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Mini Review

Flaxseed – a nutritional punch

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Abstract

Flaxseed is mainly considered as oilseed crop. Moreover, the other nutritional parameters than its oil content, make it more favorable choice for food technologist to develop functional foods. Flaxseed contains good amount of α-Linolenic Acid (ALA), a omega-3 fatty acid, protein, dietary fiber, lignan, specifically Secoisolariciresinol diglucoside (SDG). Several studies reveal that these components work well for nutritional benefit in human being. ALA is beneficial for infant brain development, reducing blood lipids and cardiovascular diseases. Flaxseed proteins are relatively high in arginine, aspartic acid and glutamic acid whereas lysine, methionine and cystine are limiting amino acid. Flaxseed dietary fiber exhibits positive effect to reduce constipation, to keep better bowel movement and as hypocholestermic agent. SDG have antioxidant activity and free oxygen radical scavenging activity. Consequently, it may have anticancer property. At some extent, SDG helps in bone development. Cyanogenic glycosides and linatine are antinutrients in flaxseed. As compared to soyabean and canola, flaxseed antinutrient effect on human health is very less. Researchers reported that flaxseed incorporated food products can have good consumer acceptability along with its nutritional benefits.

Introduction

Flaxseed, or Linseed (*Linum Usitatissimmum*), popularly known as Alsi, Jawas, Aksebija in Indian languages, is a blue flowering rabi crop and a member of family Linaceae. Annual production of flax was 3.06 million tons and Canada is the world's largest producer of flax (about 38% of total production) (Anonymous, 2000). Globally, Flaxseed is grown as either oil crop or a fiber crop with fiber linen derived from the stem of fiber varieties and oil from the seed of linseed varieties (Diederichsen *et al*., 2003; Vaisey-Genser *et al*., 2003). The plant is native to west Asia and the Mediterranean. As the source of linen fiber flax has been cultivated since at least 5000 BC, today it is mainly grown for its oil (Berugland, 2002; Oomah, 2001). The spherical fruit capsules contain two seeds in each of five compartments. The seed is flat and oval with a pointed tip. It have smooth glossy surface. It varies in color dark brown to yellow (Freeman, 1995). The texture of flaxseed is crisp and chewy possessing a pleasant nutty taste (Carter, 1996). Beyond its oilseed crop ability, proximate composition of flaxseed makes it more promising for its utilization in different food products. Flaxseed is one of the richest vegetarian source of α- linolenic acid (omega 3 fatty acid) and soluble mucilage. In present era, consumer's trend towards functional food has increased significantly as health awareness rose. Flaxseed can be one stop for novel high quality source of nutrition.

Proximate composition of flaxseed

Flax is rich in fat, protein and dietary fibre. An analysis of brown Canadian flax averaged 41% fat, 20% protein, 28% total dietary fibre, 7.7% moisture and 3.4% ash, which is the mineral-rich residue left after samples are burned (Morris, 2003). The composition of flaxseed can vary with genetics, growing environment, seed processing and method of analysis (Daun *et al*., 2003). The protein content of the seed decreases as the oil content increases (Daun and DeClercq, 1994). The oil content of flaxseed can be altered through traditional plant breeding methods, and it is affected by geography – the cool nights of northern Canada improve oil content and quality. The

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composition of flaxseed is shown in Table 1.

Brown and yellow (Omega) varieties of flaxseed are virtually identical in their nutrient content (Morris, 2003). Seed coat colour is determined by the amount of pigment present, a feature that can be changed through normal plant breeding practices. Consumers can buy brown or yellow flaxseed based on price and appearance of the flaxseed containing food product, since the nutritional value of brown and yellow flax is similar. Flaxseed oil and canola oil have the lowest levels of the nutritionally undesirable saturated fatty acids. The level of the desirable monounsaturates in flax oil is modest.

Flaxseed as a source of ALA (Omega-3 fatty acid)

There are two groups of omega fats: omega-3 and omega-6 fatty acids. Linolenic acid, eicosapentaenoic acid (EPA) and docosahexanoic acid (DHA) are three types of omega-3 fatty acids and are nutritionally important. All three fatty acids have been shown to reduce the risk of cardiovascular disease (Hurteau, 2004). Flax contains a mixture of fatty acids. It is rich in polyunsaturated fatty acids, particularly ALA, the essential omega-3 fatty acid, and linoleic acid (LA), the essential omega-6 fatty acid. These two polyunsaturated fatty acids are essential for humans – that is, the body needs them. Supercritical CO_2 extraction gave a higher average ALA content (60.5%) compared to the soxhlet extraction method (56.7%) (Bozan and Temelli, 2002). Fatty acid content of flaxseed oil is depicted in Table 2.

ALA and Linoleic acid constitutes 57% and 16.0 % of total fatty acids respectively in flax making the richest source of ALA. ALA from flaxseed exerts positive effect on blood lipids. It was found to be as effective as oleic acid (18:2η-6) and linoleic acid (18:2η-6) in the reduction of plasma total cholesterol, low density lipoprotein cholesterol and very low density lipoprotein cholesterol in 20-34 years old healthy men (Chan *et al*., 1993). 12 g of ALA was taken three times a day by group of healthy young women in the flaxseed oil capsules and compared with group given in flaxseed flour supplemented products. Impressive reductions in blood lipids were observed in both cases (Cunnane *et al*., 1993). Nettleton (2003) summarized the recommendations of leading health organizations regarding the proper ratio of n-6 to n-3 fatty acid intake. Most organizations agree that a 5:1 to 10:1 n-6 to n-3 fatty acid ratio is preferred (Institute of Medicine, 2002; WHO/FAO, 2003). However, a typical diet has an n-6 to n-3 fatty acid ratio well beyond 10:1; thus, flaxseed can be a valuable lipid source to improve the n-6 to n-3 fatty acid ratio due to the high n-3 content of flaxseed

Table 1. Proximate composition of flaxseed on common measures[a]

Form of flax	Weight(g)	Common measure	Energy (kcal)	Total fat (g)	ALA[b] (g)	Protein (g)	Total CHO[c,d] (g)	Total dietary fibre (g)
Proximate analysis	100	-	450	41.0	23.0	20.0	29.0	28.0
Whole seed	180	1 cup	810	74.0	41.0	36.0	52.0	50.0
	11	1 tbsp	50	4.5	2.5	2.2	3.0	3.0
	4	1 tsp	18	1.6	0.9	0.8	1.2	1.1
Ground seed	130	1 cup	585	53.0	30.0	26.0	38.0	36.0
	8	1 tbsp	36	3.3	1.8	1.6	2.3	2.2
	2.7	1 tsp	12	1.1	0.6	0.5	0.8	0.8
Flax oil	100	-	884	100.0	57.0	-	-	-
	14	1 tbsp	124	14.0	8.0	-	-	-
	5	1 tsp	44	5.0	2.8	-	-	-

[a]Based on a proximate analysis conducted by the Canadian Grain Commission. The fat content was determined using the American Oil Chemists' Society (AOCS) Official Method Am 2-93. The moisture content was 7.7%.
[b]ALA = Alpha-linolenic acid
[c]CHO = Carbohydrate.
dTotal Carbohydrate includes carbohydrates like sugars and starches (1 g) and total dietary fibre (28 g) per 100 g flax seeds.
(Source: Morris, D. H. 2003. Flax: A health and nutrition primer. p. 12. Winnipeg: Flax Council of Canada)

Table 2. Fatty acids content of Flaxseed oil

Parameter	Percentage (%)
Saturated fat	9.0
Monounsaturated fat	18.0
Linoleic acid (omega-6 fatty acid)	16.0
α-Linolenic acid (omega-3 fatty acid)	57.0

(Source: Morris, D. H. 2003. Flax: A health and nutrition primer. p.11. Winnipeg: Flax Council of Canada)

oil. Ranhotra *et al*. (1992) noted that flaxseed oil or blends of flaxseed oil and sunflower oil promoted cholesterol reduction in hypercholesterolemic rats compared to diets formulated with hard fats. These authors suggested that a diet with the appropriate balance of n-6 and n-3 fatty acids was preferred over diets high in n-6 fatty acids. Ground flaxseed is high in omega-3 fatty acids which have been shown to reduce hypertension, cholesterol and triglyceride level (Oomah and Maza, 1998). Oikarinen *et al*. (2005) reported that flaxseed oil may be responsible for preventing colon carcinogenesis in multiple intestinal neoplasia (Min) mice. Dwivedi *et al*. (2005) also supported this finding that flaxseed oil prevented colon tumor development in rats. Presence of ALA in breast adipose tissue was inversely related to breast cancer risk (Maillard *et al*., 2002). ALA, being the essential fatty acid, requirement can be fulfilled by intake of flaxseed products (Morris, 2004).

Flaxseed as a source of protein

The protein content in flaxseed has been reported to between 10.5% and 31% (Oomah and Mazza, 1993). Khategaon cultivars grown in India had a protein content of 21.9% (Madhusudhan and Singh, 1983). Differences in protein can be attributed to both genetics and environment. The proximate protein content of dehulled and defatted flaxseed varied considerably depending upon cultivar growth location and seed processing. Hull fraction contains lower protein levels

Table 3. Dietary Fiber content of flaxseed

Dietary Fiber component	Gram per 100 gram of flaxseed
Total Dietary	40
Soluble fiber	10
Insoluble fiber	30

(Source: Carter, J.F.1993. Potential of flaxseed and flaxseed oil in baked goods and other products in human nutrition. Cereal Foods World 38 (10): 753-759)

and that dehulling increases protein level of flaxseed protein level from 19.2% to 21.8% (Oomah and Mazza, 1997). Albumin and globulin type proteins are the major proteins in flaxseed. Flaxseed albumin comprised 20% of meal protein (Madhusudhan and Singh, 1983). Globulin fraction makes up to 73.4% and the albumin constitutes about 26.6% of total protein (Marcone *et al*., 1998). Flaxseed proteins are relatively high in arginine, aspartic acid and glutamic acid whereas lysine, methionine and cystine are limiting amino acid. Total amino acid content of the flaxseed after 8 days germination increased by 15 times with greatest increase (i.e. 200 times) being observed in glutamine and leucine compared to the original seed (Wanasundara *et al*., 1999). Oomah and Mazza (1995) compared the nutritional value of flaxseed meal with soybean meal and concluded that net protein utilization and protein efficiency ratio of flaxseed meal were slightly lower than soybean meal with the exception of protein scores, which were high in flaxseed meal. The BV of flaxseed protein was similar to those of soybean protein (Frank, 1987). El-Kady (2000) found that the biological values of Belinka and Sakha-1 flaxseed proteins were 67.70 and 66.43 respectively.

Flaxseed protein was effective in lowering plasma cholesterol and triglycerides (TAG) compared to soy protein and casein protein (Bhathena *et al*., 2002). Protein content of biscuits made from composite flour containing 15% ground flaxseed increased from 6.5% to 8.52%. The supplementation of flaxseed flour upto 15% showed no deleterious effect on the sensory attributes of biscuits (Zaib-un-Nisa, 2000). As flax is gluten-free, people who are sensitive to gluten can enjoy flax in their diets (Morris, 2003).

Flaxseed as a source of dietary fiber (Mucilage or Gum)

Dietary fiber is a communal word used to describe a variety of plant substances that are not easily digested by the enzymes responsible for digestion in humans (Eastwood and Passmore, 1983). Diets rich in dietary fibre may help reduce the risk of heart disease, diabetes, colorectal cancer, obesity and inflammation (Morris, 2003). Flaxseed is a rich source of dietary fiber (accounting 28% shown in Table 1), both soluble as well as insoluble fibers. Total dietary fiber content of flaxseed is given in Table 3.

High amount of dietary fiber adds bulk to waste products in the gut and increases bile movement in the gastrointestinal movement. It exhibits natural laxative effect of dietary fiber. Flaxseed mucilage associated with hull of flaxseed is a gum like material composed of acidic and neutral polysaccharides. The neutral fraction of flaxseed contains xylose (62.8%) where as the acidic fraction of flaxseed is comprised mainly of rhamnose (54.5%) followed by galactose (23.4%) (Cui *et al*., 1994). Low glycemic index foods containing soluble fiber not only prevent certain metabolic ramifications of insulin resistance but also reduce insulin resistance (Reaven *et a*l., 1993). Soluble fiber and other components of flaxseed fraction could potentially affect insulin secretion and its mechanism of action in maintaining plasma glucose homeostasis. Flaxseed was shown to reduce the post prandial blood glucose response in humans. Healthy female volunteers consumed 50 g ground, raw flaxseed/day for 4 weeks which provided 12-13% of energy intake (24-25 g/100 g total fat). Flaxseed raised α-linolenic acid and long-chain η-3 fatty acids in both plasma and erythrocyte lipids, as well as raising urinary thiocyanate excretion 2.2 fold. Flaxseed also lowered serum total cholesterol by 9 % and low-density-lipoprotein-cholesterol by 18 %. Changes in plasma α-linolenic acid were equivalent when 12 g α-linolenic acid/day was provided as raw flaxseed flour (50 g/day) or flaxseed oil (20 g/day) suggesting high bioavailability of α-linolenic acid from ground flaxseed. Test meals containing 50 g carbohydrate from flaxseed or 25 g flaxseed mucilage each significantly decreased postprandial blood glucose responses by 27 %. 50 g high-α-linolenic acid flaxseed/day is palatable, safe and may be nutritionally beneficial in humans by raising n-3 fatty acids in plasma and erythrocytes and by decreasing postprandial glucose responses (Cunnae *et a*l., 1993).

Similar findings were observed in post menopausal women fed 40 g/day flaxseed fortification diet (Lemay *et al*., 2002). Bread containing 25% flaxseed gave a glycemic response that was 28% lower than the control (no flaxseed) bread (Jenkins *et al*., 1999).

Flaxseed as a source of lignan (Phenolic compounds)

Flaxseed is the richest source of plant lignans (Thompson *et al*., 1991). Secoisolariciresinol diglucoside (SDG) is the predominant lignan in flaxseed with minor amount of pinoresinol and matairesinol (MAT) (Meagher *et al*., 1999; Thompson *et al*., 1991). SDG was found 2653 mg/100 g of non defatted flaxseed extract (Hall and Shultz, 2001). The

lignans of flaxseed are phytoestrogens and serves as precursors in the production of mammalian lignans. Flaxseed lignans convert to mammalian lignans enterolactone and enterodiol by intenstinal flora (Wang *et al*., 2000). Kitts *et al*. (1999) reported that enterolactone and enterodiol had greater antioxidant activity than the present lignan (SDG), suggesting that the metabolites might be the reason for the health benefits of plant lignans. Prasad (2005) suggested that lignan may act to prevent oxygen radical production, thus effectively reducing atherosclerosis. Lignans have antioxidant activity and thus may contribute to the anticancer activity of flaxseed (Yuan *et al*., 1999; Kangas *et al*., 2002; Prassad 1997). However, number of factors may contribute to the various anticancer activity of flaxseed (Thompson et al., 2005). The behavior of the lignans depends upon the biological level of estradiol. At normal estradiol levels, the lignans act as estrogen antagonists but in post menopausal women (i.e. low estradiol levels) can act as weak estrogen (Hutchins and Slavin, 2003; Rickard and Thompson, 1997). Although lignans have been shown to be protective against breast cancer, minor structural alterati*ons may influence overall activity (Sarrinen* et al., 2005). Further research is needed to explore the role of flaxseed in cancer prevention. Toure and Xueming (2010) reviewed on flaxseed lignan which provides better understanding of flaxseed antioxidant activities and suggests that flaxseed lignans may be used as natural antioxidants.

Flaxseed, in particular lignans could influence bone development. Ward *et al*. (2001b) found that rats exposed to 88 or 177.3 mg SDG/kg of body weight/day had higher bone strength than the basal diet at 50 days post natal. However, by post natal day 132, no differences in bone strength, bone mineral density were observed. Exposure to SDG did not have negative effect on bone strength (Ward *et al*., 2001b).

Anti-nutrients in flaxseed

Keeping an eye on safety of flaxseed, two compounds, cyanogenic glycosides and linatine an antipyridoxine factor are questioned frequently. Release of hydrogen cyanide from flaxseed would be minimal and below toxic lethal dose. At the recommend daily intake of about 1–2 table spoons, approximately 5–10 mg of hydrogen cyanide is released from flaxseed, which is well below the estimated acute toxic dose for an adult of 50–60 mg inorganic cyanide and below the 30–100 mg/ day humans can detoxify (Roseling, 1994). Generally roasting is carried out to eliminate cyanogenic glycosides. Wanasundara *et al*. (1993) studied on removal of cyanogenic glycosides of flaxseed meal by a two phase solvent extraction system consisting of hexanes and an alkanol (Methanol, ethanol or isopropanol) phase with or without added water and/ or ammonia. Of the 4.42 mg/g linustatin and 1.90 mg/g neolinustatin originally present in the meals, over 90% of each cyanogenic glycoside was removed under optimum conditions using methanolic solutions. Although linatine is a problem in chicks, flaxseed has not been associated with a vitamin B6 deficiency in human. In fact, no affect on serum pyridoxine levels in subjects consuming 45 g/ day of flaxseed over 5 weeks was observed (Dieken, 1992).

In addition to this, trypsin inhibitor and phytic acid are other antinutrients contained in flaxseed. But compared to soyabean and canola seeds, activity of them are low (Hall *et al*., 2006). Bhatty (1993) reported laboratory-prepared flaxseed meals containing 42–51 units of TIA (Trypsin inhibitor activity), which was slightly higher than 10–30 units observed by Madhusudhan and Singh (1983) and commercially obtained flaxseed meal (14–37 units). The contents of phytic acid were significantly different among cultivars. AC Linora has a lowest phytic acid content of 2280 mg/100 g and low ALA yellow-seeded cultivar Linola 947 has the highest content (3250 mg/100 g seed) among the eight cultivars reported (Oomah *et al.*, 1996).

Conclusion

Flaxseed (Linseed) encompasses the potential health suiting nutritional profile in it. However, many people are still unaware of the potential health benefits of flaxseed and food applications. ALA (omega-3 fatty acid), dietary fiber and Lignan (specifically SDG) content attracts food technologists to explore its abilities at fullest extent in commercial food processing sector. Recently Baking and Pasta companies have incorporated flaxseed into their formulations. General recommendation for daily intake has been 1–3 table spoons per day for ground flaxseed or 1 table spoon for flaxseed oil. Flaxseed is emerging as one of the nutritive and functional ingredient in food products. Scientific findings are growing in support of flaxseed consumption. More studies are needed to resolve the conflicting reports regarding the health benefits, in particular the role of ALA and SDG in prostate cancer and cancer in general.

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