Review Article

Bioactive Components of Flaxseed and its Health Benefits

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ABSTRACT

Flax seed (*Linum usitatissimum*) is popularly known as Alsi, Jawas, Aksebija, etc. in Indian languages, is a blue flowering crop that produces small, flat seeds ranging in colour from golden yellow to reddish brown. Flaxseed contains good amount of α-Linolenic Acid (ALA), omega-3 fatty acid, protein, dietary fiber, lignan specifically Secoisolariciresinol diglucoside (SDG). ALA is beneficial for infant brain development, reducing blood lipids and cardiovascular diseases. Flaxseed proteins (10.5% to 31%) are relatively high in arginine, aspartic acid and glutamic acid whereas lysine, methionine and cystine are limiting amino acids. Flaxseed dietary fiber exhibits positive effect to reduce constipation, to keep better bowel movement and as hypocholestermic agent. Flax seed contains dietary fibres and omega-3 fatty acids in the form of ALA, which can help reduce the risk of cancer, particularly breast and colon, by blocking tumour formation. Flax seed is an emerging as one of the key source of phytochemicals in the functional food area. The use of flax seed in different food products will be beneficial to protecting against cancer, heart disease, diabetes and lowering cholesterol level.

Keywords: Flaxseed, ALA, protein, dietary fibre, lignan, phytochemical.

INTRODUCTION

Flaxseed (*Linum usitatissimum*) belonging to family *Lineaceae*, popularly known as Alsi, Jawas, Aksebija in Indian languages, Flax seed is a blue flowering crop that produces small, flat seeds ranging in colour from golden yellow to reddish brown. The texture of flaxseed is crisp and chewy possessing a pleasant nutty taste[1]. 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 colour dark brown to yellow[2]. Flaxseed is often used to describe flax when consumed by humans while linseed denotes when it is used specifically for industrial applications[3]. Almost all parts of linseed plant are utilized for various purposes. Seed contains oil which after refining is used for edible purpose[4-5]. The stem yields fiber of good quality possessing high strength and durability. Humans have been consuming flaxseed since ancient times. It has been cultivated for fiber as well as for medicinal purposes and as nutritional product[6]. Annual production of flax was 3.06 million tons and Canada is the world's largest producer of flax (about 38% of total production)[7]. The important flaxseed growing countries include India, China, United States, and Ethiopia[4-5,8].

In India flaxseed is mainly cultivated in Madhya Pradesh, Maharashtra, Chattisgarh and Bihar. It is interesting to know that flaxseed was native of India and was a staple food crop. In India, flaxseed is still being consumed as food and as well as for medicinal purposes[9]. It enjoys a good status among oilseeds because of its versatile uses. It has emerged as an attractive nutritional food because of its exceptionally high content of alpha-linolenic acid (ALA), dietary fiber, high quality protein and phytoestrogens. Flaxseeds contain about 55% ALA, 28–30% protein and 35% fiber[10-12]. The composition of flaxseed can vary with genetics, growing environment, seed processing and method of analysis[13]. Flaxseed has been the focus of growing interest for the nutritionists and medical researchers due to its potential health benefits associated with its biologically active components-ALA, lignan-Secoisolariciresinol diglycoside (SDG) and dietary fiber[14]. Flaxseed is establishing importance in the world's food chain as a functional food. Functional food can be defined as the food or food ingredients that may provide physiological benefits and helps in preventing and/or curing of diseases[15]. Presently, flaxseed has new prospects as functional food because of consumer's growing interest for food with superb health benefits. Owing to its excellent nutritional profile and potential health benefits, it has become an attractive ingredient in the diets specially designed for specific health benefits[16]. ALA is one of the essential polyunsaturated fatty acid and reported to exhibit anti-inflammatory, anti-thrombotic and anti-arrhythmic properties[17]. Nutritionists all over the world suggest incorporation of omega 3 fatty acid sources in the diet. Flaxseed serves as the best omega-3 fatty acid source to the non-fish eaters. Edible flaxseed products include the whole flaxseed, ground meal and extracted oil or mucilage. These products have been proposed as nutritional additives in the preparation of a number of dietary items such as baked cereal products, ready to eat cereals, fiber bars, salad toppings, meat extenders, bread, muffins and spaghetti[4-5]. In spite of the multiple clinical evidences of flaxseeds, people are still unaware about its nutritional as well as therapeutic benefits.

Flaxseed Lignan (Phenolic Compounds)

Plant lignans are phenolic secondary metabolites with a basic structure consisting of two interlinked phenylpropanoid molecules (Figure 1a). There are two major classes of lignans, the dibenzylbutane lignans and the furanofuran lignans, of which secoisolariciresinol diglucoside (SDG) from flaxseed and sesamin from sesame seed are respective examples (Figure 1b and c).

The prevailing lignan in flaxseed is secoisolariciresinol diglucoside (SDG; MW = 686.7 Da; Figure 1b)[18-20] which is often referred to as secoisolariciresinol or SECO, the aglycone of SDG[21], depending on the method of analysis. In flaxseed, SDG exists in two isomeric forms, (+)-SDG and (-)-SDG, of which (+)-SDG is the major isomer[22-23]. Smaller quantities of matairesinol, isolariciresinol, lariciresinol, demethoxysecoisolariciresinol and pinoresinol have also been identified in flaxseed[20,24].

The lignan content in flaxseed differs between varieties, but has also been shown to depend on growing location and year[25-26].

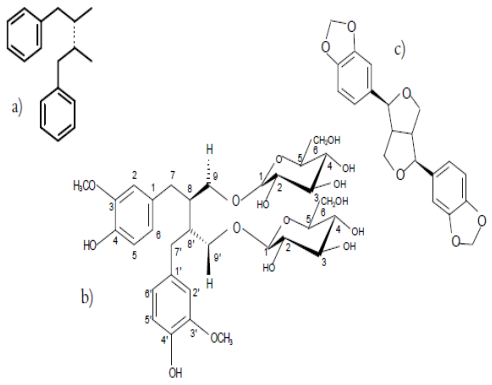

Figure 1- a): The basic structure of lignans consisting of two interlinked phenylpropanoid molecules, **b):** secoisolariciresinol diglucoside, a dibenzylbutane lignan, **c)**: sesamin, a furanofuran lignan[19,20].

Flaxseed is the richest source of plant lignans[27]. Secoisolariciresinol diglycoside (SDG) is the predominant lignan in flaxseed with minor amount of pinoresinol and matairesinol (MAT)[24,27] SDG was found 2653 mg/100 g of non-defatted flaxseed extract[28] 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[29].

The lignans are found to be abundant in fibre-rich parts of plants, as high-interest compounds with regard to antitumor activity[30-31].

The enterolignans (also called mammalian lignans) enterolactone and enterodiol were identified as metabolic products of dietary plant origin[32-36].

The fibre-rich plant foods containing hormone-like compounds such as lignans and isoflavonoids, also known as phytoestrogens, may influence oestrogen metabolism and reduce the incidence of breast and colon cancer and possibly other disease[35-40].

Dietary sources of lignans include seeds, legumes, cereals, vegetables, berries, seaweed, tea and alcoholic beverages[21,27,41-46]. Secoisolariciresinol and matairesinol were the first plant lignans identified in foods. Pinoresinol and lariciresinol are more recently identified plant lignans that contribute substantially to the total dietary lignan intakes.

Typically, Lariciresinol and pinoresinol contribute about 75% to the total lignan intake whereas secoisolariciresinol and matairesinol contribute only about 25% (Table 1)[47].

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[48]. Lignan may act to prevent oxygen radical production, thus effectively reducing atherosclerosis[49]. Lignans have antioxidant activity and thus may contribute to the anticancer activity of flaxseed[50-52].

However, number of factors may contribute to the various anticancer activity of flaxseed. Flax lignans have shown promising effects in reducing growth of cancerous tumors, especially hormone-sensitive ones such as those of the breast, endometrium and prostate[53].

Although lignans have been shown to be protective against breast cancer, minor structural alterations may influence overall activity[54].

The mammalian lignans stimulate the synthesis of sex hormone binding globulin, which binds sex hormones and reduce their circulation in blood stream, and decrease their biological activity and thus reducing the risk of developing cancer[55].

Flax lignans are reported to have antioxidant property which presumably is the main reason of the anticancer activity[50].

Secoisolariciresinol diglucoside (SDG) is one of the important lignans present in food stuff. Secoisolariciresinol diglucoside (SDG) is an antioxidant phytoestrogen present in flax, sunflower, sesame, and Pumpkin seeds. It can also fund in bread enriched withflaxseed[56].

It is a precursor of mammal lignas[27], which are produced in the colon from chemicals in foods. Secoisolariciresinol diglucoside slows the growth of human breast cancer in mice[57].

Secoisolariciresinol diglucoside may play very different role in people with the already existent cancer. In the Grade IV histology group of adult patients diagnosed with malignant glioma, high intake of secoisolariciresinol (for highest tertile compared to lowest tertile, in all cases) was associated with poorer survival[58]. In contrast, another study indicated that secoisolariciresinol extends life in high grade glioma patients[59].

Table 1: Lignan precursors as a glycones (µg / 100 g) in Food Stuff.[47]

Foodstuff	Pinoresinol	Syringaresinol	Sesamin	Lariciresinol	Secoisolariciresinol	Matairesinol	Hydroxymatairesinol
Flaxseed	871	48	not detected	1780	**165759**	529	35
Sesame seed	**47136**	205	**62724**	13060	240	1137	7209
Rye bran	**1547**	**3540**	not detected	**1503**	462	729	1017
Wheat bran	138	882	not detected	672	868	410	**2787**
Oat bran	**567**	297	not detected	**766**	90	440	**712**
Barley bran	71	140	not detected	133	42	42	**541**

Omega-3 Fatty Acid

The omega-3 (n-3) fatty acid ALA (18:3 n-3) and the omega-6 (n-6) fatty acid LA (18:2 n-6) (Figure 2) are essential fatty acids in that they are needed to maintain health[60], but cannot be synthesized from any dietary precursors by humans so they have to be present in the diet.

Alpha-linolenic acid is the main functional component of flaxseed. It serves as an exclusive source of omega-3 fatty acid in the vegetarian diets[61]. Fatty acids are termed as essential because both they are required by the body but body cannot synthesize them, therefore need to be supplied in the diet.

Human body lacks the enzymes which are required for the synthesis of these essential fatty acids[62].

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[63]. 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.

ALA and Linoleic acid constitutes 57% and 16.0% of total fatty acids respectively in flax making the richest source of ALA. These two polyunsaturated fatty acids are essential for humans – that is, the body needs them.

ALA from flaxseed exerts positive effect on blood lipids. It was found to be as effective as oleic acid (18:2 η-6) and linoleic acid (18:2 η-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[64].

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[65].

Ground flaxseed is high in omega-3 fatty acids which have been shown to reduce hypertension, cholesterol and triglyceride level[66].

Table 2: Fatty acids content of Flaxseed oil.[67]

Parameters	Amount (g/100g)
Saturated fat	9.0
Monounsaturated fat	18.0
Linoleic acid(omega-6fatty acid)	16.0
α-Linolenic acid (omega-3 fatty acid)	57.0

The clinical studies revealed that n-3 polyunsaturated fatty acids are helpful in prevention of coronary heart diseases, atherosclerosis, rheumatoid arthritis and asthma[68-69]. Daily intake of 3 g EPA and DHA for more than 12 weeks was found to be effective in reducing the inflammation of rheumatoid arthritis[69]. It has also been reported that the consumption of omega-3 dietary supplements lead to significant reduction of non-steroidal anti- inflammatory drugs[68]. Flaxseed and its oil reduces the growth of tumors at the later stage of carcinogenesis; whereas, mammalian lignan precursor exert the greatest inhibitory effect on the growth of new tumors[70]. The role of flaxseedoil in tumors prevention is attributed to its high alpha-linolenic acid. The fatty acid composition of the tumors revealed higher incorporation of alpha-linolenic acid which in turn resulted in suppression of the growth of the tumor cells[70-72]. Flaxseed possesses antioxidant and hepato protective properties. Several studies advocated the cholesterol lowering benefits of flaxseed meal[65,73-74]. Several clinical studies showed that EPA and DHA play a major role in reducing depression symptoms.

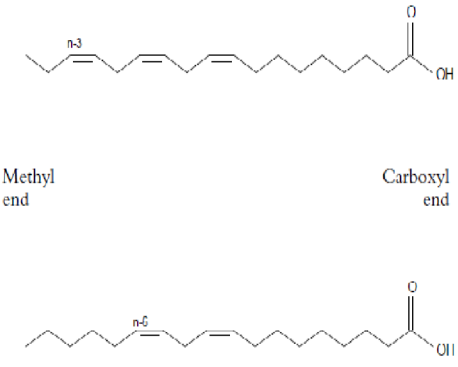

Figure 2: Chemical structure of the essential fatty acids alpha-linolenic acid (18:3 n-3; above), and linoleic acid (18:2 n-6; below)[60].

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[75]. Diets rich in dietary fibre may help reduce the risk of heart disease, diabetes, colorectal cancer, obesity and inflammation[67]. Flaxseed is a rich source of dietary fiber both soluble as well as insoluble fibers. Insoluble fiber consists of cellulose, hemicellulose and lignin[3,76]. 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%) whereas the acidic fraction of flaxseed is comprised mainly of rhamnose (54.5%) followed by galactose[77].

Table 3: Dietary fiber of flaxseed content[10].

S. No	Dietary Fiber	Amount (g/100g)
1	Total Dietary	40
2	Soluble fiber	10
3	Insoluble fibre	30

Low glycemic index foods containing soluble fiber not only prevent certain metabolic ramifications of insulin resistance but also reduce insulin resistance[78]. 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).

Similar findings were observed in post menopausal women fed 40 g/day flaxseed fortification diet[79]. Bread containing 25% flaxseed gave a glycemic response that was 28% lower than the control (no flaxseed) bread[80].

Only 10 g of flaxseed in the daily diet increases the daily fiber intake by 1 g of soluble fiber and by 3 g of insoluble fiber. Insoluble fiber helps improve laxation and prevent constipation, mainly by increasing fecal bulk and reducing bowel transit time[81]. On the other hand, water-soluble fiber helps in maintaining blood glucose levels and lowering the blood cholesterol levels[82].

Flaxseed fiber plays an important role in lowering the blood glucose levels. Studies demonstrated that insoluble fiber slows down the release of sugar in the blood and thus help in reducing blood glucose levels to great extent[83]. Studies have shown that the high intake of dietary fibers is beneficial for the prevention of obesity in both men and women[84].

Dietary Protein

Table 4: Amino acid composition of proteins from flaxseed[87,91]

Amino acid	Total proteins[87] (g/100g)	Globulins[91] (g/16gN)	Albumins[91] (g/16gN)
Aspartic acid	8.3	11.3	5.5
Glutamic acid	22.8	19.8	35
Serine	4.1	5.1	3.9
Glycine	4.9	4.8	8.3
Histidine	2.7	2.5	1.6
Arginine	10.4	11.5	13.1
Threonine	3.4	3.9	2.1
Alanine	4.3	7.9	1.9
Proline	3.6	4.5	3
Tyrosine	2.2	2.3	1.4
Valine	5.7	5.6	2.6
Methionine	1.5	1.7	0.8
Cysteine	3.3	1.4	3.5
Isoleucine	4.8	4.6	2.8
Leucine	6.7	5.8	5.4
Phenylalanine	5.1	5.9	2.4
Lysine	4.4	3.1	4.9

The protein content in flaxseed has been reported to between 10.5% and 31%[76]. Khategaon cultivars grown in India had a protein content of 21.9%[86]. 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 and that dehulling increases protein level of flaxseed protein level from 19.2% to 21.8%.[85] Flaxseed proteins have similar nitrogen extractability at varying pH and ionic strength with other oilseed sources of proteins[76]. Flaxseed proteins were reported to be 20% albumins of low molecular weight proteins (1.6S and 2S) and 80% globulins as high molecular weight proteins (11S and 12S) and were found to be structurally more lipophilic than soybean proteins due to the influence of their polysaccharide composition. Albumin and globulin type proteins are the major proteins in flaxseed[76]. Nutritional value and amino acid profile of flaxseeds are comparable to that of soya proteins[76,87]. Flaxseed protein is rich in arginine, aspartic acid and glutamic acid, while lysine is limiting[4-5,88]. High cysteine and methionine contents improve the antioxidant levels, thus helps in reducing risk of cancer[16]. 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[89-90]. The BV of flaxseed protein was similar to those of soybean protein.[91] Flaxseed protein was effective in lowering plasma cholesterol and triglycerides (TAG) compared to soy protein and casein protein[92]. Flaxseed proteins exhibit

antifungal properties against Alternariasolani, Candida albicans and Aspergillus flavus[93-94]. It also contains peptides with bioactivities related to the decrease in risk factors of CVD. The high plant protein content of flaxseed is of interest, especially since it has been suggested that plant proteins reduce serum cholesterol levels.

Tocopherols in Flaxseed

Tocopherols (vitamin E) are the most powerful fat soluble antioxidants. They exist in four homologous isomers: α (5, 7, 8-trimethyltocol), *β*(5, 8-dimethyltocol), *γ*(7, 8-dimethyltocol), and *δ*(8-methyltocol), which differ in number or position of methyl groups in the molecules. The various tocopherols differ in their biological activities and their ability to protect fats and oils from oxidative rancidity. Generally, antioxidative and biological activities of the isomers increase and decrease, respectively, in the following order: α, *β*, *γ*, and *δ*[95-96]. Tocopherol is important especially when flaxseed is used for animal feed since decrease in both α - and *γ*-tocopherols in rat issues with increasing dietary flaxseed has been reported[97]. Furthermore, tocopherol naturally present in foods has been strongly correlated with the polyunsaturated fatty acid since it counteracts the potential oxidative stress caused by fats in the diet[98].

The tocopherol level in plants is governed by the level of unsaturated fatty acids; a simple increase in unsaturation results in the formation of higher amounts of antioxidants to protect the oil[99]. Variation in tocopherol levels of sesame seed oil has been ascribed to differences in genotype, maturity level, and environmental temperature during seed development[100-101]. Other factors, such as seed, oil storage, and processing, are known to affect tocopherol levels in vegetable oils. The tocopherol content was highest in flaxseed and flaxseed oil followed by poppy seed, safflower seed and oil (Table 5)[104]. A commercial flaxseed variety grown in 1994 was reported to contain 0.88, 2.42, 9.2, 0.24, and 12.74 mg/100 g of seed (wb) of R-, â-, ç-, and ä-tocopherols and total tocopherols, respectively, and was essentially devoid of tocotrienols[102]. Total tocopherol content of 9 flaxseed varieties grown at 13 worldwide geographic locations ranged from 39.5 to 50 mg/100 g of oil (mean value of 43.6 mg/100 g of oil), and these differences in total tocopherol content were primarily due to location[103].

Table 5: Tocopherols content different samples[104]

Samples	α- Tocopherol (mg/100 g)	β- Tocopherol (mg/100 g)	γ- Tocopherol (mg/100 g)	Total (mg/100 g)
Flax seed	0.10 ± 0.01	ND	13.93 ± 0.10	14.03
Poppy seed	1.40 ± 0.02	0.53 ± 0.03	8.70 ± 0.20	10.63
Safflower seed	10.21 ± 0.40	1.19 ± 0.32	ND	11.4
Flax oil	0.59 ± 0.01	ND	75.67 ± 1.30	76.26
Poppy oil	5.53 ± 0.20	1.67 ± 0.21	21.74 ± 1.20	28.94
Safflower oil	44.09 ± 2.10	7.23 ± 0.30	ND	51.32

ND = Not Detected

Lipoxygenase Enzyme in Flaxseed

Lipoxygenase (linoleate:oxygen 13-oxidoreductase, EC 1.13.11.12) is widely distributed in plants. It catalyzes the hydro peroxidation of polyunsaturated fatty acids and esters containing *cis*,*cis*-1,4-pentadiene moieties[105]. The fatty acid hydro peroxides, which are highly reactive, are converted via a number of enzymatic reactions into compounds of significant physiological role in plant growth and development, senescence, wound and other stress responses, synthesis of regulator molecules, nitrogen partitioning, and lipid mobilization during germination[106-107]. Because many products of the lipoxygenase reaction (or derivatives thereof) are aromatic, the presence of lipoxygenase activity in many foods can affect their properties, such as color, texture, functionality, and nutritive value, particularly during long-term storage in both desirable and undesirable ways[108-110].

Although the enzyme has been well studied in soybeans for several decades, investigations on flaxseed lipoxygenase have been limited. Flaxseed lipoxygenase possessed a high degree of specificity for attachment of oxygen to linoleic and linolenic acids[111]. Thus, with lipoxygenase from flaxseed, 80% and 88% of 13-hydroxyoctadecadienoate (13-isomer) were formed when linoleate and linolenic acid served as the substrate, respectively. Later, characterized a prostaglandin-like metabolite (phytonoic acid) produced on incubation of linolenic acid with an extract of flaxseed acetone powder (presumed to contain flaxseed lipoxygenase)[112]. The predominant formation of 13-hydroperoxides due to the oxidation of linolenic acid by flaxseed lipoxygenase was later confirmed by Grosch[113], who described flaxseed lipoxygenase as a poor carotene “oxidase”. Flaxseed lipoxygenase behaves similar to type 1 soybean lipoxygenase (L-1), but it produces only small amounts of volatile carbonyl compounds and aroma substances unlike in soybeans[113]. The absence of type II lipoxygenase in flaxseed was demonstrated by Vernooy-Gerritsen[114] who saw no cross-reactivity with extracts from flax in immune diffusion assays using an antibody against highly purified soybean cotyledon lipoxygenase-2. Recent evidence obtained following purification of lipoxygenase from flaxseed has allowed the identification of its activity to an iron-containing protein of 130 kDa which upon incubation with R-linolenic acid, forms 13-hydroperoxy-9,11,13(*Z*,*E*,*Z*,)-octadecatrienoic acid[115]. The flaxseed lipoxygenase enzyme is very labile (*T*1/2) 4 h at 4 °C, exhibits a broad pH activity around 6.2, and is reduced by *β*-mercaptoethanol to monomeric bands (23 and 20 kDa)[115].

Cyanogenic Comounds in Flaxseed

Cyanogenic glucosides are nitrogenous secondary plant metabolites derived from amino acids. Their presence in crop species has several important implications. High levels of cyanogenic compounds severely restrict the amount of such meals in animal rations. The possibility of

improving the commercial value of some crops by reducing the levels of cyanogenic glucosides has generated considerable interest in understanding their changes in Flaxseed. The major cyanogenic glucosides present in flaxseed have been identified as linustatin and neolinustatin, a ***p*** gentiobioside of acetone cyanohydrin, and methyl ethylketone cyanohydrin, respectively[116]. The presence of a minor component, linamarin (l-cyano-lmethylethyl P-D-glucopyranoside), along with diglucosides linustatin and neolinustatin was detected in linseed meal by thin-layer chromatography[117]. Recently, Schilcher and Wilkens-Sauter (1986) found only traces of linamarin in their quantitative determination of cyanogenic glucosides of 48 flax samples using reversed phase HPLC[118]. These contradictory reports on the presence of linamarin in flaxseed imply limitations in the analytical procedures employed in the extraction, separation and detection of cyanogenic glucosides. Bhatty[118] (1990, personal communication) reported strong seasonal effects on the total cyanogenic glucoside of eight flax cultivars grown at several locations in 1987 and 1989. The effect of the environment on flaxseed cyanogenic glucosides was also alluded to by Schilcher and Wilkens-Saute.[119]

Anti-Nutrients

Flaxseeds contain anti-nutrients that may have adverse influence on the health and well-being of human population. Cyanogenic glycosides and linatine an anti-pyridoxine factor are questioned frequently. Fiber type linseed has a higher percentage of glycosides than the seed type, and ripe seed contains less glycoside than the immature seed. Whole flaxseed contains 250–550 mg/100 g cyanogenic glycoside[4-5]. In the intestine, cyanogenic glycosides release hydrogen cyanide, a potent respiratory inhibitor, by intestinal β-glycosidase that produces thiocyanates. Thiocyanates interfere with iodine uptake by thyroid gland and long term exposure aggravates iodine-deficiency disorders, goiter and cretinism. Cyanogenic glycosides are heat labile and easily destroyed by processing methods namely autoclaving, microwave roasting, pelleting and by certain detoxifying enzymes such as β-glycosidases, releasing hydrogen cyanide which can be evaporated by using steam[65,120-121]. Generally roasting is carried out to eliminate cyanogenic glycosides[122].

Linatine (antipyrodoxidine factor) has been identified as a vitamin B6 antagonist in case of chicks. While in humans, flaxseeds are not found to be associated with vitamin B6 deficiency[123-124].

In fact, no effect on serum pyridoxine levels in subjects consuming 45 g/ day of flaxseed over 5 weeks was observed[123]. In addition to this, trypsin inhibitor and Phytic acid, another anti-nutrient present in flaxseed, ranges from 23 to 33 g/kg of the flaxseed meal[125-126]. Phytic acid interferes with the absorption of calcium, zinc, magnesium, copper and iron. It is a strong chelator. Forming protein and mineral-phytic acid complexes and thus reducing their bioavailability[127-128]. Clinical studies reveal that flaxseed fed rats had no effect on their Zn status. Ganorkar and Jain (2013) have also reviewed that flaxseed antinutrients have lesser impact on human health as compared to that of soyabean and canola[129]. Trypsin inhibitors are also reported in flaxseed, though activity is insignificant as compared to soybean and canola seeds[118].

CONCLUSION

The present review shows that, the nutraceutical value and different health benefits of flaxseed and its oil with reference to evidence based literatures. This encourages development of new branded healthy and functional foods using flaxseeds, oil and cakes. 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. Today a major portion of world is suffering from disorders like cardiovascular diseases, diabetes, hypertension, neurological disorders hence there is a need to cure the people by adopting natural strategy. Flaxseed is one of the emerging foods which have the potential of curing these disorders. Flaxseed is emerging as one of the nutritive and functional ingredient in food products. Apart from being an excellent oil seed, flaxseed can be used in food, skin care, hair care and other health care products.

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