REVIEW

Flaxseed – A miraculous defense against some critical maladies

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Abstract: Presence of omega-3, omega-6 rich oil, alpha-linoleic acid, dietary fibers, secoisolariciresinol diglucoside, protein and minerals in flaxseed constitute a very strong basis for the utilization of flaxseed in various food preparations as a curative agent. An extensive body of literature illustrates that flaxseed has gained a significant position in the domain of nutritional sciences owing to its pivotal role as an antioxidant agent. The review discusses at length, numerous health benefits of flaxseed typically focusing its preventive role against cardiovascular diseases, cancer, diabetes and enhancement of spatial memory. Massive increase in the size of population with a special emphasize to the developing countries, there is an urge for exploration of the alternative dietary resources that can meet the dietary and nutritional needs of forthcoming generations. With respect to its remarkable nutritional importance, the review in question enables researchers engaged in nutritional sciences to further investigate the therapeutic value of flaxseed functional components and their dietary application in various food products and availability in processed foods as well as in the human cell line.

Keywords: Flaxseed, fibers, health benefits, cardiovascular diseases, cancer, diabetes.

INTRODUCTION

Flaxseed (*Linum usitatissimum*) is an agronomic crop that produces small seeds which are further utilized for the extraction of oil, meal and powder preparation. The seed is a healthy source of oil containing poly-unsaturated fatty acids, digestible proteins, and lignans. Apart from being an affluent source of α-linolenic acid (ALA) oil, flaxseed has a great potential to provide good quality protein, soluble dietary fibers and considerable amount of healthy plant phenolics. Diverse utilization of flax dates back to more than 6000 BC with respect to their specific nutritional components. Daily dietary consumption of these nutrients possessing nutraceutical properties in the form of flaxseed supplemented diet may reduce chances of cardiovascular disorders, breast, prostate and colon cancers development (Giada, 2010; Jhala and Hall, 2010). Flax seed is rapidly gaining popularity as an emerging functional food for its potential bioactive compounds i.e. α-linolenic acid (ALA), fiber, and lignans secoisolariciresinol diglycoside (SDG) which shows to be anti-carcinogenic, anti-oxidative and anti-estrogenic. A substantial transition from non food uses of flaxseed to its utilization as a part of human diet due to its potential health benefits and chemo-protective properties linked with omega-3s and lignan phytoestrogens that has been witnessed specifically in the western societies (Singh *et al.,* 2011)**.**

Major nutritional components of flaxseed include ALA rich oil, protein, minerals and a greater proportion of non-nutritional lignan-rich dietary fiber. On the dry weight basis, flaxseed contain 20% protein, 27% total dietary fiber 41% oil, 4% ash and 8% moisture. Albeit, flaxseed proteins are not complete in nature but the deficiency may be overcome effectively by enrichment with products containing amino acids that form complete proteins (Madhusudhan, 2009). To deal such a constraint, flaxseed is substituted with dairy and meat based products. Among the protein fractions, being the storage protein in flaxseed, globulin constitutes up to 66% of its total protein contents (Chung *et al.,* 2005).

Flaxseed nutritional profile predominantly exhibit significant health promoting properties with almost everything that positively affect cholesterol levels resulting in a beneficial impact on cardiovascular disorders and cancer risks. Polyunsaturated fatty acids including omega-3 and ALA, soluble dietary fiber, and lignans having cardio-protective effects have been accepted as vital components of flaxseed making it unique in the array of functional foods. Daily dietary consumption patterns of flaxseed in hypercholesterolemic patients have been reported to lower down the total cholesterol to a significant extent (Dahl *et al.,* 2005; Bassett *et al.,* 2009).

Higher protein and dietary fiber content of flaxseed add up its functional characteristics in flaxseed based dietary patterns. Flax meals, after oil extraction contains 35.5% protein, 3.5% fat, 6% ash and 70% total digestible nutrients (Lay and Dybing, 1989). Significant amount of

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protein, soluble fibers and lignan contents represents nutritional prospects of flax seed meal and positively associated with health beneficial properties including antioxidant, estrogenic and anti-estrogenic qualities (Hall *et al.,* 2006). Acid and alkaline soluble fractionation of flaxseed yields 66.5 g and 71.1 g per 100 g protein, 23.0 g and 21.5 g per 100 g carbohydrate, and 1.80 g and 2.10 g per 100 g fat. Mueller *et al.* (2010) has reported acid soluble fraction of flaxseed carbohydrate and dietary fibers to contain 33.3 g and 32.3 g per 100 g protein, 55.6 g and 57.3 g per 100 g carbohydrate and 0.30 g and 0.60 g per 100 g fat. Flax seed as a nutritional additive for the preparation of certain dietary items like baked products, ready to eat cereals and fiber bars having good health impacts has been widely recognized in all parts of the world. Supplementation of flax seed in a variety of foods have been well established as a mean to enhance the nutritional profile of the food e.g. addition of flaxseed flour in corn tortillas increases total protein and fat contents of the final product. Different flours are used in bread recipes to improve nutritional profiles of finished product. Wheat flour cannot be claimed as complete nutritional recipes due to deficiency of some essential components like lysine and presence of some health intolerable elements that might cause allergies and celiac diseases. Flours extracted from some other edible grains like oat, barley, flaxseed can provide an ample quantity of good quality protein and dietary fiber and contribute effectively in the reduction of chronic disorders like cardiovascular diseases, cancer and diabetes (Pourafshar *et al.,* 2010). Enrichment of corn tortilla with ground flaxseed at a concentration of 20% increases fat and protein percentage from 42.7-120.0g and 91.0-129.3g per kg of the finished product, respectively (Rendon-Villalobos *et al.,* 2009). Similarly, organoleptically acceptable cookies can be prepared by supplementing 20% flax in foods as an ingredient (Hussain *et al.,* 2006).

Flaxseed is commercially processed for oil extraction, powder preparation and improvement of physicochemical properties. Numerous processing techniques of flaxseed that operates during oil extraction right from cleaning up to solvent extraction increase its protein, ash and soluble carbohydrate contents with an increase of in vitro protein digestibility. Comparing egg protein with alkaline soluble protein fractions of flaxseed, higher emulsification properties with higher contents of SDG have been observed (Mueller *et al.,* 2010).

EXCELLING FEATURES OF FLAXSEED

Flaxseed fibers

Most specific ingredient of flaxseed that could exert positive effects on blood cholesterol level is its fiber that has been tested by numerous studies both on animals and humans. Flaxseed contains 28g of dietary fibers per 100g of seed, thirty three percent of it constitute soluble dietary fiber and associated with enhanced insulin sensitivity, and significant blood cholesterol reduction that ultimately lower down the level of cardiovascular risk factors (Pereira *et al.,* 2004). Flaxseed being an increasingly used dietary supplement possesses several human health benefits and its insoluble fibers hold a strong water-binding capacity thus providing bulk to the diet making it substantially beneficial for the treatment of constipation, irritable bowel syndrome and diverticular disease. Soluble fibers of flaxseed have shown to exert a positive effect in controlling hypoglycemic conditions, reduction in constipation and serum cholesterol levels, colorectal cancer, breast cancer and prostate cancer with significant reduction in cardiovascular diseases. Tarpila *et al.* (2005) reports flaxseed supplemented diet to raise the serum enterolactone levels that lessens frequency of acute coronary heart diseases ultimately reducing coronary deaths cases. Numerous findings reporting the consequences of flaxseed consumption on the lipid profile of blood indicate a considerable improvement in human blood lipids profile in type 2 diabetes. Lignans reduce "bad" LDL-cholesterol (LDL-C) levels thus having a good impact on cardiovascular health. Flaxseed fiber, mucilage gums and insoluble lignans, in addition to their natural laxative effects show the great tendency to reduce blood glucose levels in response to normal dietary carbohydrate intake and help out in reduction of certain menopausal symptoms.

Flaxseed phyto-oestrogens in the form of lignans have been extensively studied due to their potential health benefits. Daily dietary supplementation of SDG derived from flaxseed extract for a period of 6 to 8 weeks significantly reduces total cholesterol and LDL cholesterol by 22.0% and 24.38%, respectively. Similarly significant improvement in glycemic control but no predominant reduction in the level of fasting glucose as well as development of insulin resistance was observed (Pan *et al.,* 2007). Various flaxseed species have been reported to contain SDG and its diastereoisomers up to a level of 2.59 and 0.5%, respectively (Eliasson *et al.,* 2003). A dietary supplementation of SDG higher dose i.e. 600 mg for a period of 6 to 8 weeks significantly lowered fasting plasma glucose up to 25-56 and 24-96%, respectively (Zhang *et al.,* 2008). Tendency to use flaxseed hull as a potential source of SDG and carrying hepatoprotective properties has been on the peak in the recent years. Pretreatment of flaxseed SDG given to rats potentially restores hepatic enzymes including catalase by 37.70%, peroxidase by 108.22% and superoxide dismutase by 23.89% at a dietary SDG supplementation of 150 μg/kg body weight (Rajesha *et al.,* 2010).

Maternal intake of 25% flaxseed supplemented diets for a period of 21 days, significantly reduces milk total cholesterol and increases 17 b-estradiol and leptin. During the normal period of lactation, maternal dietary effects of

flaxseed were assessed on the body mass composition and the milk profile of the mother. Further feeding of offspring at this milk for a period of 21days, reduces overall body mass including body and visceral fat masses (Troina *et al.,* 2010).

Flaxseed oil

Unsaturated and poly unsaturated oils are preferred over animal fats due to their potential health benefits. Beside conventional plant sources, flaxseed is thought to be containing an ample quantity of oil with higher percentage of poly unsaturated fatty acids (PUFA). Human body, under ideal conditions needs a balanced proportion of some healthy essential fatty acids i.e. omega-3 and omega-6 but in actual scenario, modern western diets are deficient in these essential fatty acids. This state of affairs might be controlled by flaxseed that can supply ample quantity of essential fatty acid omega-3. It has been reported that higher omega-6 intake have a tendency of clotting blood platelets forming the basis of thrombosis eventually leading to atherosclerosis (Madhusudhan, 2009).

Oil seeds provide a healthy oil profile that may have potential as a source of specialty oils on the ground of their immense health properties. Oils rich in unsaturated and poly unsaturated fatty acids and tocopherol are preferred to be added in infant's formulas and different food products to gain maximum nutraceutical and health related properties (Moyad, 2005; Bozan and Temelli, 2008). Special diets can be formulated using flaxseed oil to meet the standard health requirements. Such kind of supplemented products can be effectively used by the community with special dietary requirements (Rendon-Villalobos *et al.,* 2009).

Previous studies indicate that flaxseed hull oil extraction with different solvents and extraction technique can yield 9 to 28% oil with a variant profile of neutral lipids, phospholipids, acidic lipids and free fatty acids i.e. 92.5%, 3.1%, 2.4% and 2.1%, respectively. Oils with highest antioxidant capacity were extracted by supercritical CO_2 yielding the hull with maximum SDG level i.e. 53 mg/g (Oomah and Sitter, 2009). Beside SDG, flaxseed oil contains many phenolic compounds like ferulic acid, coumaric acid, diphyllin, vanillin pinoresinol and *p*-hydroxybenzoic acid (Herchi *et al.,* 2011). Almost 57% of total flaxseed fat is consist of omega-3 poly unsaturated fats that if included in dietary habits can increase blood clotting time and subsequently reduce blood pressure and cardiac stroke risks. Lignan glycosides of flaxseed oil vary during storage period at different storage temperatures, as well as light and dark periods. SDG quantified from flaxseed lipids by a reliable and sensitive HPLC method revealed preserving effect of flaxseed oil from oxidative deterioration during lower storage temperatures and dark periods (Bravi *et al.,* 2011).

Dietary fatty acid, ALA has been reported to reduce cardiovascular risks on dietary supplementation (Harper *et al.,* 2006). Flaxseed oil contains 58.3% γ-linolenic acid among major fatty acids. Being a rich source of γ-tocopherol, 100g of flaxseed oil contains 79.4 mg of γ-tocopherol. Flax seed oil has shown to comparatively less oxidative stability as compared with safflower and poppy seed oil i.e. 1.57h, 2.87h and 5.56h, respectively at 110ºC (Bozan and Temelli, 2008).

HEALTH SIGNIFICANCE OF FLAXSEED

In addition to soybeans, oats, psyllium, garlic, tea, fish, grapes and nuts, flaxseed is proven to be the functional food that not only justify the nutritional requirements but also impart its characteristic role in preventing various diseases. Omega-3 fatty acids contents of flax seed oil anticipates numerous health promising properties including reduction in the incidence of aberrant crypt foci (ACF) which is a precursor lesion in developing colon. In rat model, glutathione-s-transferase (GST) activities that have been found to increase on feeding 14% flaxseed oil and 20% flaxseed meal as compared to controlled rats and those fed with soybean oil diets (Williams *et al.,* 2007).

Serum Lipid Profile Improvement

Flaxseed and products derived thereof, improve the lipids pool of blood by reducing total and LDL cholesterol e.g. SDG isolates of flaxseed have been characteristically represented to reduce atherosclerosis development in rabbits demonstrating it to be a very effective antioxidant with serum lipids lowering ability. This has also been found to suppress hypercholesterolemia atherosclerosis development. A regular diet supplemented with flaxseed isolated SDG at a rate of 20mg/kg body weight/day reduces atherosclerosis lesions development from 84 to 24% (Prasad, 2008). Regular dietary consumption of flaxseed SDG significantly decreases LDL-C levels thus maintaining lower level of bad cholesterol as compared to high density lipoprotein cholesterol. Oral administration of 100mg flaxseed SDG for a period of 12 weeks can decrease blood cholesterol level and hepatic disorders induced by hypercholesterolemia in humans (Fukumitsu *et al.,* 2010).

Other studies suggested a regular intake of 25% flaxseed supplemented diet for a period of 180 days to attain significant reduction in serum LDL and triacylglycerols. Similarly a dietary intake of 10% flaxseed for a period of 30 days has indicated a substantial reduction in blood cholesterol level of rat models (Abdel-Rahman *et al.,* 2010).

Synthesis of bile acids greater than normal level is associated with the consumption of flaxseed and its oil. A comparative study conducted to evaluate the effect of flaxseed and its derived oil on in the Golden Syrian

Hamsters after ovariectomy, increased bile acid synthesis with subsequent reduction in blood cholesterol (Lucas *et al.,* 2011).

Cardiovascular Protection

Among the wide range of functional foods, flaxseed stands out as a potential candidate containing therapeutic value for cardiovascular risk reduction. Major constituents of the flaxseed i.e. α-linolenic acid, soluble fibers and lignans have been shown to be promising for atherosclerotic cardiovascular diseases prevention. Beside cardiovascular diseases, various components of flaxseed possess antioxidant, anti-inflammatory, anti-carcinogenic, hypoglycemic, anti-platelet properties (Bloedon and Szapary, 2004; Verghese *et al.,* 2011).

An emerging class of phytoestrogens i.e. ALA and dietary lignans have been reported by Mandasescu *et al.* (2005) to be excessively available in flaxseed and believed to carry lipid-lowering and antioxidant properties that positively alter cardiovascular risk. Being a good source of ALA, flaxseed increases its levels in serum if consumed with regular diet. In another study by Bloedon *et al.* (2008) on flaxseed demonstrated modest low density lipoprotein cholesterol (LDL-C) reducing effect on lipoproteins and improved insulin sensitivity in hyperlipidemic adults. The study conferred a reduction in LDL-C by ~14% levels after continuous consumption for a period of 5weeks as compared to wheat. The aforementioned findings are well supported by the work of Dodin *et al.* (2005) that ingestion of yellow flaxseed powder ~ 40g reduces blood serum HDL cholesterol levels of menopausal women to a significant extent.

Eicosanoides derived from omega-3-fatty acids, present in flaxseed primarily improves heart function by reducing blood cholesterol. A proportionate effect on blood cholesterol concentration and low-density lipoprotein fraction has been linked with higher concentrations of flaxseeds in the diets indicating greater reduction in LDL protein, serum and liver cholesterol (Gambus *et al.,* 2004; Cintra *et al.,* 2006). Various studies report significant beneficial effect of flaxseed on the heart function suggesting a daily consumption of 40g of whole yellow omega flaxseed ground into powder and supplemented in baked products modulates several CVD risk markers (Dodin *et al.,* 2005; Mandasescu *et al.,* 2005; Bloedon *et al.,* 2008).

Free radical scavenging

Some highly reactive compounds commonly recognized as reactive oxygen species (ROS) that generate due to exposure of endothelial cells to some radioactive sources and lead to certain degenerative disorders (Szotowski *et al.,* 2007). Formation of free radicals in diabetic patients has been represented by Maritim *et al.* (2003) as a process of oxidation and non-enzymatic glycation of glucose and proteins followed by its degradation. Some more precise studies have reported lungs damages probably linked with free radicals (Kinniry *et al.,* 2006; Lee *et al.,* 2008). Studies on dietary flaxseed have confirmed its role as a potential radio protector against radiation induced injuries during x-ray radiation therapy for oncological treatments (Lee *et al.,* 2009). Being a rich source of natural antioxidants, dietary supplementation of flaxseed has been gaining popularity. Flax lignans possess antioxidant properties; specifically SDG isolated from flaxseed has shown direct hydroxyl radical scavenging properties to inhibit lipid peroxidation in some in vitro studies.

Cancer preventive and curative potential

A new genomic technology namely nutritional modulation of carcinogenic pathways has been under investigation in the form of functional foods with specific nutrients having therapeutic values as preventive and curative strategy for the treatment of some complicated health disorders. Tendency to cure the maladies like gastric ulcers, cardiovascular disorders, prostate and colorectal carcinoma by utilization of functional foods is increasing day by day. Smoking, alcoholism, lack of physical activity, imbalanced dietary intake and poor nutrition has been associated to the onset of such health issues. Seeds of edible crops are often used in the normal dietary patterns of Asian and African communities, while their role as functional food ingredients and a preventive as well as curative strategy for cancer have been frequently discussed by researchers. Investigations into the flaxseed for cancer prevention owing to its s bioactive metabolic components have been made and have proven to be beneficial (Bergman *et al.,* 2007). A broad study have been reported by Power and Thompson (2011) critically focusing reduction in the process of cancer progression in relation to the consumption of flaxseed and its antioxidant, estrogenic, and antiestrogenic effects that influence the prostate cellular proliferation.

Phytoestrogens are biologically active estrogenic compounds found in flaxseed that influence protein synthesis, cell proliferation, hormone metabolism, angiogenesis and intracellular enzymes (Branca and Lorenzetti, 2005). Mammalian metabolites of flaxseed lignans i.e. enterodiol and enterolactone can serve as a protective approach to cope with pre-cancer cellular alterations. Like phytoestrogens, flaxseed lignans metabolize estrogens and are supposed to serve in prostate and breast cancer prevention strategies as an adjuvant in hormone replacement therapy (Thompson *et al.,* 2005; Knust *et al.,* 2006; Adolphe *et al.,* 2010). Acid hydrolysis followed by alcoholic extraction in the form of hexane and ethyl acetate mixture is the most suitable strategy for the extraction of flaxseed lignans active components i.e. secoisolariciresinol (97% purity) and anhydro secoisolariciresinol (98% purity). Anhydro secoisolariciresinol act as cancer modulator and its

extraction from flaxseed lignans is comparatively more efficient than secoisolariciresinol. Modulation concentration of flaxseed secoisolariciresinol for breast cancer cells development has been reported as 50-100 μM by Lehraiki *et al.* (2010). Diets formulated by fat restriction and flaxseed supplementation, if included in regular dietary plan can affect the prostate cell biology. Omega-6 and omega-3 fatty acids sources i.e. fats with natural or enriched higher concentration from corn oil and flaxseed oil, respectively, play a significant role in inhibiting development of chemically induced tumors in laboratory animals thus reducing chances of colon cancer initiation (Bhatia *et al.,* 2011). At a lower levels of oestradiol, reducing effect on the growth of oestrogen receptors and breast cancer cells of human have been demonstrated by n-3 fatty acid rich fractions of flaxseed cotyledon. Flaxseed cotyledons based diet feed to tumor induced mice (82g/kg) for a period of 8 weeks significantly lowers the cell proliferation process and reduces tumor growth area (Chen *et al.,* 2011). Dietary combination of flaxseed oil (8%) with primary anticancer drugs can significantly reduce breast tumor development ~89% as compare to primary drug treatment alone for a period of 4 weeks (Mason *et al.,* 2010).

Hypoglycemic effects of flaxseed

Global health surveys estimates devastating effects of diabetes in the next few decades afflicting a great size of World population. Looking forward to cope such malignancies, long term strategies can be built by re-editing the daily dietary plans. Flaxseed flour supplementation in the diet has been suggested as a preventive measure against diabetes and associated other complications (Maritim *et al.,* 2003; Ugochukwu *et al.,* 2003). Diets supplemented with flaxseeds have shown to exert an improved liver and kidney antioxidant enzymes activities of diabetic animals. Diabetes is more or less associated with the higher levels of plasma and kidney malonaldialdehyde (MDA) in addition to the reduction of the antioxidant enzymes pool.

Significant reduction in MDA levels with tubular dilation and glomerular hypertrophy of histological section of rat's kidney has been proposed by Makni *et al.,* (2010) suggesting dietary intake of flaxseed based diet for 10 weeks very helpful for the prevention of diabetes and its complications. Diabetic complications in the form of oxidative stress and macrosomia can be observed in fetus of diabetic mothers. Dietary supplementation of fatty acids as proposed by modern research could be help full to counter such complications in mother's womb by her improved dietary patterns. Flaxseed fats being rich in ω3- and ω6-polyunsaturated fatty acids in the flaxseed based diets of diabetic mothers are reported to be a remedy of diabetic complications in mothers as well as her offspring by decreasing MDA levels and increasing liver enzyme concentration (Makni *et al.,* 2011).

In addition to C-peptide, insulin growth factors (IGF) and binding proteins (IGF-BP) in the form of IGF-1 and IGF-BP3 are recognized as insulin growth marker. The growth markers production as well as circulation is however affected by non-healthy dietary patterns. Flaxseed supplementation in the regular diets of postmenopausal women demonstrates no negative effect on the circulation of insulin markers in serum (Sturgeon *et al.,* 2011).

Improvement of spatial memory

Loss in spatial memory is very much associated with accumulation of lipid peroxide in the hippocampus. Higher levels of flaxseed nutritional as well as non-nutritional components like antioxidants in the form N-3 fatty acids most often referred as ω-3 fatty acids i.e. ALA, docosahexaenoic acid (DHA) and dietary fibers i.e. lignans, in addition to reduction of body mass reduces levels of lipid peroxide in the hippocampus. Studies on flax feed dam suggest that improvement in hippocampus ALA and DHA concentration results in reduction of spatial memory inhibitors thus increases learning ability of flaxseed feed dams (Fernandes *et al.,* 2011).

Consumer acceptance of flaxseed and its consumption patterns

As a functional food, flaxseed is supplemented in different food preparations to enhance their food value with the help of its bioactive compounds like dietary fibers and n-3 fatty acids. Sensory acceptability of such nutritious and healthy foods is very much associated with the functional components of these diets. Higher amounts of flaxseed flour supplementation in bakery products beside their potential health benefits in the form of its functional components like α-Linolenic acid, lignan and antioxidants might affect organoleptic properties (Aliani *et al.,* 2011). Acceptance of flaxseed as a dietary functional food ingredient in cakes assessed at structured nine point hedonic scale revealed consumer acceptance up to 30% supplementation level (Moraes *et al.,* 2010). Flaxseed breads beside their higher contents of mono and polyunsaturated fatty acids are well accepted on the ground of color, texture and firmness (Calderelli *et al.,* 2010). Flaxseed fatty acids are less heat stable and results in production of some oxidized products and contaminants like acrylamide and hydroxymethyl furfural. Corn starch with higher amylase contents can be used to form complexes with flaxseed oil particles that significantly reduce lipid oxidation and prevent formation of acrylamide and hydroxymethyl furfural during flaxseed supplemented bread baking (Gokmen *et al.,* 2011). Sensory acceptance scores for appearance, flavor, tenderness, juiciness and overall acceptability of flaxseed flour supplemented beef patties decreases by increasing its supplementation level. Organoleptically acceptable and nutritionally improved beef patties have been primed by Bilek and Turhan (2009) suggesting supplementation levels of flaxseed flour ~ 6%. Flaxseed flour added to

Table 1: Summary of some major studies on various health aspects of flaxseed from 1995 to 2004

References	Conclusion
Thompson (1995)	Lignans isolated from flaxseed reduces intestinal absorption of testosterone and can inhibit proliferation of prostate tissue.
Cunnane *et al*. (1995)	Higher rate of flaxseed flour substitution in the rats diets exhibit a significant decline in the serum, liver and LDL cholesterol
Geil *et al*. (1995)	Serum cholesterol is associated with prostate cancer and dietary intervention with flaxseed reduces serum cholesterol by 4.2 to 10.9% in men.
Cunnane *et al*. (1995) Jenkins *et al*. (1999)	Reduction in the LDL cholesterol is attributed to flaxseed soluble fibers.
Arjmandi *et al*. (1998)	40g daily dietary intake of flaxseed reduces HDL-C ~ 4.6% in postmenopausal women. Meanwhile higher rate of HDL-C has been noticed in men as compared to women.
Expert Panel on Food Safety and Nutrition (1998)	Unique nutritional profile of flaxseed associated with its polyunsaturated fatty acids and soluble dietary fibers recognize the crop world wise as health beneficial food source.
Denis *et al*. (1999)	Plant based n-3 fatty acids being linked with triglycerides reduction are widely accepted.
Thomas, (1999) Yip *et al*. (1999)	Being a rich source of ALA, flaxseed is one of the best plant sources that serve the purpose adequately.
Denis *et al*. (1999) Thomas, (1999)	Low fat flaxseed based diets are recognized as rich source of phytoestrogens that can effect prostate cellular proliferation.
Sciarra & Toscano (2000)	ALA derived from flaxseed oil could be a remedial strategy in patients facing higher blood pressures.
Connor (2000)	Dietary lignans and phytoestrogens have a strong potential to reduce lipid levels in addition to their antioxidant properties. Flaxseed is a well recognized source of such miraculous functional food components.
Demark *et al*. (2001)	Reduction in the rate of prostate proliferation and increase in the apoptotic index of prostate cancer patients adheres to the low-fat, flaxseed-supplemented diets as compared to the historic controls.
Lemay *et al*. (2002)	Women reported as hypercholestrolemic when fed with 40g flaxseed supplemented diets daily, a significant reduction in their cholesterol level was noticed.
Banerjee & Maulik (2002)	Flaxseed dietary fibers carry anti-inflammatory and anti-proliferative properties that are thought to reduce the risk of atherosclerosis.
Lucas *et al*. (2002)	Feeding postmenopausal women with diets supplemented with 40g of flaxseed daily for a continuous period of 3 months reduces serum cholesterol up to 6% as compared to a wheat flour control diet.
Bhathena *et al*. (2003)	Rats studies reveal flaxseed based diets to reduce plasma total cholesterol on regular ingestion.
Goodstine (2003)	Free radical scavenging and serum lipid capabilities are associated with flaxseed dietary fibers that not only reduce the rate of tumor epithelial proliferation but also increase apoptotic index as compared to the controls.
Vollmer *et al*. (2003)	Researchers explored flaxseed diet in relation to prostatic hyperplasia, suggesting more epidemiologic studies to be conducted.
Bhathena *et al*. (2003)	A minor but significant reduction in the level of liver transaminases is associated with flaxseed. However, no such findings representing significant changes have been reported from human. Reduction in hepatosteatosis (fatty liver condition) by dietary intake of flaxseed has been observed in rat models.
Pereira *et al*. (2004)	On the weight basis, flaxseed is comprised of 28% dietary fibers. Soluble fiber constitutes about 9.33% of dietary fibers and predominately associated with cholesterol reduction and reduced risk of cardiovascular diseases as well as improved sensational secretion of insulin.
Zhao *et al*. (2004)	Dietary inclusion of flaxseed in the regular diets reduces HDL-C up to 10.5% as compared to sunflower and fish oil i.e. 5.6 and 3%, respectively.
Bemelmans *et al*. (2004) Demark- Wahnefried *et al*. (2004) Lucas *et al*. (2004)	Low fats diets formulated flaxseed supplementation might create some positive changes in prostate cell biology and linked characters.

wheat flour as a fortifying strategy needs to be investigated to earn utmost beneficial outcomes. However, the nutritional and pecuniary aspects of such fortification should be evaluated for their possible effects on sensorial and functional characteristics of the finished food products in addition to the bioavailability of the essential food components (Akhtar *et al.,* 2010).

CONCLUSIONS

New and safer trends towards the development of nutritionally enriched foods with medicinal importance are on the peak. Various ailments related to unhealthy dietary patterns, environmental stress induced degenerative disorders and overburdened life styles are

few major possible reasons behind digestive disorders, cardiovascular risks and certain chronic diseases like cancer. Hence there is an immense need of developing strategies towards development of preventive instead of curative plans by selecting most appropriate dietary patterns that could effectively meet nutraceutical challenges. Flaxseed is a forgotten nutritional crop that is augmented with various nutraceutical components including ω-3 and ω-6, ALA, dietary fibers i.e. lignan specifically secoisolariciresinol diglucoside. A plentiful work has been performed in last decade at nutritional and health beneficial properties of the flaxseed up to animal as well as human cell lines level that suggest its incorporation in regular dietary pattern as a preventive measure against certain health disorders including chronic diseases. Flaxseed flour and oil supplementation in normal diets has been accepted by sensory penalist at certain acceptable dosage levels where its health beneficial effects can effectively be met.

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