diet. In the human body the enzymes needed to synthesize these essential fatty acids are deficient (de Lorgeril *et al*. 2001) [18].

Table 3: Fatty Acid profile of flaxseed oil comparing with Soyabeen and sesame

Fatty acid	Value (%)			References
	Flaxseed	Soya been	Sesame	
Saturated fat	9	15.7	15.7	Morris, D. H. 2003.and Dubois *et al*. 2007 [54, 56, 22]
Monounsaturated fat	18	24.2	40.1	
Linoleic acid (omega -6 fatty acid)	16	52.1	45.3	
a-Linolenic acid (omega-3 f at t y a c i d)	57	7.8	0.4	

A daily intake of 3 g EPA and DHA over 12 weeks proved effective in reducing inflammation of rheumatoid arthritis (Kremer 2000). It has also been stated that consumption of omega-3 dietary supplements leads to a major reduction in non-steroidal anti-inflammatory drugs (Arend and Dayer 1995) [3].

The flaxseed contains antioxidant and hepatoprotective properties. Several research has indicated that the benefits of cholesterol from flaxseed meals (Cunnane *et al*. 1993; Ridges *et al*. 2001; Bhathena *et al*. 2003) [16, 17, 72, 73, 6]. A analysis of hyper cholesterolemic rats fed on supplemented flaxseed chutney diet (15 per cent) showed a large reduction in LDL cholesterol and total Serum cholesterol, and HDL cholesterol does not improve. Flaxseed lignans have neutralized lipid peroxidation products in rats intoxicated with CCl (Shakir and Madhu sudan 2007) [77].

Researchers are studying whether omega-3 fatty acids found in flaxseed can help protect against certain infections and medical conditions including ulcers, migraine headaches, attention deficit / hyperactivity disorder, eating disorders, preterm labor, emphysema, psoriasis, glaucoma, Lyme disease, lupus, and panic attacks (Harper CR., 2006) [36, 37].

Lignan

Lignan-rich foods are part of a healthy dietary pattern; essential is the role of lignans to prevent hormone-associated cancers, osteoporosis and cardiovascular diseases..

Lignans are phytoestrogens, which are abundantly available in fiber-rich grains, cereals (wheat, barley, and oats), legumes (bean, lentil, and soybean), vegetables (broccoli, garlic, asparagus, and carrots), fruit, berries, tea, and alcoholic beverages. Flaxseed produces some 75-800 times more lignans than grains of cereals, legumes, fruits and vegetables (Mazur *et al*. 2000; Meagher and Beecher 2000; Murphy and Hendrich 2002; Hosseinian and Beta 2009) [50, 52, 57, 38, 40]. Diglycoside secoisolariciresinol (SDG) along with a small portion of matairesinol, is the main lignan of flaxseed.

In the human colon, SDG is metabolized by bacteria to synthesize mammalian lignans known as enterodiol (END) and enterolactone (ENL) (Chen *et al*. 2007). The gastrointestinal microflora acts on the lignans in human body to release SECO, a non-sugar moiety of SDG. Additional hydroxylation and microflora demethylation result in the production of mammalian lignan-enterodiol (END), which is then oxidized to produce enterolactone (ENL) (Morris 2007; Hu *et al*. 2007; Toure and Xueming 2010) [39].

In humans lignan serves as antioxidants. Flax seed contains 800 times more lignans than any other plant seed (except sesame seeds that have 47 times less lignan than flax seed), so it is considered to be one of the richest plant lignans sources. The lignans are converted to phytoestrogenic compounds after ingestion of flax. Studies also shown that it is known that the chemical release of phytoestrogenic compounds inhibits the function of hormone-sensitive cancers (Morris, H.M., 2007) [55]. However, the behavior of flax lignans is reportedly dependent on the presence of different bacteria (Clavel T., *et al*., 1991) [13]. Eating 2-4 table spoon of flaxseed in daily diet is recommended to help prevent the cancerous tumors from developing.

Flaxseed lignans play an important role in preventing various types of cancer specially the hormone sensitive ones. Flax lignans are reported to have antioxidant property which presumably is the main reason of the anticancer activity (Schweigerer *et al*. 1992; Prasad 1997) [11, 67]. Research studies also demonstrate SDG's ability to scavenge hydroxyl-free radicals and showed that it is a potent antioxidant human body that generates free radicals during fat, protein, and carbohydrate oxidation. Free radicals destroy tissues, membrane lipids, nucleic acids, cancer-causing proteins, lung diseases, neurological diseases, premature ageing and diabetes (Prasad 1997; Toure and Xueming 2010; Singh *et al*. 2011a, b) [67, 83, 84].

Dietary Fiber

In pure, acid detergent, neutral detergent and complete fibers (cellulose, lignin, and hemicellulose), flaxseed meal is touch. The quality of fibers ranges from 22% to 26%, double the amount of high fiber beans. A half-ounce of dry whole flax seed offers 20 to 25 percent of your daily fiber needs. Flaxseed contains soluble and insoluble dietary fibers in a ratio ranging from 20:80 to 40:60. The main insoluble fiber fraction consists of cellulose and lignin, with the mucilage gums being the soluble fiber fractions (Qian KY., 2012 and Cui W. 1996) [69, 14].

Flaxseed protein has shown reduction of fat absorption in animal and human by fecal excretion. Mette *et al*. 2012 found that the dissipation of a flax dietary fiber extract rich in viscous dietary fibers substantially improved the excretion of fat and reduced total and LDL cholesterol with no effect on appetite (Kristensen M,. 2012) [46, 47].

Flaxseed mucilage is composed of acidic and neutral polysaccharides. The neutral fraction is L-arabinose, Dxylose and D-galactose and arabinoxylan, and includes L-rhamnose, L-fucose, L-galactose, and Dgalactouronic acid (Wanasundara and Shahidi, 1997) [91].

Both soluble and insoluble fibers have their bulking effect in the large intestine, resulting in increased dryness and weight of colon contents and faeces. Soluble fiber enhances the binding of water, initially through the binding ability of its macromolecules, and later through increasing the microbial mass. Compared to insoluble fiber, the contribution of

soluble fibre to faecal weight was negligible. However, recent study has shown it to be of the same magnitude (Malkki 2004) [48].

Diets rich in dietary fibre can help lower the risk of heart disease, diabetes, colorectal cancer, obesity and inflammation (Morris, 2003) [54, 56]. High dietary fiber adds bulk to waste products in the intestine and improves bile movement in gastrointestinal motion. It has a natural laxative effect from dietary fibre. Flaxseed mucilage associated with flaxseed hull is a gum-like substance consisting of acidic polysaccharides and neutrals. The neutral fraction of flaxseed includes xylose (62.8%) where, as the acid fraction of flaxseed consists primarily of rhamnose (54.5%) followed by galactose (23.4%) (Cui *et al*., 1994) [15]. In addition to preventing other metabolic consequences of insulin resistance, low glycemic index foods containing soluble fiber often improve insulin resistance (Reaven *et al*., 1993) [70].

Dietary fiber has historically been used to treat constipation, an irritable bowel condition (Cann *et al*. 1984; Tarpila *et al*. 2005) [86]. Dietary fiber slows gastric emptying, controls post-prandial blood glucose levels and is useful for constipation prevention (Spiller 1994). Flaxseed fiber plays a key role in reducing blood glucose levels. Studies have shown that insoluble fiber inhibits blood sugar release and thereby helps to significantly reduce blood glucose levels (Thakur *et al*. 2009; Kapoor *et al*. 2011) [87, 44].

Table 4: Dietary Fiber content of flaxseed

Dietary Fiber component	Gram per 100 gram of flaxseed	References
Total Dietary	40	Carter, J.F.1993 [9].
Soluble fiber	10	
Insoluble fiber	30	

Flaxseed for industrial application

Linseed oil is the main raw material used to produce linoleum flooring. Linseed oil is the main raw material used to produce linoleum flooring. In the manufacture of Process of linoleum, oxidized linseed oil is combined with rosin and other raw material to form linoleum granules that are pressed onto a jute backrest, rendering linoleum sheets (Green floor linoleum floor Linoleum flooring. Accessed: 23 April 2008). This natural material is made from a renewable resource and is robust and attractive.

As already discussed, flaxseed oil is rich in polyunsaturated fatty acids, the alpha-linolenic acid in particular. Decades ago, flaxseed was mostly used in the manufacture of drying oil, paints, coatings, and inks etc. Fresh flaxseed is golden yellow in colour, has a neutral taste and is highly sensitive to heat, light, oxygen; hence, it is typically extracted by cold pressing when intended for edible purposes (Choo *et al*. 2007a, b). b) [10].

Flax seed mucilage has stronger emulsification properties than Tween 80 and Arabic gum and has potential industrial applications (Minker, E., *et al*., 1973) [53]. Dehulling of flax seed is also an essential method for added industrial prepavalue goods. Attempts were made to extract flax seed hydrocolloidal gum with dry dehulling of seeds to obtain low and high protein products (Dev, D. K., and E. Quensel, 1988) [20]. The hull fraction obtained through this method may be used as a raw material for phytochemic extraction (Oomah, D. B., and G. Mazza, 1998) [64].

Flax fibre has kept a prominent role in the textile industry for decades. The pre-historic Lake Dwellers of Switzerland used flax fiber to produce linen > 5000 years BP. The art of weaving flax fiber to linen may have originated in Egypt as winding-clothes were made of flax fiber for the bodies of the Egyptian pharaohs. It was introduced then in India, where linen was worn by many tribes before cotton was used (Richharia, R.H., 1962) [71].

After the six months of storage (Ogunronbi *et al*. 2011) [59], the bread prepared with the flaxseed oil cake at a rate between 10 and 15 percent had peroxide levels far below threshold limits. Flaxseed is often mixed into animal feed to enhance the nutritional consistency of the meat and fat derived from it. Omega-3 enriched eggs, and pork products are now commercially available (Kassis *et al*. 2011) [45].

Flax bast fibers are mainly phloem cells in which the thickness of the cell wall can exceed 10 µm and more (10 to 100 times greater than that of other types of cells). One of the disadvantages of flax is that best fiber is isolated from other stem fibres. Traditionally, this was achieved by retting; commercially, two conventional methods were used to retard flax for industrial quality fibres, water-and dew-retting (Sharma, H.S.S. and C.F. Van Sumere, 1992) [78]. Owing to the high drying costs and the contamination from the anaerobic decomposition of flax stem in lakes and rivers, the process of water retting was discontinued. Dew-retting has also limitations including poor quality fibre and is restricted to regions which have appropriate moisture and temperature ranges suitable for retting (Foulk JA *et al.*, 2002) [27].

Use of flax oil in food applications where stability is important Green and Marshall (Green, A. G. and D. R. Marshall, 1984) [34] isolated mutants with an a-linolenic acid as small as 1-3 per cent, a level considered appropriate for conventional edible oil applications with self-stability (Rowland, G. G., 1991). Solin is the name given by the Canadian Flax Council to describe flax cultivars for use in the food industry with less than 5 per cent ALA. A domestic source of a vegetable oil high in palmitic acid also has potential for producing high quality margarines in Canada. Even edible linseed oil offers an ability to manufacture substitute oil for cocoa butter (Rowland, G. G., *et al*., 1995) [75]. However, this oil has reduced health benefits due to the reduction in (<5%) ALA content.

It has several industrial applications, due to its high alpha-linolenic acid content. Cantered on scientific studies on the stupendous health benefits of linolenic acid, it attracted academics from different fields to make serious efforts to extend their food applications. Plant breeders, food technologists and nutritionists use traditional and molecular approaches to modify flaxseed's fatty acid profile and establish the attractive demand for food. In this regard, the initiative (Green 1995) reduced flaxseed oil alpha-linolenic acid to less than 5%. For such cultivars containinglessthan5 percent alphalinolenic acid, Flax council has given the name solin. The high concentrations of palmitic acid, oleic acid, linoleic acid in solin cultivars make them suitable for margarine processing and shortening (Hosseinian *et al.*, 2004) [38].

Table 5: Flaxseed processing research conducted at College of Food Technology, VNMKV, Parbhani

Sr. No.	Flaxseed Processing research finding	References
1	Development and quality evaluation of multi oilseed high fiber energy bar with incorporated Flaxseed.	Shinde E.M. and Pawar V.S. (2019) [79, 80]
2	Comparative study on effect of roasting Treatment on nutritional properties of flaxseed	Shinde E.M. and Pawar V.S. (2019) [79, 80]
3	Development and quality evaluation of flaxseed fortified nutra laddu	Ghatge P.U. and Shinde E.M. (2020) [29, 30]
4	Standardization of process technology and quality assessment of flaxseed incorporated nutra cookies	Ghatge P.U. and Shinde E.M. (2020) [29, 30]

Conclusion

The flaxseed has properties both nutritional and functional. In fact, the quality of compounds such as polyunsaturated fatty acids, essential amino acids, vitamin E, lignans, and dietary fibers makes flaxseed a source to meet basic human dietary and health-care needs. ALA (omega-3 fatty acid), dietary fiber and Lignan (specifically SDG) content attract food technologists to explore their abilities in the commercial food processing sector to the fullest extent. Different clinical studies have shown that the constituents of flaxseed provide preventive and therapeutic benefits for disease.

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