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Flax Seed: A Potential Medicinal Food

Charu Katare*, Sonali Saxena, Supriya Agrawal, GBKS Prasad and P.S. Bisen

Govt. K.R. G. PG Autonomous College, Gwalior, India

Abstract

Growing awareness about the role of diet and quest for human wellness has fuelled interest in 'Functional foods' and functional attributes of many traditional foods are being reinvented. Flax continues to surge forward in its recognition as a functional food and has recently gained attention in the area of cardiovascular disease primarily because it is the richest known source of alpha-linolenic acid, the phytoestrogen, lignans, as well as being a good source of soluble fiber. Lignans have diverse range of biological activities and flax seeds contain a lignin derivative, secoisolariciresinol diglucoside which get metabolized into the mammalian lignans. The flax lignans influence the early risk markers of mammary and colonic carcinogenesis in animal models. Regular consumption of flaxseed products can affect serum total and low-density lipoprotein cholesterol concentrations, reduce postprandial glucose absorption, decrease some markers of inflammation and raise serum levels of the omega-3 fatty acids, ALA and eicosapentaenoic acid. The flax seed has been shown to possess significant antioxidant and anti-inflammatory functions in experimental as well as human studies. The flax seed supplementation in diet revealed potential health benefits in situations like cardiovascular risk, certain types of cancers and other metabolic disorders. There are number of studies indicating the role of raw flaxseed and its baked products in health promotion and disease prevention. This review highlights the potential of 'flax seed' as a 'neutraceutical' and its role as a protective and therapeutic medicinal food.

Introduction

Good health is a challenge of modern-day living as the current civilization is plagued by several degenerative lifestyle diseases. With rapidly changing global health scenario and fast realization of the ill effects of uncontrolled food processing and overmedication; plant products have gained the well deserved attention. Growing awareness about the role of diet and quest for wellness has fuelled interest in foods that can work like medicine. 'Functional foods' or 'neutraceuticals' are foods or dietary components that may provide a health benefit beyond basic nutrition. Functional foods deliver a health boost beyond what is expected from their traditional nutrient content [1]. Functional attributes of many traditional foods are being discovered, while new food products are being developed with beneficial components. Flaxseed continues to surge forward in its recognition as a functional food, being rich in the essential omega-3 fatty acid, alpha linolenic acid and many phytochemicals. Flaxseed also provides dietary fiber and protein (flax primer) an was singled out as one of six neutraceuticals [2] (Figure 1). Flaxseeds combined with an abundance of omega-3 fatty acids makes them an increasingly popular addition to the diets of many a health conscious consumer.

Composition

Flaxseeds have a hard shell that is smooth and shiny and the color ranges from deep amber to reddish brown depending upon whether the flax is of the golden or brown variety. The envelope or testa of the seed contains about 15% of mucilage. Flaxseed is rich in fat, protein and dietary fibre. The composition of flaxseed can vary with genetics, growing environment and method of seed processing [3], the composition of flaxseed is provided in (Table 1). An analysis of brown Canadian flaxseed averaged 41% fat, 20% protein, 28% total dietary fibre, 7.7% moisture and 3.4% ash [4,5]. The protein content of the seed decreases as the oil content increases [6]. It is well known that flax seeds are a source of high content of polyunsaturated fatty acids [7]. Flaxseed has become known as a functional food due to its nutritional composition, which has positive effects on disease prevention providing health-beneficial components [8].

Figure 1: Flax Seeds.

Fatty acids

Flaxseed has been valued historically for its abundance of fat, which provides a unique mix of fatty acids (Figure 2). Flaxseed is rich in the essential omega-3 fatty acid, alpha linolenic acid. The omega-3 fatty acids have biologic effects that make them useful in preventing and managing chronic conditions such as type 2 diabetes, kidney disease, rheumatoid arthritis, high blood pressure, coronary heart disease, stroke, Alzheimer disease, alcoholism and certain types of cancers [9]. The high alpha linolenic acid (C18:3, n-3] content of flaxseed oil and

***Corresponding author:** Charu katare, Govt. K.R. G. PG Autonomous College, Gwalior, India, E-mail: katarec@yahoo.in

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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 11 4	1 cup 1 Tbsp 1 tsp	810 50 18	74.0 4.5 1.6	41.0 2.5 0.9	36.0 2.2 0.8	52.0 3.0 1.2	50.0 3.0 1.1
Milled seed	130 8 2.7	1 cup 1 Tbsp 1 tsp	585 36 12	53.0 3.3 1.	30.0 1.8 0.6	26.0 1.6 0.5	38.0 2.3 0.8	36.0 2.2 0.8
Flax oil	100 14 5	1 cup 1 Tbsp 1 tsp	884 124 44	100.0 14.0 5.0	57.0 8.0 2.8	- - -	- - -	- - -

[a]Based on a proximate analysis conducted by the Canadian Grain Commission (Anonymous. 2001). 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, the essential omega-3 fatty acid.
[c]CHO = Carbohydrate.
[d]Total Carbohydrate includes carbohydrates like sugars and starches (1g) and total dietary fibre (28g) per 100 g flax seeds. .

Table 1: Proximate composition of flax based on common measures[a].

the observed protective effects of omega-3 fatty acids on cancer have led to the hypothesis that the fatty acid composition of flaxseed may render it protective against cancer [10].

Protein

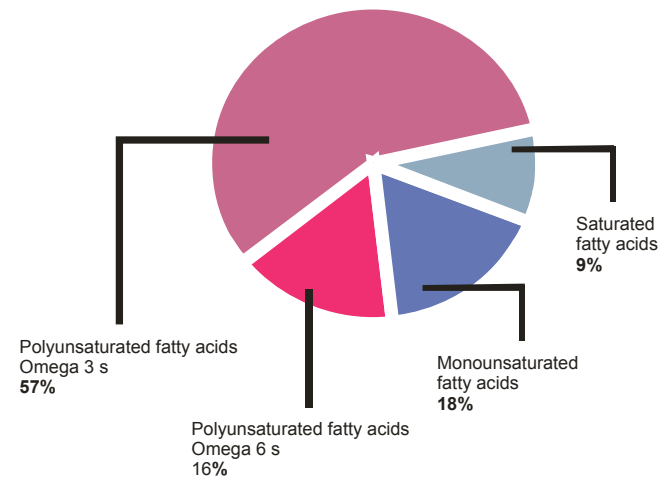
The amino acid pattern of flax protein is similar to that of soybean protein, which is viewed as one of the most nutritious of the plant proteins. There appears to be little difference in the amino acid content of the protein from two flax varieties shown in Table 2. Flax is gluten-free. The specific agent in gluten that causes a condition known as 'celiac disease' is gliadin, which is rich in the amino acids proline and glutamine [11].

Carbohydrates

Flaxseed is low in carbohydrate [4]. For this reason, flax contributes little to total carbohydrate intake.

Fibre

Total fibre is the sum of dietary fibre and functional fibre. Functional fibre consists of nondigestible carbohydrates that have been extracted from plants, purified and added to foods and other products.



Source-Simopoulos AP (1999) Prostaglandins Leuko Essent Fatty Acids 60: 421-429.

Figure 2: Fatty Acid Composition of Flax Oil.

Amino Acid	Flax Cultivar [a]		
	Brown flax (Nor Lin)	Yellow Flax (Omega)	Soy Flour [b]
Alanine	4.4	4.5	4.1
Arginine	9.2	9.4	7.3
Aspartic acid	9.3	9.7	11.7
Cystine	1.1	1.1	1.1
Glutamic acid	19.6	19.7	18.6
Glycine	5.8	5.8	4.0
Histidine*	2.2	2.3	2.5
Isoleucine*	4.0	4.0	4.7
Leucine*	5.8	5.9	7.7
Lysine*	4.0	3.9	5.8
Methionine*	1.5	1.4	1.2
Phenylalanine*	4.6	4.7	5.1
Proline	3.5	3.5	5.2
Serine	4.5	4.6	4.9
Threonine*	3.6	3.7	3.6
Tryptophan*[c]	1.8	NR[d]	NR
Tyrosine	2.3	2.3	3.4
Valine*	4.6	4.7	5.2

[a]Oomah and Mazza (2). [b]Friedman and Levin (84). [c]Bhatty and Cherdkiatgumchai (mixture of NorLin, NorMan and McGregor cultivars) (85). [d]NR = Not reported. *Essential amino acids for humans.

Table 2: Amino acid composition of flax cultivar in comparison to Soy protein.

Dietary fibre and functional fibre are not digested and absorbed by the human small intestine and, therefore, pass relatively intact into the large intestine [12]. Total fibre accounts for about 28% of the weight of full-fat flax seeds. On the basis of solubility, there are two main types of fibre, soluble and insoluble. Flax contains both soluble and insoluble dietary fibre (Table 3). Dietary fibre acts as a bulking agent in the gut. It increases stool weight and the viscosity of digested material, while also decreasing the transit time of material through the gut. In this manner, dietary fibre helps control appetite and blood glucose, promotes laxation and reduces blood lipids. Diets rich in dietary fibre may help reduce the risk of heart disease, diabetes, colorectal cancer, obesity and inflammation [13-16]. The soluble and insoluble dietary fibre content of flax varies, as shown below [3]. The major fibre fractions in flax consist of the following:

Cellulose: The main structural material of plant cell walls.

Mucilage gums: Flax mucilage consists of three distinct types of arabinoxylans which form large aggregates in solution and contribute

to its gel qualities [17]. Mucilage gums extracted from flax seeds are added to laxatives and cough syrups [18].

Lignin: It is a highly-branched fibre found within the cell walls of woody plants. Lignins are related to a similar-sounding compound–lignans. Both are part of plant cell walls and are associated with cell wall carbohydrates. Lignins contribute to the strength and rigidity of the cell walls. Lignans are phytochemicals whose role in human nutrition, particularly cancer prevention, is being studied actively [19].

Phenolics

Phenolics are plant derived compounds that have many different functions, including adding colour to the plant and attracting bees and other insects for pollination [20]. Many phenolics appear to have anticancer and antioxidant effects in humans [21-23]. Flax contains at least three types of phenolics [2,24] viz., phenolic acids (about 1%), flavonoids (35-70 mg/ 100 g) and lignans. Lignans are found in amounts ranging from 1 mg/g of seed to nearly 26 mg/g of seed [25]. Flax contains 75 to 100 times more lignans than any other plant source. They are also considered phytoestrogens, they help balance hormone levels, such as estrogen, in the body. They've also been found to help reduce menopause symptoms, similar to soy phytoestrogens [26]. The principal lignan present in the flaxseed is secoisolariciresinol diglucoside (SDG), which occurs as component of linear esterlinked complex in which the C6-OH of the glucose of SDG is esterified to the carboxylic acid of hydroxymethyl glutaric acid.

Vitamins and minerals

Flaxseed contains several water and fat-soluble vitamins [27]. As listed out in Table 4. Vitamin E is present abundantly in flax primarily as gammatocopherol [28]. Gamma-tocopherol is an antioxidant that protects cell proteins and fats from oxidation; promotes sodium excretion in the urine, which may help lower blood pressure; and helps lower the risk of heart disease, some types of cancer and Alzheimer disease [29,30]. The tocopherol content of flax is affected by the variety, maturity of the seed, growing region, growing conditions and method of extraction. The gammatocopherol content can range from 8.5 to 39.5 mg/100 g of seed or about 0.7- 3.2 mg/tbsp of milled flax [3]. Flax contains a small amount of vitamin K in the form of phylloquinone, which is the plant form of the vitamin. Vitamin K plays an essential role in the formation of certain proteins involved in blood clotting and in building bone [31,32]. The mineral content of flaxseed [27] is shown in Table 5. One tablespoon of milled flaxseed contains 34 mg of magnesium, about the same amount of magnesium found in a 250 mL (8-oz) container of low-fat yogurt with fruit, 30 g (1 oz) of pecan halves, or half a fried chicken breast (140 g). The potassium content of milled flax is about 66 mg per tablespoon or about the same amount of potassium found in one slice of toasted typical pumpernickel bread, a 175 mL (6-oz) mug of brewed tea or a hard-boiled egg [32]. Flax is low in sodium.

Nutrient antagonists

Flaxseed contains two compounds phytic acid and oxalate – that bind calcium, copper, iron, magnesium and zinc to form insoluble complexes in the intestine [33]. Flax contains less than 10 mg of oxalate/kg and about 0.8-1.5% phytic acid by seed weight. The amount of phytic acid in flaxseed is comparable to that found in peanuts and soybeans [3]. Phytic acid is widely distributed in plant foods. In cases where there is an imbalance in the intake of phytates, calcium and zinc, rats show diminished growth and decreased bone zinc levels [29,34]. Studies show, however, that, at least in rats, phytic acid lowers blood glucose and reduces the incidence of colon cancer [29].

Soluble fibre		Insoluble fibre
Whole flax seed (1 tbsp)	0.6 - 1.2 g	1.8 - 2.4 g
Milled flax (1 tbsp)	0.4 - 0.9 g	1.3 -1.8 g

Table 3: Fibre content of flax seed [88].

Water soluble	mg/100g[a]	mg/tbsp milled flax
Ascorbic acid / Vitamin C	0.50	0.04
Thiamin/vitamin B_1	0.53	0.04
Riboflavin/vitamin B_2	0.23	0.02
Niacin/nicotinic acid	3.21	0.26
Pyridoxine/viatamin B_6	0.61	0.05
Pantothenic acid	0.57	0.05
	mcg/100g	mcg/100g
Folic acid	112	9.0
Biotin	6	0.5
Fat soluble		
Carotenes	not detected	not detected
Vitamin E_b		
Alpha-tocopherol	7	0.10
Delta-tocopherol	10	0.14
Gamma-tocopherol	552	7.73
		mcg/tbsp milled flax
Vitamin K_c		0.3

Source: http://www.ars.usda.gov/nutrientdata)

[a]Composite sample of whole flax (86).

[b]Tocopherol values represent the average of four varieties (87). The following forms of vitamin E were not detected: beta-tocopherol and alpha-, delta- and gamma-tocotrienol.

[c]As phylloquinone (Nutrient Data Laboratory, Beltsville Human Nutrition Research Center, Agricultural Research Service. USDA's National Nutrient Database for Standard Reference.

Table 4: Vitamin Content in Flax.

	mg/100gm	**mg/tbsp milled flax**
Calcium	236	19.0
Copper	1	0.1
Iron	5	0.4
Magnesium	431	34.0
Manganese	3	0.2
Phosphorus	622	50.0
Potassium	831	66.0
Sodium	27	2.0
zinc	4	0.3

Table 5: Mineral Content of Flax.

Nutritional Attributes of Flaxseed

Flaxseed has long history of use in India and flaxseed preparations are particularly considered for its nutrients and therapeutic property [35]. In Southern India, flaxseed is partly being consumed by at lower levels as flaxseed chutney. *Linum Usitatissimum L*, the linseed producing plant belongs to the family Linoceae. Flaxseed is exceptionally rich source of mammalian lignan precursor secoisolariciresinol diglucoside present at levels 75-800 times greater than other plants known [36].

Preliminary studies on flaxseed chutney in rats in the laboratory experiment showed encouraging results on lipid lowering action and protection against liver damage [37]. Whole flaxseeds are known to lower total and LDL cholesterol levels, reduce postprandial glucose absorption, decrease some markers of inflammation and raise serum levels of omega-3 fatty acids. The lipid-lowering effect of flaxseeds is due to the lignans and/or fiber, since defatted flaxseeds have the same cholesterol-lowering effect as whole flaxseeds. The major nutrients of flax viz., ALA and SDG can hold up to baking temperatures. One study found that heating whole or ground flax at temperatures as high as 350°C for 60 minutes had little effect on fatty-acid composition or oxidation and did not generate new trans forms of ALA or other undesirable fatty –acid by products. Flaxseed's gluten-free protein and fiber content also provides nutritional benefits and it appear to have antioxidant, anticancer and antimicrobial activities [26]. Cunnane et al. [38] reported that up to 50gm high alpha-linolenic acid flaxseed / per 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 blood glucose responses. Consumption of 50gm flaxseed per day four week resulted in alpha linolenate in adipose tissue and n-3 polyunsaturates were increased in plasma lipids. Plasma cholesterol was also reduced by upto 8 % and total urinary lignan excretion was increased more than fivefold ($P< 0.05$) along with 30% increase in bowel movements per week [39]. A comparison of biological effect of dietary Alphalinolenic Acid (ALA) with long chain omega-3 derivatives revealed that ALA is not equivalent in its biological effect to the long chain omega-3 fatty acids found in marine fish oils. However, ALA is metabolized to eicosapentaenoic acid, which may replace arachidonic acid in membrane phospholipids. Ingestion of flax seed oil may alter the generation of eicosanoids, pro coagulant activity and other membrane–dependent responses and exert anti allergic, anti atherosclerotic, anti arrhythmic effects. Beneficial effects of flax seed oil have been shown in prevention and management of cardiovascular diseases [40].

Also present in the flaxseed and in resulting lignan extracts are significant quantities of 2 cinnaminic acid glycoside. Several studies indicate that the biological activity of flaxseed results from their conversion to the mammalian lignans Enterolactone (EL) and Enterodiol(ED) [25]. The mammalian lignans enterolactone and enterodiol are produced in colon by the action of bacteria on the plant precursor secoisolariciresinol diglucoside, which is found in higher concentration in flaxseed [41].

Studies conducted on bioavailability of ALA when the flaxseed was ingested in the form of whole seed, milled seed or as flaxseed oil revealed that flax oil and milled flaxseed delivered significant levels of ALA to the plasma whereas whole flaxseed did not. Whole seed and oil preparations induced adverse gastrointestinal effects within 4 weeks in some subjects. The milled flaxseed may represent a good form of flaxseed for human consumption to avoid serious side-effects and still provide significant increases in ALA to the body [42] .Ground flaxseed showed a modest but short lived LDL-C lowering effect, yet reduces Lp(a) and improved insulin sensitivity in hyperlipidemic adults. The HDL-C lowering effect of flaxseed in men as reported in one report warrants additional study [43]. Food allergy to flax appears to be fairly rare, with only handful of allergic reactions reported in the medical literature [44-48]. Cyanogenic glycosides are a group of natural substances found in plants that release cyanide, a poisonous compound, when degraded by enzymes or organic acids. In several clinical studies, volunteers ate muffins containing 50 g (5-6 tbsp) of milled flax daily for up to 6 weeks without ill effects. Muffins made with milled flax showed no trace of the cyanogenic glycosides, suggesting that cooking destroys the enzyme that metabolizes the glycosides [38].

Health Benefits of Flaxseed

Anti-diabetic functions

Daily lignan supplementation resulted in modest, yet statistically significant improvements in glycemic control in type 2 diabetic patients without apparently affecting fasting glucose, lipid profiles and insulin sensitivity [49]. Peak blood glucose values were improved by ingestion of flaxseed fibre in healthy subjects [50]. After removing oil, the flax cake mixed with antioxidants (chilli) could serve as a supplement to the poorest of poor suffering from diabetes in rural populations [51]. It has been found that SDG isolated from flaxseed is effective in retarding development of diabetes in Zucker diabetic fatty/Gmi-fa/fa female rats [52]. Flaxseed lignin, SDG reduced high-fat diet-induced visceral and liver fat accumulation and improved hyperlipidaemia, hypercholesterolemia, hyperinsulinaemia and hyperleptinaemia. These effects may prevent obesity and may reduce cardiovascular risk associated with lifestyle diseases, such as diabetes, atherosclerosis and hypertension. Flaxseeds, which also contain PUFA and dietary fiber, are therefore a promising food to help decrease the risk of lifestyle related diseases [53].

Anti-oxidant functions

The antioxidant activity of the flaxseed has been shown to reduce total cholesterol [54] as well as platelet aggregation [55]. The flaxseed lignin Secoisolariciresinol Diglucoside (SDG) and mammalian lignans enterodiol (ED) and enterolactone (EL) were previously shown to be effective antioxidants against DNA damage and lipid peroxidation. Inhibition of activated cell chemiluminescence by supra-physiological concentrations of secoisolariciresinol (SECO), ED and EL were also evaluated. The lignan antioxidant activity was attributed to the 3-methoxy-4-hydroxyl substituents of SDG and SECO [42]. Secoisolariciresinol diglucoside from flaxseed has been shown to be effective in preventing/delaying the development of type-1 and type-2 diabetes. The hypoglycemic effect of SDG in type-2 diabetes has been suggested to be due to its antioxidant activity. It may be possible that the hypoglycemic effect of SDG in type-2 diabetes is due to suppression of expression of Phospho enol pyruvate carboxy kinase enzyme, a rate limiting enzyme in glyconeogenetic pathway [56]. Antioxidant property of flaxseed chutney was evident from lowered lipid peroxidation (TBARS) and predictor enzyme γ-glutamyl transpeptidase profile in azoxymethane treated rats.

Anti-inflammatory functions

Administration of lignan capsules (360mg/d) for 12 weeks to diabetic subjects with mild hypercholesterolemia resulted in significant reduction in C-reactive protein levels [57]. Flaxseed lignans are converted by intestinal bacteria into the so called enterolignans, enterodiol and enterolactove. Information on bioavailabity of entero-lignans is scanty and the mean relative bioavailability of enterolignans from whole compared with ground flaxseed was 28% ($p<or =0.01$), where as that of crushed compared with ground flaxseed was 43% ($p<or =0.01$). Crushing and milling of flaxseed substantially improve the bioavailabity of the enterolignans [58]. There was a significant increase in serum alpha linolenic acid, eicosapentaenoic acid and docosapentaenoic acid and serum enterolactove concentration was doubled during flaxseed supplementation [59]. Lignans have been shown to have positive effects in lowering relative risk factors for

heart disease. Use of flax seed or SDG has been shown to have positive effects in both lupus and polycystic kidney disease models. Flax seed has also been reported to be hepatoprotective. There are many possible mechanistic explanations for the observed bioactivities including involvement in hormonal metabolism or availability, angiogenesis, antioxidation and gene suppression [60].

Flaxseed in cancer

Studies on the activity of lignans on breast, colon, prostate and thyroid cancer has generally shown beneficial effects although there are some studies with either no conclusive or negative effect. Flaxseed has been shown to reduce the early risk markers for and incidence of mammary and colonic carcinogenesis in animal models [10,61-63]. Lignans from flaxseed have been shown to reduce mammary tumor size by >50% and tumor number by 37% [64] in carcinogen-treated rats. Effect of flaxseed feeding on risk markers of cancer in humans [65] demonstrated that the ingestion of 10 g of flaxseed per day elicited several hormonal changes associated with reduced breast cancer risk. Flavanoids, herbacetin 3, 7- Odimethyl ether [55] and herbacetin [66], the aglycone of 1, were shown to mediate antioxidant activity which may contribute to the chemopreventive activity of flaxseed [67]. Epidemiologic studies have also shown that the prevalence of breast cancer is lower in countries where the diet is vegetarian [68,69] and that lignin concentrations were found significantly lower in omnivores and in women with breast cancer [66,70]. Thus, it is becoming increasingly obvious that lignans possess many beneficial properties. Both phytoestrogen and dietary fibre have been shown to have cancer protective effects. Flaxseeds significantly increased urinary excretion of lignans without changing the serum hormone concentration of premenopausal women suggesting that the chemoprotective effects reported for flaxseed may have resulted from mechanism other than a hormonal effect [71].

Flaxseed in CVD

Flaxseed has recently gained attention in the area of cardiovascular disease primarily because it is the richest known source of both Alpha-linolenic acid (ALA) and the phytoestrogen, lignans, as well as being a good source of soluble fiber. Human studies have shown that flaxseed can modestly reduce serum total and low-density lipoprotein cholesterol concentrations, reduce postprandial glucose absorption, decrease some markers of inflammation and raise serum levels of the omega-3 fatty acids, ALA and eicosapentaenoic acid. Alpha-linolenic acid is the natural precursor of the cardioprotective long-chain n-3 fatty acids. A 12-week dietary supplementation with flaxseed oil, rich in ALA (8 g/day), on blood pressure in middle-aged dyslipidaemic men resulted in significantly lower systolic and diastolic blood pressure levels [72,73].

Partially defatted flaxseed reduced total cholesterol (4.6 ± 1.2%; $P = 0.001$), LDL cholesterol (7.6 ± *1.8%;* $P < 0.001$), apolipoprotein B (5.4 ± 1.4%; $P = 0.001$) and apolipoprotein A-I (5.8 ± *1.9%;* $P = 0.005$), but had no effect on serum lipoprotein ratios. There were no significant effects on serum HDL cholesterol, serum protein carbonyl content, or ex vivo androgen or progestin activity. Unexpectedly, serum protein thiol groups were significantly lower (10.8 ± 3.6%; $P = 0.007$) suggesting increased oxidation [74]. Dietary flaxseed has been shown to have potent antiatherogenic effects in rabbits. When LDL receptor deficient mice (LDLrKO) were administered a 10% flaxseed-supplemented diet for 24w, a reduction of circulating cholesterol levels was observed indicating the anti-atherogenic effect of flax seeds [75]. Flaxseed supplementation was associated with significant reductions in TC (-17.2%), LDL-C (-3.9%), TG (-36.3%) and TC/HDL-C ratio (-33.5%). Dietary flaxseed significantly improves lipid profile in hyperlipidemic patients and may favorably modify cardiovascular risk factors. Studies on experimental animals indicated that flax and pumpkin seed mixture had antiatherogenic and hepatoprotective effect probably mediated by unsaturated fatty acids in the mixture [76]. Flaxseeds are richest source of lignans that are converted to enterolactone by intestinal microflora. Enterolactone has been suggested to be the prime active compound mediating atherosclerosis protective effects [77]. Flaxseed regimen reduced serum levels of both low-density- and high-densitylipoprotein cholesterol by 4.7% and triglyceride by 12.8%. Serum apolipoprotein A-1 and apolipoprotein B concentrations were significantly reduced by 6 and 7.5%, respectively, by the flaxseed administration in postmenopausal women. Markers of bone formation and resorption were not affected by either of the treatments. The flaxseed supplementation thus improves lipid profiles but has no effect on biomarkers of bone metabolism in postmenopausal women [78,79].

Flaxseed in nephrology

Flaxseed derivatives, including both oil and flax lignans, modify progression of renal injury in animal models, including Han: SP RD-cy Polycystic Kidney Disease (PKD) [80]. Male obese SHR/N-cp rats were randomly assigned to one of three diets containing either 20% casein, 20% soy protein concentrate, or 20% flaxseed meal. Except for the protein source, all three diets were identical and contained similar amounts of protein, fat, carbohydrates, minerals and vitamins. All animals were maintained on these diets for 6 months. All three groups had similar amounts of food intake and body weight gain and exhibited fasting hyperglycemia and hyperinsulinemia. Plasma glucose levels did not differ among the three groups, but plasma insulin concentration was significantly lower in rats fed flaxseed meal than those fed either casein or soy protein concentrate. Mean plasma creatinine, creatinine clearance and urinary urea excretion also did not differ significantly between the three groups. By contrast, urinary protein excretion was significantly lower ($P < 0.01$) in rats fed flaxseed than in rats fed either casein or soy protein concentrate. It's concluded that dietary protein substitution with flaxseed meal reduces proteinuria and glomerular and tubulointerstitial lesions in obese SHR/N-cp rats and that flaxseed meal is more effective than soy protein in reducing proteinuria and renal histologic abnormalities in this model. The reduction in proteinuria and renal injury was independent of the amount of protein intake and glycemic control. Which dietary component(s) present in flaxseed meal is (are) responsible for the renal protective effect remains to be determined [81].

Flaxseed in bone health

Alpha linolenic acid, the omega-3 fat found in flaxseed promotes bone health by helping to prevent excessive bone turnover-when consumption of foods rich in these omega-3 fat results in a lower ratio of omega-6 to omega-3 fats in the diet [82]. When the women who had been having 14 hot flashes per week for at least a month and weren't taking estrogen to relieve their menopausal symptoms were fed 2 tablespoons of crushed flaxseed twice daily for six weeks, the women halved their number of daily hot flashes while taking flaxseed. In addition, the intensity of the women's hot flashes dropped by 57%. Side effects included abdominal bloating (14 women) and mild diarrhea (8 women) [83].

Conclusion

The modern civilization, which due to technological advances, developed medicines which are quick acting, potent and capable to treat & provide symptomatic relief, has now started to feel the need for longer lasting & more fundamental cures for their problems of health. Attention now being shifted from relief to prevention & cure. The intention is to go back to nature & use natural materials & methods of ancient times. Functional foods and nutraceuticals may provide a means to reduce the increasing burden on the health care system by a continuous preventive mechanism. Plant foods as medicines are assuming greater importance in the primary health care of individuals and communities in many developed as well as developing countries. A large number of phytochemicals and bioactives are present in foods of plant origin. The synergistic effects rendered by a combination of bioactives present in source materials and the complementary nature of phytochemicals from different sources are important factors to consider in the formulation of functional foods and in the choice of a healthy diet. Both nutraceuticals and functional foods contain the active ingredients with physiological activities with healthier and happier lifestyle. Studies during the last three decades uncovered nutritional benefits of flaxseed related to its unique composition. Processing innovations in more-recent years have enhanced flaxseeds use as an ingredient, making it available in many forms with specific nutritional benefits for todays health conscious consumers.

Flaxseed derived lignans have been part of both diet and herbal medicines for centuries. The isolation from flax seed of the lignan derivative secoisolariciresinol diglucoside facilitated exploration of anti-tumor activity of SDG and its metabolites. The lignan products, enterolactone and, to a lesser extent, enterodiol have been shown to influence the early risk markers for and incidence of mammary and colonic carcinogenesis in animal models, decreased cell proliferation *in vitro*. Flaxseed is a rich source of Alpha linolenic acid (ALA), fiber and lignans, making it a potentially attractive functional food for modulating cardiovascular risk. Being the richest source of ALA and soluble fiber, flax reduces serum total and lowdensity lipoprotein cholesterol concentrations, reduce postprandial glucose absorption, decrease some markers of inflammation and raise serum levels of the omega-3 fatty acids, ALA and eicosapentaenoic acid. More research is needed to define the role of this functional food in reducing cancer and cardiovascular risks. Studies are required as to how the cellular pathways are affected by flax seed ingredients in life style disorders and other cellular disorders such as cancer.

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